Impacts of Power Generation and Transmission

Power Plants and Air Quality

There are 34 power plants operating in Maryland with a capacity rating of two or more megawatts (MW), the majority of which (28 out of the 34) burn fossil fuels to produce electricity. This process of burning fossil fuels produces many different air pollutants, including oxides of nitrogen (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOCs), and particulate matter; and toxic or hazardous air pollutants such as mercury. Fossil fuel combustion also produces greenhouse gases (GHG), including carbon dioxide (CO_2). To improve the quality of air, the State has taken a number of actions to regulate air pollution, many focused on coal-fired power plants.

The Clean Air Act (CAA) was the first major federal environmental law in the United States that required the development and enforcement of regulations to protect the general public from air pollutants known to cause harmful effects to human health. The CAA authorized the United States Environmental Protection Agency (EPA) to develop ambient air quality standards — referred to as National Ambient Air Quality Standards (NAAQS) — for six common air pollutants (known as the "criteria" pollutants). The NAAQS represent the maximum pollutant concentrations that are allowable in ambient air. "Primary" NAAQS are based on health risk assessments and are designed to protect the health of sensitive populations such as asthmatics, children, and the elderly. "Secondary" NAAQS are not as stringent but are designed to protect the public welfare by increasing visibility and preventing damage to crops, animals, and vegetation. Table 4-1 lists the current NAAQS.

Table 4-1. National Ambient Air Quality Standards

Pollutant	Primary NAAQS	Averaging Times	Secondary NAAQS
Carbon Monoxide	9 parts per million (ppm) (10 milligrams per cubic meter - mg/m^3)	8-hour	None
	35 ppm (40 mg/m^3)	1-hour	None
Lead	1.5 micrograms per cubic meter ($\mu g/m^3$)	Quarterly average	Same as Primary
Nitrogen Dioxide	0.053 ppm (100 micrograms per cubic meter - $\mu g/m^3$)	Annual arithmetic mean	Same as Primary
Particulate Matter (PM2.5)	15.0 $\mu g/m^3$	Annual arithmetic mean	Same as Primary
	(PM10) 150 $\mu g/m^3$ (PM2.5) 35 $\mu g/m^3$	24-hour	Same as Primary
Ozone	0.08 ppm	8-hour	Same as Primary
	0.12 ppm	1-hour (applies only in limited areas)	Same as Primary
Sulfur Oxides	0.03 ppm	Annual arithmetic mean	-------
	0.14 ppm	24-hour	-------
	-------	3-hour	0.5 ppm (1,300 $\mu g/m3$)

The six criteria pollutants as they relate to fossil fuel combustion in power plants are as follows:

- ***Nitrogen dioxide (NO_2)*** *– a product of fossil fuel combustion. The nitrogen-based exhaust product from power plants and other combustion sources is termed NO_x and is composed of several compounds including nitrogen oxide (NO) and NO_2. NO_x emitted by combustion sources is primarily in the form of NO, which is rapidly converted to NO_2 in the atmosphere. In the presence of sunlight and heat, NO_x reacts with VOCs to form ground-level ozone (smog).*
- ***Sulfur oxides*** *– also a product of combustion. Sulfur oxides are released when sulfur-containing fuels such as oil and coal are burned. SO_2 is the predominant oxide of sulfur.*
- ***Particulate matter (PM)*** *– dust, dirt, and liquid droplets that form during combustion of fossil fuels or in the atmosphere by chemical transformation and condensation of liquid droplets. Particulate matter is defined by the size of its particles. PM10, for example, contains particles smaller than 10 microns in diameter, and PM2.5 is composed of particles smaller than 2.5 microns in diameter.*
- ***Carbon monoxide (CO)*** *– formed by incomplete combustion of carbon-based fuels during the combustion process.*
- ***Lead –*** *a metal emitted into ambient air in the form of particulate matter. Fossil fuel combustion in power plants is typically a very minor source of this pollutant relative to other industries.*

Figure 4-1
Maryland Monitoring Station Locations

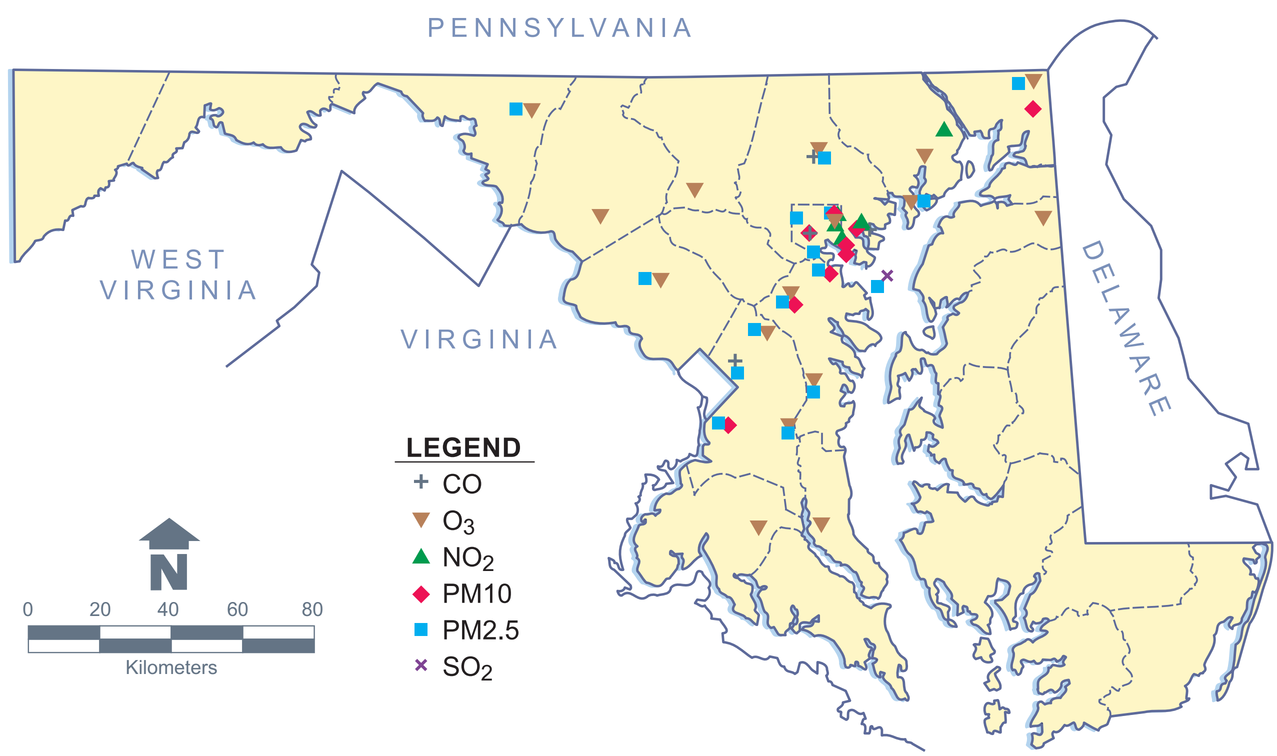
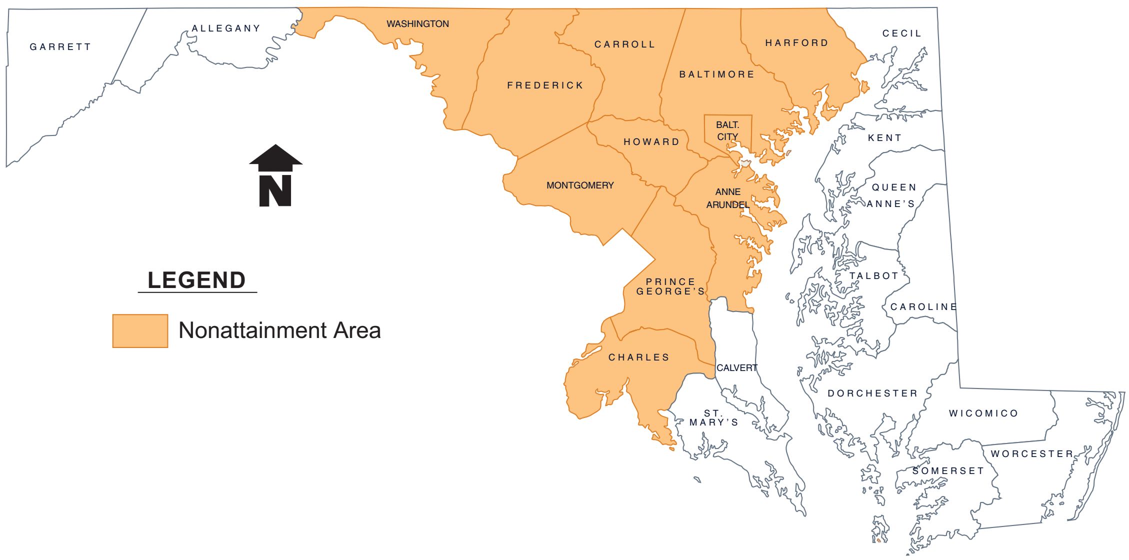


Figure 4-2
Fine Particle (PM2.5) Nonattainment Areas



- ***Ozone (O_3)*** *– is not emitted, but forms in lower levels of the atmosphere as "smog" when NO_x and VOCs react in the presence of sunlight and elevated temperatures.*

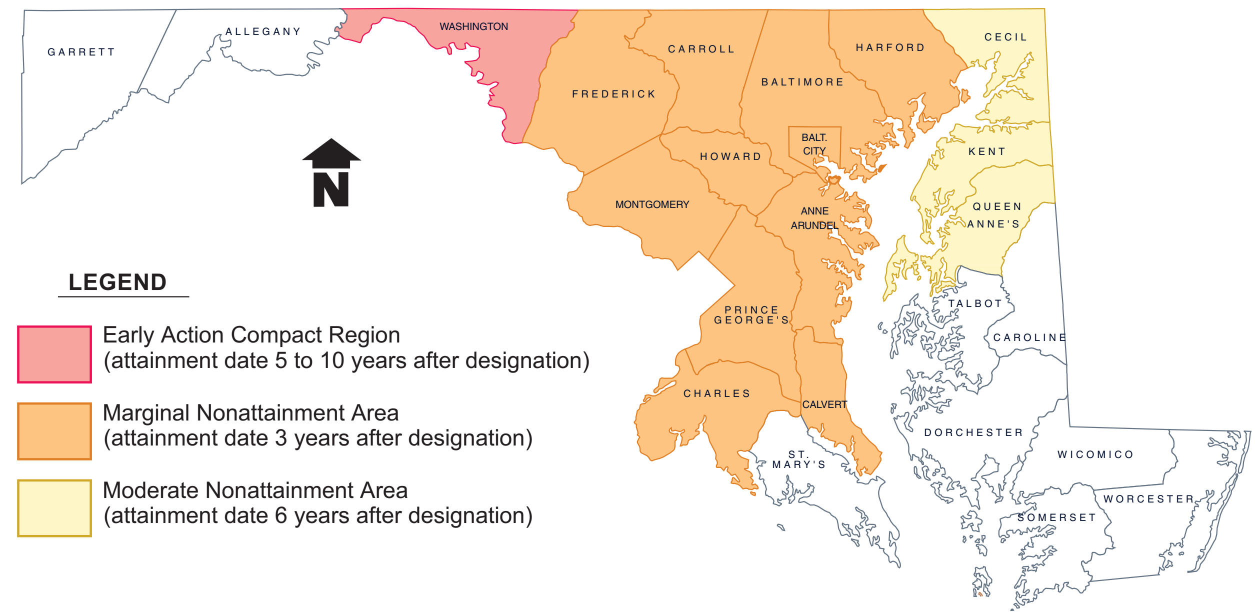
The EPA, and state and local air regulatory agencies such as Maryland Department of the Environment (MDE), monitor concentrations of the criteria pollutants near ground level at various locations across the country. The monitoring locations in Maryland are shown in Figure 4-1. If monitoring indicates that the concentration of a pollutant exceeds the NAAQS in any area of the country, that area is labeled a "nonattainment area" for that pollutant, meaning that the area is not attaining the ambient standard. Conversely, any area in which the concentration of a criteria pollutant is below the NAAQS is labeled an "attainment area," indicating that the NAAQS is being met.

The attainment/nonattainment designation is made by states and EPA on a pollutant-by-pollutant basis. The air quality in an area, therefore, may be designated attainment for some pollutants and nonattainment for other pollutants simultaneously. Currently, all of Maryland is in attainment with the NAAQS for most of the criteria pollutants (SO_2, NO_2, PM10, CO, and lead). However, central Maryland counties are non-attainment for the new PM2.5 standard. In addition, much of the urbanized portion of Maryland is not meeting the NAAQS for ozone.

In September 2006, EPA revised the PM2.5 24-hour average from 65 to 35 $\mu g/m^3$. The Agency expects designations based on 2007-2009 air quality data to take effect in 2010. The current PM2.5 nonattainment areas in Maryland, based on the 65 $\mu g/m^3$ standard, are depicted in Figure 4-2.

In April 2004, EPA re-designated areas throughout the country for the ozone NAAQS. States are given a certain amount of time to regulate emissions sources contributing to air quality issues, and to come into compliance with the standards in those areas deemed as nonattainment. Depending on the classification ("early action," "marginal," or "moderate") of the severity of ozone concentrations, the time to reach attainment ranges from 5 to 20 years. Figure 4-3 depicts the new ozone nonattainment area designations in Maryland. If air quality in these

Figure 4-3
New Ozone Nonattainment Areas



areas does not improve so that the State can demonstrate compliance with the NAAQS on schedule, the State will need to continue to develop new and more rigorous emissions reductions programs until attainment with the standards is achieved.

Because ozone is recognized as a regional, rather than local issue, the entire state is treated as an ozone nonattainment area, despite the fact that many counties are in attainment with the ozone standard (as shown in Figure 4-3).

Current Emissions from Power Plants

As previously discussed, the process of burning fossil fuels produces many different air pollutants. These emissions are often discussed in terms of three classes of pollutants: criteria pollutants, hazardous (or toxic) pollutants, and greenhouse gases. Nationwide, power plants contribute about one-fifth of all NO_x, roughly two-thirds of SO_2, one-third of mercury, and close to two-fifths of carbon dioxide (CO_2) emissions.

Power Plant SO_2 and NO_x Pollutant Emissions

Among the criteria pollutants, SO_2 and NO_x are the most highly regulated by EPA because they are the principal pollutants that react with water vapor and other chemicals in the air to cause acid precipitation. Overall, power plants account for the majority (69%) of the SO_2 emissions and nearly 22 percent of the NO_x emissions from all sources in the United States. In Maryland, coal-fired power plants account for the majority (99.95% SO_2 and 93% NO_x) of total power plant emissions. Figure 4-4 presents SO_2 emissions from coal-fired power plants

Figure 4-4
Maryland Coal-Fired Power Plant SO_2 Emissions

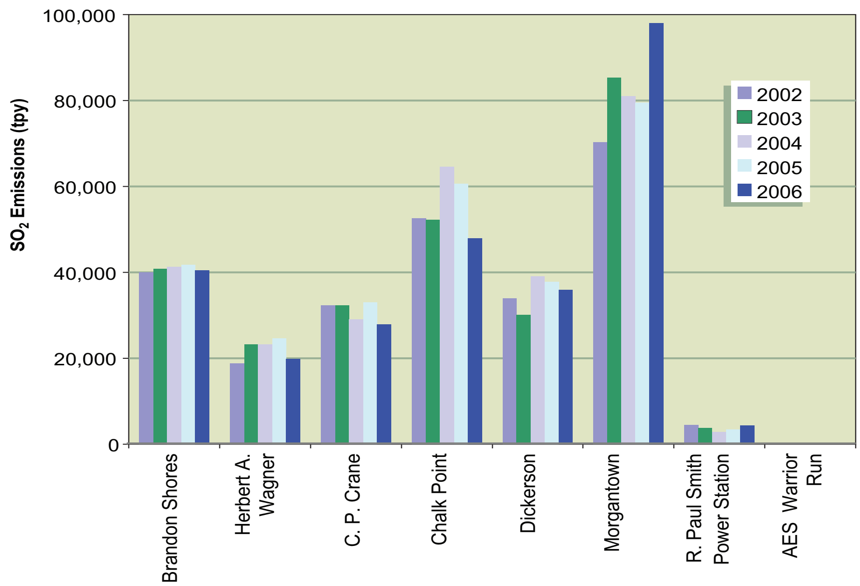
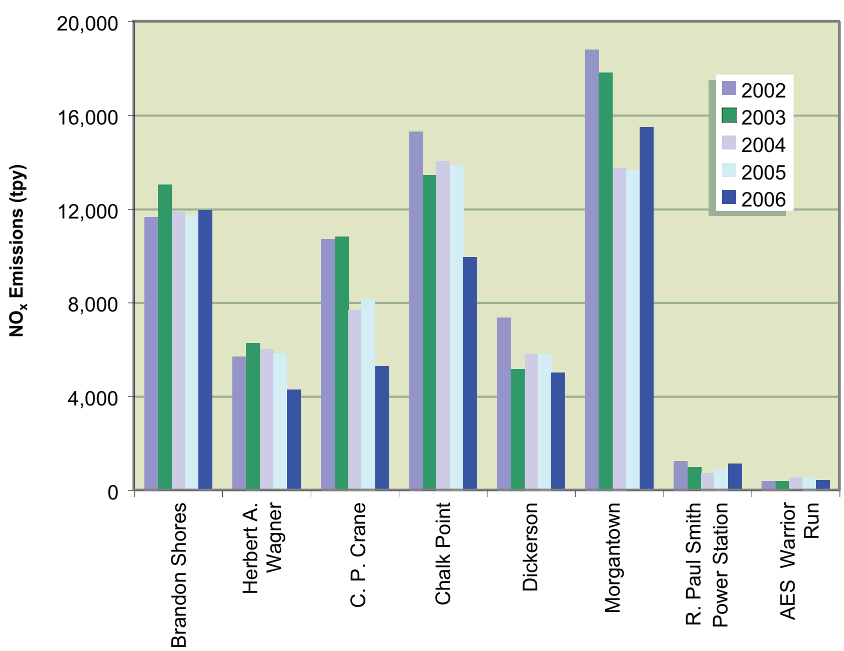


Figure 4-5
Maryland Coal-Fired Power Plant NO_x Emissions



PM2.5

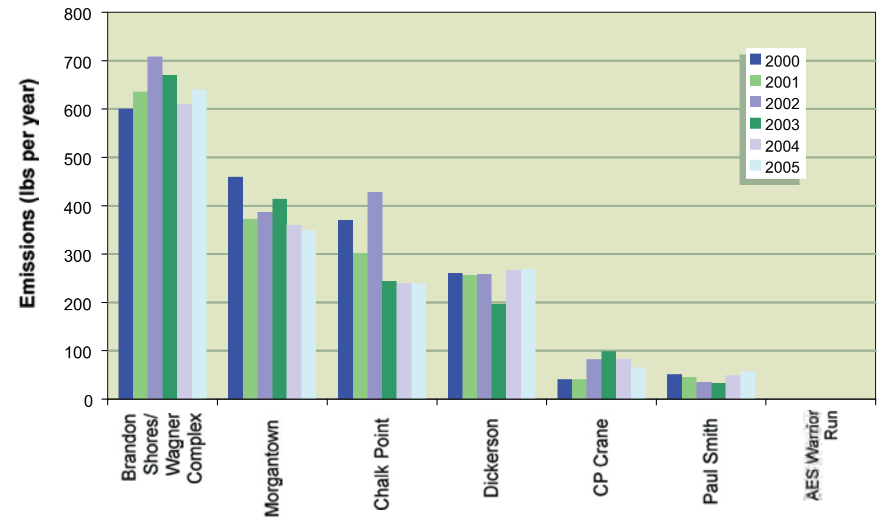
PM2.5, or fine particulate matter, consists of particles (such as dust, soot, and liquid droplets) measuring less than 2.5 microns in diameter. The particles are about 1/30th the diameter of a human hair. PM2.5 is created and emitted by many sources. It can either be emitted as fine particulate matter (such as dust, ash from burning activities, etc.) or can be created when gases (such as SO_x and NO_x) form particles during transport. Fine particulate matter is different from many other air pollutants in that it is not a chemical compound itself, but is comprised of various compounds in particle form. Common sources include:

- *smoke and soot from forest fires,*
- *wind-blown dust,*
- *fly ash from coal burning,*
- *particles emitted from motor vehicles,*
- *hydrocarbons associated with vehicles, power plants, and natural vegetation emissions, and*
- *SO_2 and NO_x emitted from fossil fuel combustion.*

Fine particles pose a great health risk because of their ability to cause asthma attacks, aggravate respiratory and cardiovascular disease, and decrease lung function.

in Maryland during the years 2002 to 2006 and Figure 4-5 presents NO_x emissions over the same time period. The figures indicate that both NO_x emissions and SO_2 emissions fluctuated over the years for the coal-fired power plants. However, because there were no other known major changes during this time period, such as the installation of control equipment or fuel switching, this

Figure 4-6
Maryland Coal-Fired Power Plant Mercury Emissions



fluctuation is assumed to be due to facility maintenance or variation in electricity generation over the years (i.e., demand growth). For reference, emissions from the Maryland coal-fired power plants for the years 2000 through 2006 can be found in Appendix E.

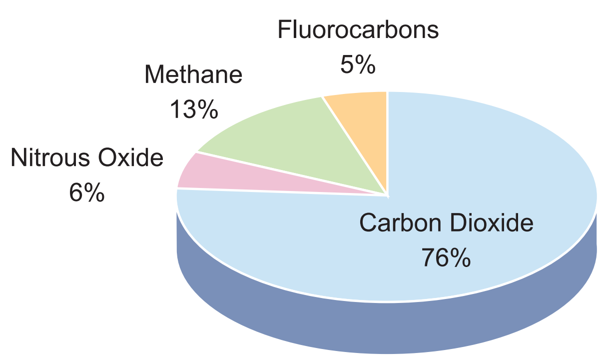
Hazardous Air Pollutant Emissions

In 1990, Congress amended the CAA to regulate a class of pollutants that cause or might cause an adverse impact to the environment. These pollutants are referred to as toxic or hazardous air pollutants (HAPs). There are currently 187 pollutants on EPA's list of HAPs. Although some HAPs occur naturally, most HAPs originate from man-made mobile or industrial sources such as factories, refineries, and power plants.

Although fossil fuel-fired power plants emit HAPs, chemical plants and petroleum refineries that use and emit highly toxic compounds have historically been considered a more significant source of air toxics than power plants. Prior to the CAA Amendments of 1990, EPA regulations did not apply to HAP emissions from power plants. Many states, including Maryland, have developed toxic air pollutant regulations; however, in Maryland, fuel burning sources are exempt from these regulations.

Among the HAPs emitted by power plants, mercury is a pollutant of primary concern because of its significant adverse health effects. Coal-fired power plants account for nearly 30 to 35 percent of the total 115 tons of mercury emitted nationally in a given year. Figure 4-6 represents annual emissions of mercury from Maryland's coal-fired power plants.

Figure 4-7
GHGs in the Earth's Atmosphere



Greenhouse Gas Emissions

A GHG is any gas that absorbs infrared radiation in the atmosphere. Common GHGs include water vapor, CO_2, methane, NO_x, ozone, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons, and sulfur hexafluoride (SF6). As shown in Figure 4-7, CO_2 is clearly the most prevalent GHG in our atmosphere. GHGs are generated naturally in relatively small quantities as well as anthropogenically (i.e., man-made) from a number of different sources such as agriculture, fuel combustion, gas distribution, mining, oil and gas, transport, landfills, sewage sludge, and other industries. CO_2 is the most common of anthropogenic GHGs, and is by far the largest volume GHG in terms of annuall emissions.

According to a study published by the Energy Information Administration (EIA), emissions of CO_2 and other GHGs in the United States increased about 17 percent from 1990 to 2000. This rise can be attributed largely to the increased use of fossil fuels. As Figure 4-8 illustrates, the four major sectors contributing to CO_2 emissions from fossil fuel consumption (as defined by the EIA) are transportation, industrial, residential, and commercial. Emissions from power plants are allocated in proportion to the electricity consumed in each sector. Electricity generation alone accounted for 41 percent of the CO_2 from fossil fuel combustion in 2005.

Figure 4-8
Breakdown of CO_2 Emissions from Fossil Fuel Consumption
(as reported by EPA in 2005)

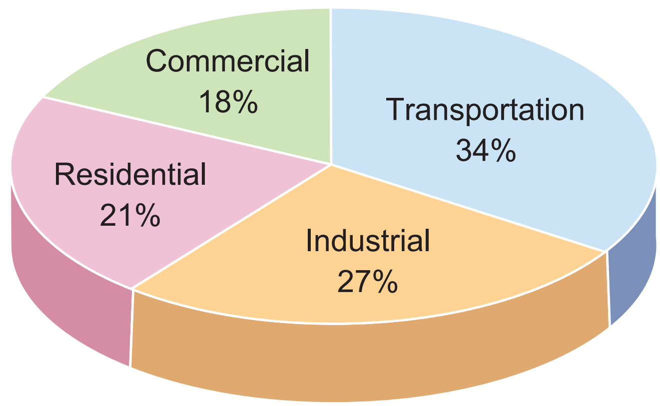


Table 4-2 presents the actual CO_2 emissions from the Maryland power plants for the years 2002 through 2006. In an effort to reduce CO_2 emissions, Maryland recently joined the Regional Greenhouse Gas Initiative (RGGI), a cooperative effort by Northeastern and Mid-Atlantic states (see discussion in the Climate Change section, page 74).

Table 4-2. Maryland Power Plant CO_2 Emissions

Maryland Power Plant	Emissions (tons per year)				
	2002	2003	2004	2005	2006
Brandon Shores	7,573,937	8,148,887	7,875,005	8,134,939	8,094,442
C P Crane	2,446,256	2,601,391	2,196,962	2,385,668	2,087,302
Chalk Point	6,387,632	6,249,667	6,814,163	6,952,254	4,659,234
Dickerson	3,182,191	2,761,809	3,472,925	3,527,948	3,249,702
Herbert A Wagner	3,220,518	3,612,518	3,720,789	3,853,522	2,888,357
Morgantown	7,435,745	7,759,622	6,318,751	6,156,779	7,226,692
Panda Brandywine	109,598	106,497	64,347	75,988	159,456
Perryman	34,757	33,014	96,421	37,002	38,852
R. Paul Smith Power Station	618,455	544,713	410,146	488,778	615,251
Riverside	32,412	8,305	2,873	13,167	10,540
Rock Springs Generating Facility	N/A	165,707	129,436	218,266	82,157
Vienna	169,805	103,158	52,551	139,698	13,643

Source: EPA Clean Air Markets

Potential Impacts From Power Plant Air Emissions

Ozone

The persistent ozone "smog" problem in many areas of the country has been one of the most important drivers for regulation of power plant NO_x emissions over the past decade. Ozone exists naturally in the upper levels of the atmosphere (from 6 to 30 miles, or 10 to 48 kilometers, above the Earth's surface) and protects the Earth from harmful ultraviolet rays. Although ozone is helpful in the stratosphere, it is harmful when it occurs in the troposphere, or the layer closest to the Earth's surface. Ozone is an invisible gas that is the major component of photochemical smog. It is not emitted directly into the atmosphere in significant amounts but instead forms through chemical reactions in the atmosphere. Ground-level ozone is formed when the precursor compounds — NO_x from both mobile and stationary combustion sources (such as automobiles and power plants respectively), and VOCs from industrial, chemical, and petroleum facilities and from natural sources — react in the presence of sunlight and elevated temperatures. Ozone levels are consequently highest during the summer months when the hours of daylight are greater and the sun's rays are more direct.

Weather plays such an important role in the formation of ozone that the EPA has established an "ozone season" extending from May through September each year (when hot, stagnant conditions are most prevalent), and has developed regulations that require power plants to restrict NO_x emissions during the summer months.

Ground-level ozone is a problem not only because it creates unsightly smog and inhibits visibility, but also because of the adverse human health effects it can cause. Breathing air with high ozone concentrations can cause chest pain, throat irritation, and congestion; it can also worsen pre-existing conditions like emphysema, bronchitis, and asthma. Children and the elderly are especially vulnerable to health problems caused by ground-level ozone.

Ozone is a regional problem, and transport of ozone and its precursors across large sections of the United States makes control and reduction of ozone smog a particularly difficult issue. As mentioned earlier, while much of Maryland achieves the ambient ozone standards, the entire State is designated as nonattainment for ozone because of the regional aspect of ozone. All of the eastern United States from northern Virginia through Maine are designated ozone nonattainment areas and are collectively referred to as the "Northeast Ozone Transport Region."

Because ozone pollution is a regional phenomenon, it cannot be addressed effectively on a state-by-state basis. In September 1998, therefore, EPA finalized a rule based on analysis conducted by representatives from EPA, the Environmental Council of the States, and various industry and environmental groups. The rule required Maryland, 21 other states, and the District of Columbia to develop regulations to be incorporated into each state's State Implementation Plan (SIP) to reduce regional transport of ozone from stationary sources of NO_x. Because the regulation called for changes to SIPs from this group of states, it is known as the "NO_x SIP Call," and it required power plants and some other large sources to achieve regional reductions in NO_x emissions of 70 percent from baseline years beginning in the ozone season 2004. Power plants and other large NO_x sources in Maryland and the region reduced emissions to meet the goals of the NO_x SIP Call; however, ozone pollution continues to be an issue in the East. Therefore, power plants in the region are also now subject to additional NO_x control requirements, including recently enacted Federal and State programs.

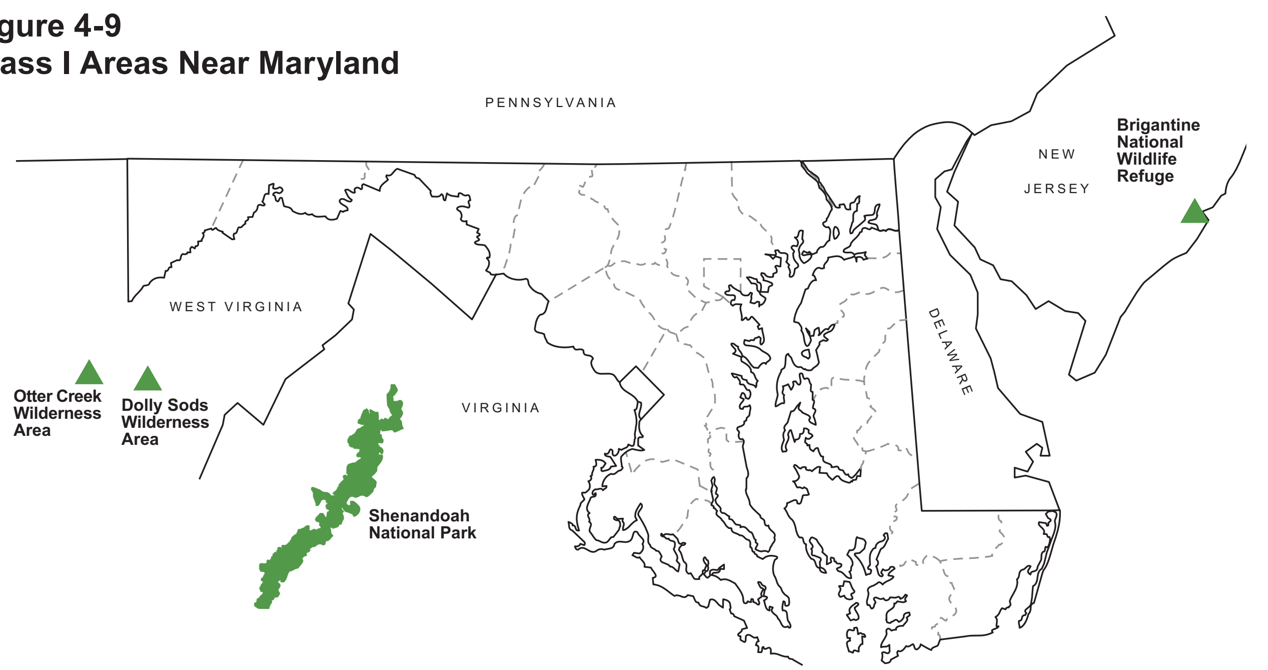
Visibility and Regional Haze

Certain gases and larger particles can interfere with the ability of an observer to view an object. Visibility is defined as the "greatest distance up to which a black object can be seen against the horizon." In general, it refers to the conditions which can facilitate the appreciation of natural landscapes. The national visibility goal, which was established as a part of the CAA Amendments of 1977, requires improving the visibility in federally managed "Class I areas" (see nearby Class I areas in Figure 4-9). These areas include more than 150 parks and wilderness areas across the United States that are considered pristine air quality areas. Since 1998, EPA and other agencies have been monitoring visibility in these areas.

In 1999, EPA finalized the Regional Haze Rule, which required states to set up periodic goals for improving visibility in natural areas. EPA has now amended the Regional Haze rule to require large, older coal-fired power plants, such as the Morgantown, Chalk Point, and Brandon Shores plants in Maryland, to implement pollution controls called Best Available Retrofit Technology (BART). The requirements contained in recently enacted Federal programs, as well as Maryland's HAA, are anticipated to fulfill BART requirements for Maryland power plants.

It has long been recognized that large air emissions sources with tall stacks, such as power plants, have the potential to transport pollutants across long distances and thus can affect air quality in remote areas. To protect Class I Areas from this process, developers of new power plants or projects to modify or expand existing power plants must evaluate potential air impacts to Class I Areas. In Maryland,

Figure 4-9
Class I Areas Near Maryland



this has meant that the State has evaluated potential impacts to four Class I Areas in the region (see Figure 4-9) as part of new major power plant projects in Maryland. Air modeling is used in these evaluations to determine whether a new or modified power plant will adversely affect air quality in Class I Areas. If adverse impacts are projected, the State may impose additional pollution control requirements or emissions limitations to mitigate impacts to Class I Areas.

PPRP has also been involved with evaluating the impacts of industrial and utility sources in Maryland on federally managed Class I areas in the vicinity of Maryland. Since 2004, PPRP has participated in a coordinated effort with Northeast States for Coordinated Air Use Management (NESCAUM) and the State of Vermont to evaluate impacts of visibility-impairing sources in the Eastern United States. The study evaluated the tools and techniques currently available for identifying contributions to regional haze in the Northeast and Mid-Atlantic regions. PPRP was involved with the application of a dispersion model, CALPUFF, for estimating visibility degradation in Class I areas. The model identified the contributions of sources in different states in the Eastern United States to visibility impairment in various Class I areas in the region. PPRP continues to support and contribute to this ongoing work.

The Mid-Atlantic Northeast Visibility Union (MANE-VU) is conducting several projects to provide states with the information needed to increase air quality within their states and region. Ongoing projects include quantifying air pollution impacts on visibility, identifying and analyzing potential strategies to improve visibility, and building a regional consensus for action. By 2008, MANE-VU member states will develop plans to improve visibility in their state and throughout the region and submit these plans to EPA.

Acid Rain

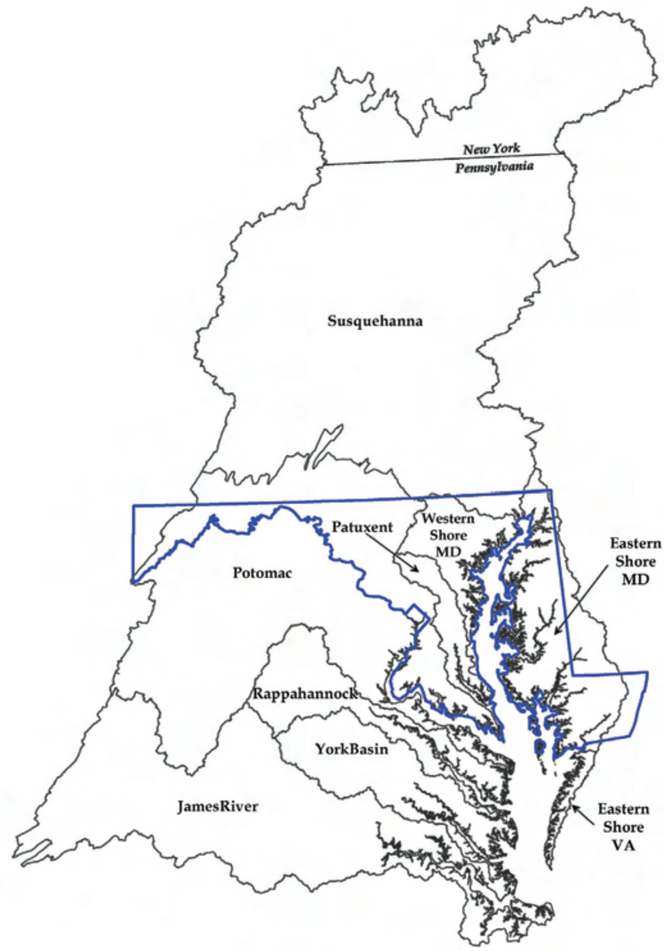
Acid rain occurs when precursor pollutants NO_x and SO_2 react with water and oxidants in the atmosphere to form acidic compounds. These acidic compounds, when deposited with precipitation ("acid rain") or deposited with dry particles ("dry deposition"), acidify lakes and streams and damage forest and coastal ecosystems, as well as man-made structures.

The Acid Rain Program was established under the CAA Amendments of 1990 with the goal of reducing acid rain by limiting NO_x and SO_2 emissions. The program capped total SO_2 emissions from power plants at 8.95 million tons nationally by 2000. SO_2 emissions are controlled with an allowance trading system, under which affected power plants are allocated a certain number of tons of SO_2 annually. These plants must then either reduce emissions to stay under the allowance cap or purchase SO_2 "allowances" from power plants that have over-controlled and banked excess SO_2 credits. NO_x emissions are controlled with rate-based limits (in units such as pounds per million Btu, lb/MMBtu) applied to certain coal-fired electric facilities.

Efforts to reduce acid rain have been highly successful nationwide. For 31 states and Washington, D.C., SO_2 emissions in 2000-2003 were lower than annual emissions in 1990. In 2003, total NO_x emissions from all power sources were 37 percent below 1990 emissions levels. These reductions have been achieved even as the inputs used to generate power have increased 30 percent since 1990.

Maryland has not seen similar SO_2 reductions over the period, because until passage of the Maryland HAA, no power plants in Maryland had installed SO_2 control devices.

Figure 4-10
Tributary Areas of the Chesapeake Bay



Nitrogen Deposition

The Chesapeake Bay is the largest estuary in the United States. Protection and restoration of living resources in the Bay has been the goal of the Chesapeake Bay Program since its inception in 1983. The Chesapeake Bay Program is a regional partnership which comprises the States of Maryland, Pennsylvania, and Virginia, the Chesapeake Bay Commission, EPA, and other participating advisory groups.

Reducing nitrogen input from controllable sources is a high priority because excess nitrogen is one of the major sources of eutrophication — caused by the increase of chemical nutrients, typically containing nitrogen or phosphorus — in the Chesapeake Bay. The 1987 Chesapeake Bay Agreement established a goal of reducing controllable nitrogen by 40 percent compared to 1985 levels, and program participants reaffirmed that goal in their 2000 agreement. The Chesapeake Bay Program estimates that approximately 30 percent of the nitrogen load to the Bay comes from atmospheric deposition and subsequent transport of nitrogen through the watershed. Much of this loading comes from NO_x emissions from power plants, industrial sources, and mobile sources. Increased efforts have been devoted recently to the role of ammonia in deposition processes.

For more than a decade, PPRP has evaluated the regional sources of NO_x emissions and their impacts on the Chesapeake Bay. PPRP is working with the Chesapeake Bay Program and the individual tributary teams to plan mitigation strategies. A map of the major subwatershed (tributary) areas in the Chesapeake Bay watershed is shown in Figure 4-10. As a part of this effort, advanced computer modeling systems are used to simulate the transport and subsequent deposition of emissions from these regional sources to the Chesapeake Bay. The actual loading to the Bay is calculated using a similar methodology that the United States Geological Survey uses with its land-to-bay models. NO_x emissions contribute to a total annual nitrogen load into the watershed of approximately 38 million pounds (17 million kilograms), based on emissions of NO_x in 1996, compared to a total load from all sources of approximately 300 million pounds.

The model allows PPRP to evaluate the relative contribution of Maryland sources and other regional sources to deposition totals, since sources located farther from Maryland have a relatively smaller impact on the Bay than sources located closer

Figure 4-11
Illustration of Location and Magnitude of Utility NO_x Sources and Transport

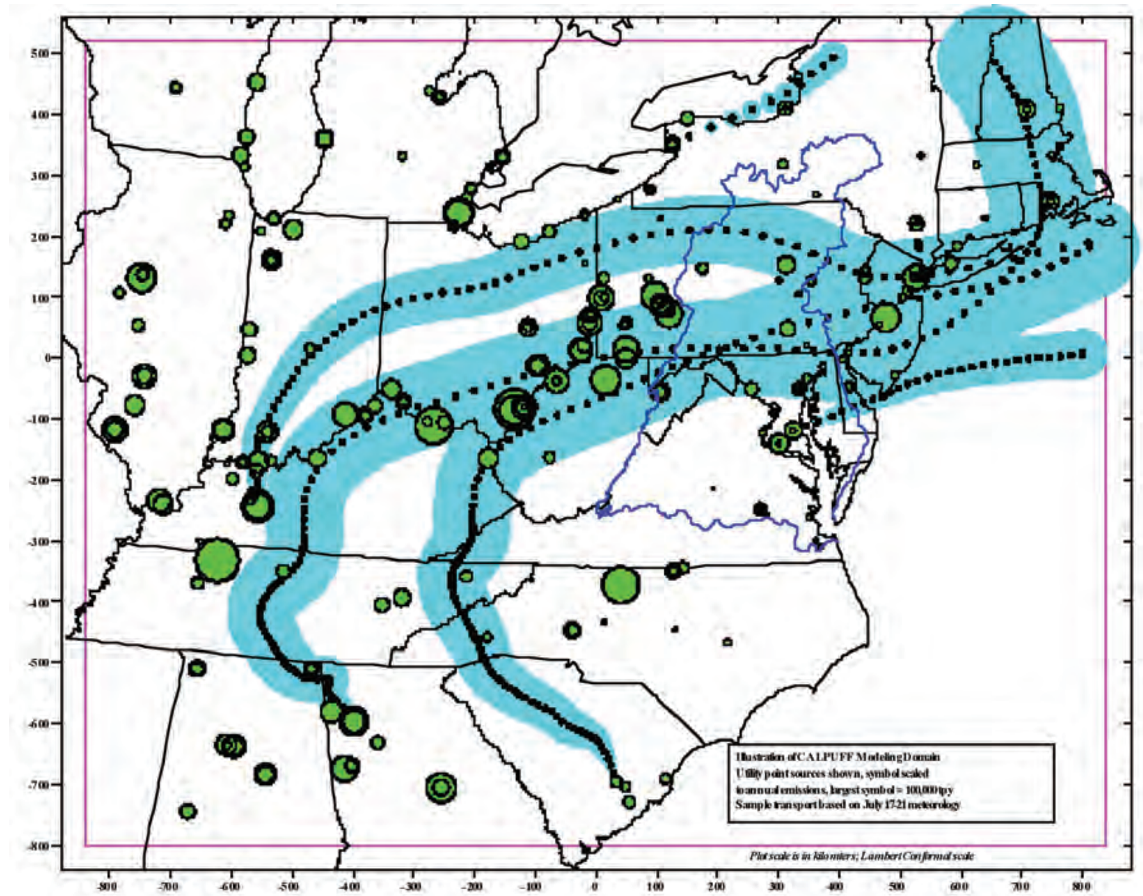


Table 4-3. Relative Contributions to Nitrogen Loading to the Chesapeake Bay

Source	Maryland	Other States	Total
Pounds of nitrogen per year			
Power Generation	1.1	11.5	12.6
Mobile Sources	2.8	9.9	12.7
Industry	0.3	3.1	3.4
Area Sources	1.6	7.7	9.3
Total	**5.7**	**32.3**	**38.0**
Percent of total			
Power Generation	2.8%	30.3%	33.1%
Mobile Sources	7.3%	26.2%	33.5%
Industry	0.9%	8.1%	8.9%
Area Sources	4.1%	20.4%	24.5%
Total	**15.1%**	**84.9%**	**100.0%**

to the Bay. The model also allows for a comparison of contributions to nitrogen loading from different NO_x source types (see Table 4-3). As a part of this study, an “emissions credit and benefit” scheme is developed to evaluate the impacts of emission reductions for sources located in different states. The credit refers to the source for which the emissions are reduced and the benefit refers to the tributary and state that derive the benefit from the emission reductions. Using this scheme, regional and local agencies can better plan for emission reduction strategies. An illustration of location and magnitude of utility NO_x sources and transport is shown in Figure 4-11. This figure also shows, for a small number of sources selected for the purpose of illustration, how the plumes from power plants and associated NO_x emissions can be transported many hundreds of miles over several days. The symbols at the center of the plume illustrations represent the location of the plume in one-hour time increments, while the blue shaded area represents an approximation of the horizontal extent of the plume, showing how the plume grows with distance downwind.

Mercury Deposition

The primary stationary sources of mercury nationally are (in order of decreasing emissions) coal-fired power plants, gold mining, municipal waste combustors, chlor-alkali plants, medical waste incinerators, and cement plants. Emissions of some source categories (notably medical waste incinerators) have decreased in recent years due to EPA regulations.

There are two main ways in which mercury in the atmosphere is deposited on the earth's surface: wet deposition, in which mercury is deposited via precipitation, and dry deposition, in which particulate mercury is transferred from the atmosphere to the earth in the absence of precipitation. Mercury in the atmosphere occurs in three forms: elemental, reactive, and particulate. Reactive mercury is mercury in a gaseous, ionic form; particulate mercury is mercury bound to airborne particles. Both forms are water soluble, and tend to remain in the atmosphere for one to ten days. As such, these forms of mercury are usually deposited locally or regionally. Elemental mercury is not soluble in water and does not deposit as readily as the other two forms, often existing in the atmosphere for over a year. All three forms are emitted by coal-fired power plants.

Power plants contribute between 65 and 70 percent of the total mercury emissions in Maryland, and so PPRP has been actively involved in the study of regional sources of mercury emissions and their impacts on the Chesapeake Bay. In cooperation with the University of Maryland, PPRP has sponsored several deposition monitoring programs and continues to evaluate the impacts of toxic emissions from power plants in Maryland. A mercury monitor has been in operation in Beltsville, Maryland since June 2004. In June 2005, PPRP initiated a project to measure ambient air mercury concentrations at the Piney Run monitoring site in Garrett County, Maryland using a continuous mercury monitoring instrument. This state-of-the-art monitoring effort will provide valuable data to the mercury research community.

As part of a complex, on-going study, PPRP has been evaluating dry and wet mercury deposition contributed by Maryland and regional mercury sources. The location of sources of mercury emissions close to Maryland, and the location of some of the water bodies and watersheds evaluated in PPRP's study, are shown in Figure 4-12. Results of the study indicate once the mercury emissions control programs required by recently enacted State and Federal programs are in place, total mercury loading in Maryland will be reduced by an estimated 30 percent and the role of power plants in contributing to mercury deposition within the State, compared to non-power plant regional sources and the global background, will be greatly reduced, as illustrated in Figure 4-13.

Figure 4-12
Location of Mercury Sources and Watersheds within Maryland

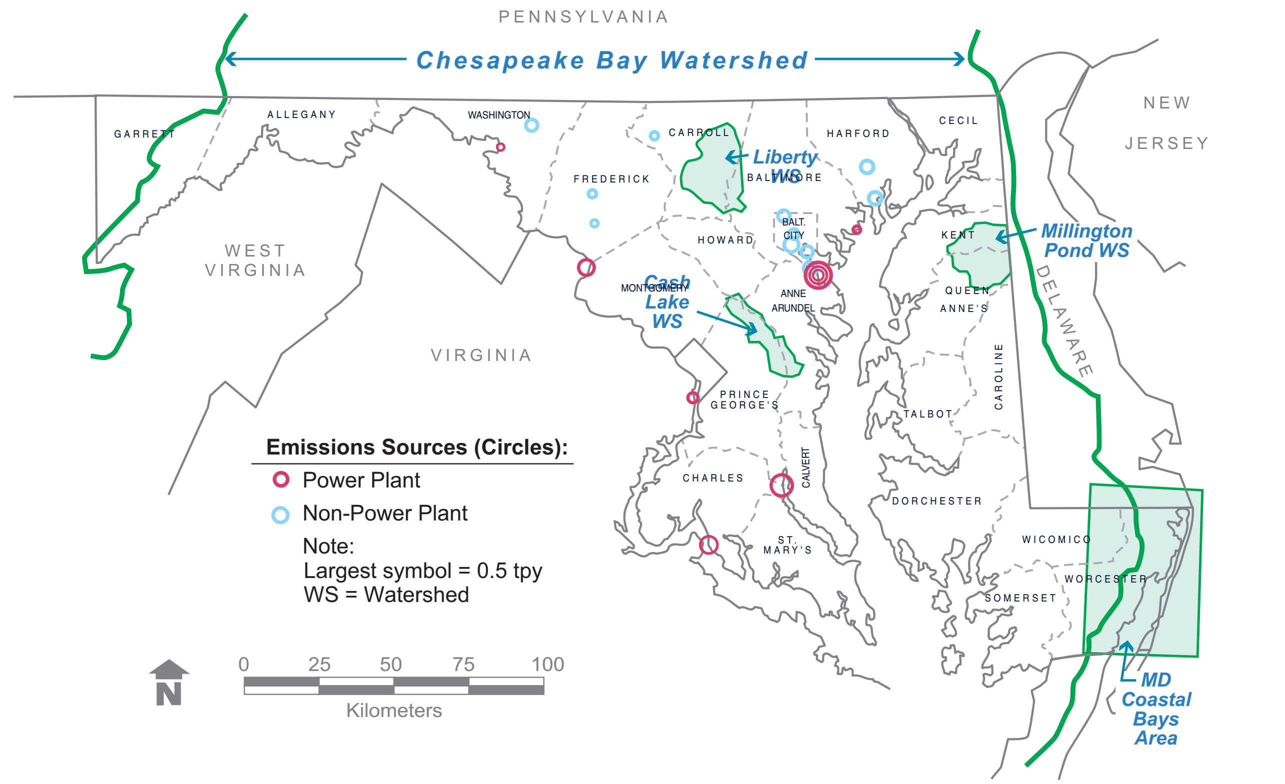
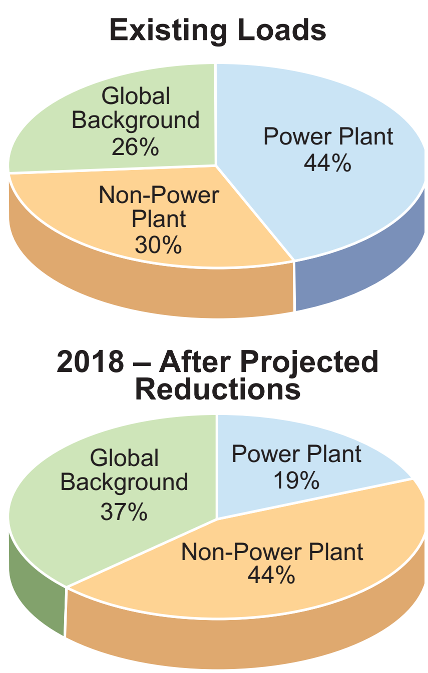


Figure 4-13
Contributions to Mercury Loading in Maryland

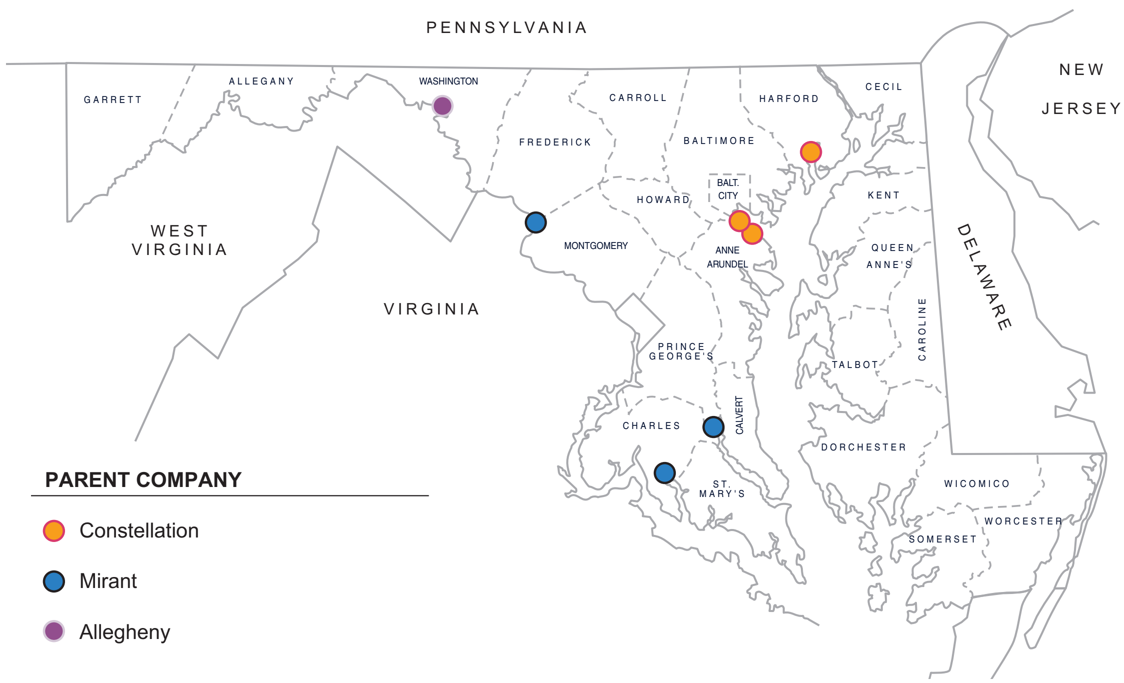


The Effects of the Maryland Healthy Air Act of 2006

The Maryland Healthy Air Act (HAA) was signed into law in April 2006 and the Maryland Department of the Environment (MDE) developed enabling regulations for the HAA that became effective in January 2007. The HAA requires substantial reductions in emissions of NO_x, SO_2, and mercury from 15 coal-fired generating units at seven power plants in Maryland. The HAA also requires Maryland to participate in a multi-state program known as the Regional Greenhouse Gas Initiative (RGGI) to reduce emissions of pollutants, including CO_2, that contribute to climate change. Emissions reductions will take place in two phases; the Phase I will begin in 2009/2010, and Phase II will begin in 2012/2013, depending on the pollutant.

The HAA regulates NO_x and SO_2 emissions based on a pollutant "cap-and-trade" program in which the State establishes annual, state-wide total tonnage emissions caps separately for NO_x and SO_2, and then allocates a portion of the annual state-wide caps to each of the 15 individual coal-fired power plant generating units subject to the HAA. These 15 units are depicted in Figure 4-14. Power plant owners can comply by reducing emissions at each unit to meet the

Figure 4-14
Coal-Fired Power Plant Generating Units Subject to the HAA



unit's cap, or can comply with the caps on a system-wide basis, by over-controlling emissions at some plants and trading the excess allowances to other HAA plants that the company owns and operates in Maryland. Table 4-4 lists the HAA caps and reduction requirements in the HAA regulations.

Instead of a cap-and-trade program, the mercury provisions of the HAA require affected power plants to achieve percentage reductions in emissions of mercury from a baseline year. Plants must achieve overall unit-by-unit reductions in mercury emissions of at least 80 percent for Phase I and 90 percent beginning in Phase II and thereafter. Compliance with this overall mercury removal efficiency can either be demonstrated by complying with a mercury emission rate or by meeting a mercury emission cap. The owner or operator of the facilities must notify MDE as to which compliance method they elect by the beginning of each compliance period (January 1, 2010 and January 1, 2013). The chosen method of compliance must be adhered to for the duration of the given compliance period; however, the method of compliance can be changed for the next compliance period. If an owner or operator chooses to demonstrate compliance using the mercury mass emission cap, they must apply this method to all of their facilities. Table 4-5 lists the applicable emission rates for each of the compliance methodologies.

Table 4-4. Emissions Caps and Reduction Requirements in MDE's HAA Emergency Regulations (COMAR 26.11.27) in Tons

Generating Unit	NO_x (2009) Annual	NO_x (2012) Annual	NO_x (2009) Ozone Season	NO_x (2012) Ozone Season	SO_2 (2010) Annual	SO_2 (2013) Annual
CONSTELLATION						
Brandon Shores Unit 1	2,927	2,414	1,359	1,124	7,041	5,392
Brandon Shores Unit 2	3,055	2,519	1,449	1,195	7,347	5,627
C.P. Crane Unit 1	832	686	345	284	2,000	1,532
C.P. Crane Unit 2	894	737	385	317	2,149	1,646
Wagner Unit 2	673	555	278	229	1,618	1,239
Wagner Unit 3	1,352	1,115	583	481	3,252	2,490
CONSTELLATION TOTAL	**9,733**	**8,026**	**4,399**	**3,630**	**23,407**	**17,926**
MIRANT						
Chalk Point Unit 1	1,415	1,166	611	503	3,403	2,606
Chalk Point Unit 2	1,484	1,223	657	542	3,568	2,733
Dickerson Unit 1	672	554	311	257	1,616	1,238
Dickerson Unit 2	736	607	333	274	1,770	1,355
Dickerson Unit 3	698	575	314	259	1,678	1,285
Morgantown Unit 1	2,540	2,094	1,053	868	6,108	4,678
Morgantown Unit 2	2,522	2,079	1,048	864	6,066	4,646
MIRANT TOTAL	**10,067**	**8,298**	**4,327**	**3,567**	**24,209**	**18,541**
ALLEGHENY						
R. P. Smith Unit 3	67	55	27	22	161	124
R.P. Smith Unit 4	349	288	143	118	841	644

Table 4-5. Compliance Methods for Meeting Mercury Removal Efficiencies under HAA

Affected Facility	Mercury Emission Rate (Ounces per Trillion BTU Heat Input)		Mercury Mass Emission Cap (tons per year)	
	Beginning January 1, 2010	Beginning January 1, 2013	Beginning January 1, 2010	Beginning January 1, 2013
Brandon Shores	21	10	94	46
C.P. Crane	37	18	26	13
Chalk Point	40	20	108	54
Dickerson	38	19	74	37
H.A. Wagner	25	12	68	33
Morgantown	27	14	127	66
R. Paul Smith	35	18	14	7

Proposed HAA Air Pollution Control Projects

In response to the HAA, several of the coal-fired power plants are installing air pollution control equipment. Most fossil fuel-fired power plants in Maryland are already equipped with air pollution control systems for PM and NO_x emissions; however, with the exception of the fluidized bed combustion coal-fired plant at Warrior Run, no power plants in Maryland currently have any SO_2 controls in operation. A list of existing controls is presented in Table 4-6.

Power plants in Maryland have flexibility in choosing how they will achieve emissions reduction targets under the HAA. Most of the coal-fired generating units in Maryland are planning to install major new air pollution control systems to reduce NO_x, SO_2 and/or mercury, as described below. In 2006, Constellation Power Source Generation, Inc. (CPSG) and Mirant Mid-Atlantic, LLC (Mirant) submitted seven applications to the Maryland PSC for authorization to install pollution control systems at their coal-fired power plants in Maryland to comply with the Maryland HAA. A list of proposed controls for the HAA affected facilities is presented in Table 4-7.

A flue gas desulfurization system (typically referred to as a "scrubber") is the most widely used technique for removing sulfur from exhaust gases from large sources like power plants. The flue gas enters an absorber, where it is sprayed with water slurry (mix of water and lime/limestone). The calcium from the limestone reacts with the SO_2 (in the exhaust gas) to form calcium sulfite or calcium sulfate. A portion of the slurry from the reaction tank is pumped into the thickener, where the solids settle before going to a filter. These solids produce gypsum, which is a marketable by-product. Figure 4-15 illustrates a typical scrubber configuration.

Figure 4-15
Limestone Forced Oxidation Flue Gas Dexulfurization Process

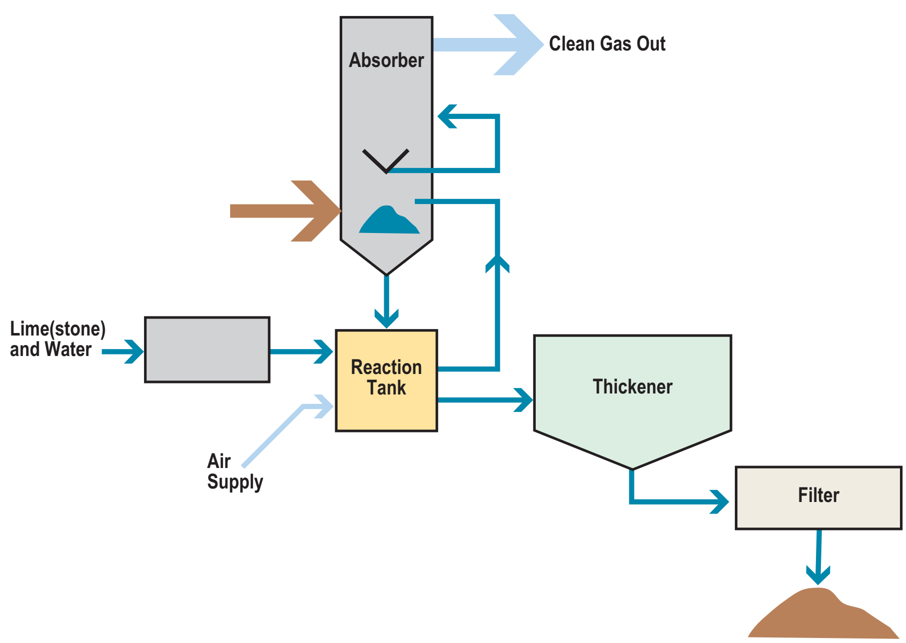


Table 4-6. Existing Air Pollution Controls at Power Plants in Maryland*

Facility	Unit ID	SO_2	NO_x	PM
AES Warrior Run	001	Fluidized Bed Limestone Injection	Ammonia Injection; Selective Non-Catalytic Reduction (SNCR)	Baghouse
Brandon Shores	1 & 2		Low NO_x Burner Technology w/ Overfire Air; Selective Catalytic Reduction (SCR)	Cyclone
C P Crane	1 & 2		Overfire Air; Combustion Modification/ Fuel Reburning	Baghouse
Chalk Point	3, GT1 & GT2	No Controls		
	GT3; GT4; GT5 & GT 6		Water Injection	
	1 & 2		Low NO_x Burner Technology (Dry Bottom only); Overfire Air (OFA)	Electrostatic Precipitator
	4		Overfire Air	
	SMECO		Water Injection	
Dickerson	1, 2 & 3		Low NO_x Burner Technology w/ OFA	Electrostatic Precipitator; Wet Scrubber (Unit 1 only); Baghouse (Unit 2&3 only)
	GT2 & GT3		Water Injection	
Gould Street	3			Electrostatic Precipitator
Herbert A Wagner	1 & 4			Electrostatic Precipitator
	2 & 3		Low NO_x Burner Technology; SCR (Unit 3 only)	Electrostatic Precipitator
Luke Paper Company	PR003		SNCR	
	PR004		Low NO_x Burner w/Close-coupled OFA	Cyclone, Electrostatic Precipitator
	PR005	No Controls		
Morgantown	1 & 2		Low NO_x Burner Technology w/ Closed-coupled/Separated OFA	Electrostatic Precipitator
	GT1, GT2, GT3, GT4, GT5, GT6		No Controls	
Panda Brandywine	1 & 2		Water Injection	
Perryman	51		Water Injection	
	CT1, CT2, CT3,CT4	No Controls		
R. Paul Smith Power Station	11		Low NO_x w/ OFA	Electrostatic Precipitator
	9		Low NO_x Burner Technology	Electrostatic Precipitator
Riverside	14,CT6, CT7,CT8	No Controls		
Rock Springs Generating Facility	1, 2, 3 & 4		Dry Low NO_x Burner Technology	
Vienna	10 & 8	No Controls		
Westport	CT5	No Controls		

* Units highlighted in gray are subject to Maryland's HAA

Table 4-7. Proposed Controls at the HAA Affected Facilities

Facility	Proposed Controls NO_x	SO_2	Mercury
Brandon Shores	Operation of the SCR all year long	FGD	PAC and co-benefit reduction from the SCR/FGD
Wagner	ROFA®, ROFA® plus SNCR or SNCR (or equivalent)	None proposed at this time	FSI or ACI (or equivalent)
Crane	Rotamix®, ROFA® plus SNCR, SNCR, or SNCR with rich reagent injection (or equivalent)	None proposed at this time	FSI or ACI (or equivalent)
Morgantown	SCR	FGD	Co-benefit reductions from the SCR/FGD
Chalk Point	SCR	FGD	Co-benefit reductions from the SCR/FGD
Dickerson	None proposed at this time	FGD	Co-benefit reductions from the FGD

A selective non-catalytic reduction (SNCR) system converts NO_x emissions in the flue gas into elemental nitrogen and water by injecting a nitrogen-based chemical reagent, most commonly urea or ammonia. A selective catalytic reduction (SCR) system is similar to SNCR in that it uses ammonia injection in the flue gas to convert NO_x emissions to elemental nitrogen and water. However, the key difference between SCR and SNCR is the presence of a catalyst, which accelerates the chemical reactions. The catalyst is needed because SCR systems operate at much lower temperatures than do SNCR systems. Figure 4-16 illustrates a typical SCR.

Of the 15 generating units subject to HAA, five will control SO_2 through the install of an FGD; eight will control NO_x through the installation of an SCR or SNCR; and six are proposing to control mercury through sorbent injection. Mercury will also be reduced in all units as a co-benefit of the operation of FGD and/or the SCR/SNCR systems. Substantial emission reductions at all facilities are expected with the installation of the proposed air pollution control equipment. Estimated reductions from the proposed equipment at the CPSG facilities currently include:

- *Brandon Shores*
  - *SO_2 -96%*
  - *NO_x -90% (through the increased use of the SCR all year long)*
- *Wagner*
  - *NO_x -34%*
  - *Mercury -18 to -41%*
- *Crane*
  - *NO_x -25%*
  - *Mercury -10 to -40%*

Figure 4-16
SCR System

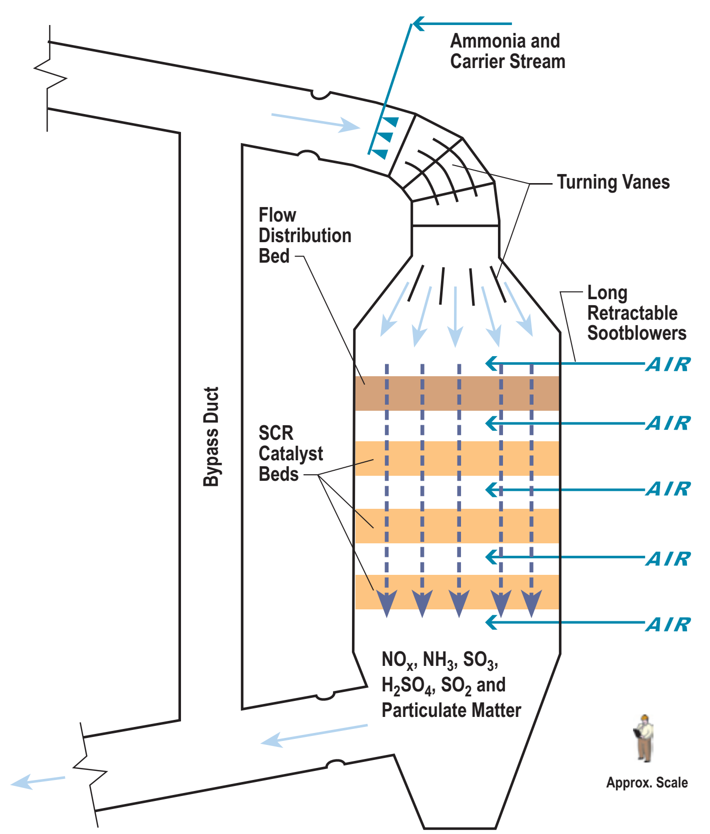


Figure 4-17
NO_x Emissions Reductions Under the Healthy Air Act

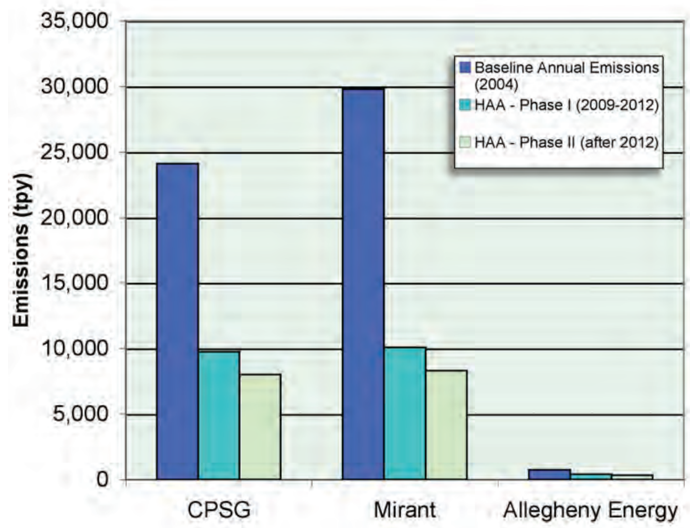
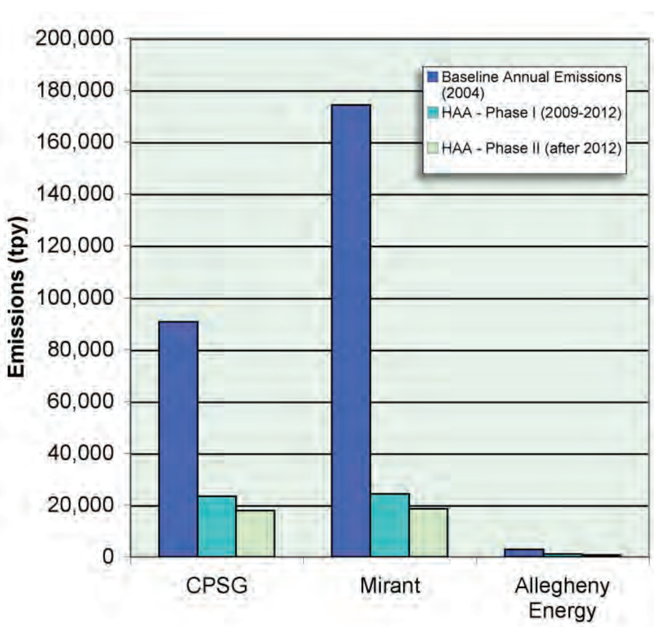


Figure 4-18
SO_2 Emissions Reductions Under the Healthy Air Act



Estimated reductions from the proposed equipment at the Mirant facilities currently include:

- *Morgantown*
  - *SO_2 -92%*
- *Chalk Point*
  - *SO_2 -92%*
  - *NO_x -85%*
- *Dickerson*
  - *SO_2 -92%*

Given the nature of the proposed equipment and the flexibility of the HAA, it has not been determined that the installation of this equipment alone will allow CPSG and Mirant to attain the caps set forth by the HAA. In addition, there may be some co-benefit to the reduction of emissions from the existing equipment. Therefore, both CPSG and Mirant are currently developing strategies to further reduce emissions, if necessary.

To better illustrate the overall emission reductions that will results from the HAA, the annual pre-HAA emissions from 2004 were compared to the projected post-HAA controlled emissions. Figure 4-17 presents emission reductions of NO_x in tons per year, by company under HAA, and Figure 4-18 presents emission reductions of SO_2 in tons per year, by company. On average across the state, NO_x emissions will be reduced by 57% in Phase I of the HAA and 64% in Phase II. The average reduction in SO_2 emissions will be 75% in Phase I of the HAA and 81% in Phase II.

Air Quality Benefits

The implementation of the HAA will result in significant decreases in emissions of SO_2, NO_x, and mercury from coal-fired power plants in Maryland. These reductions will result in anticipated improvements in air quality within Maryland, including improvements related to ground-level ozone concentrations, acid deposition, nutrient loading to the Chesapeake Bay, and reduced concentrations of sulfate aerosols that contribute to the current nonattainment status for PM2.5.

PPRP has conducted an air quality modeling analysis to quantify the benefits of the projected HAA emissions reductions to air quality and acid deposition within Maryland, and nutrient loading to the Chesapeake Bay. The overall benefits from the HAA emissions reductions predicted from the modeling analysis are shown in Table 4-8. These modeling results indicate that the HAA will have a significant effect on the environment in Maryland. The benefits of the HAA emissions reductions produce air quality improvements and reduced deposition and nutrient loading across a wide area. The beneficial effects of these projects occur primarily within Maryland and the Chesapeake Bay.

Other Regulatory Drivers Affecting Power Plants

In addition to the Clean Air Act NAAQS and Maryland's recent HAA, there are other major regulatory programs which apply to power plants in Maryland. These include the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR), which are described in greater detail below.

Clean Air Interstate Rule

The EPA finalized CAIR on March 10, 2005. The rule affects 28 eastern states and Washington, D.C.,

Sulfuric Acid Mist (SAM) Emissions from Coal-Fired Power Plants

SAM is primarily formed from the reaction of water with sulfur trioxide (SO_3), a pollutant formed by the oxidation of the sulfur in coals burned in coal-fired power plants. The majority of the sulfur in the coal is oxidized to SO_2 with only a small portion oxidized to SO_3. Additionally, common power plant controls such as selective catalytic reduction (SCR) units, which convert nitrogen oxides (NO_x) to harmless nitrogen gas, utilize a catalyst that can further oxidize SO_2 to SO_3, which increases the probability of SAM formation. Although some SO_3 is converted to SAM in the combustion gases due to the water vapor from combustion, and more is converted when in contact with the water vapor in the atmosphere downwind of the stack, a wet scrubber (common control technology designed to mitigate SO_2 emissions) will provide an abundant supply of water vapor to make the reaction proceed. Without some form of SAM control, the mist can exacerbate the visible flue gas plume that is characteristic of wet scrubbers (partially due to water vapor condensing at the outlet of the stack), and can increase ambient SAM concentrations near the plant. Therefore, it is advisable for plants considering installing wet scrubbers to remove the SO_3 prior to the wet scrubber.

Common practice in the power plant industry is to inject specially designed alkali sorbent material into the flue gas (calcium- or magnesium-based solids), forming fine particulate which is removed by existing PM controls. Of the four Maryland facilities that are planning to install wet scrubbers — Brandon Shores, Chalk Point, Dickerson, and Morgantown — all include SAM control measures.

Table 4-8. Summary of Air Quality Benefits from HAA Compliance Projects

Scenario	Pre-HAA Controls	Post-HAA Controls	Total Reduction
SULFATE AEROSOL (PM2.5) MAXIMUM CONCENTRATIONS			
Annual Average (ug/m^3)	0.58	0.24	0.34
Maximum 24-hour Average (ug/m^3)	9.32	4.45	4.87
SULFATE AEROSOL (PM2.5) AVERAGE CONCENTRATIONS WITHIN THE PM2.5 NONATTAINMENT AREA			
Annual Average (ug/m^3)	0.35	0.09	0.26
Maximum 24-hour Average (ug/m^3)	3.80	0.88	2.92
ACIDIC DEPOSITION (SULFUR) WITHIN MARYLAND			
Total Sulfur Loading (kg/year)	15,673,424	3,389,516	12,283,909
NITROGEN LOADING TO THE CHESAPEAKE BAY			
Total Nitrogen Loading (kg/year)	437,441	156,622	280,819
MERCURY LOADING WITHIN MARYLAND			
Total Mercury Loading (g/year)	76,162	7,616	68,546

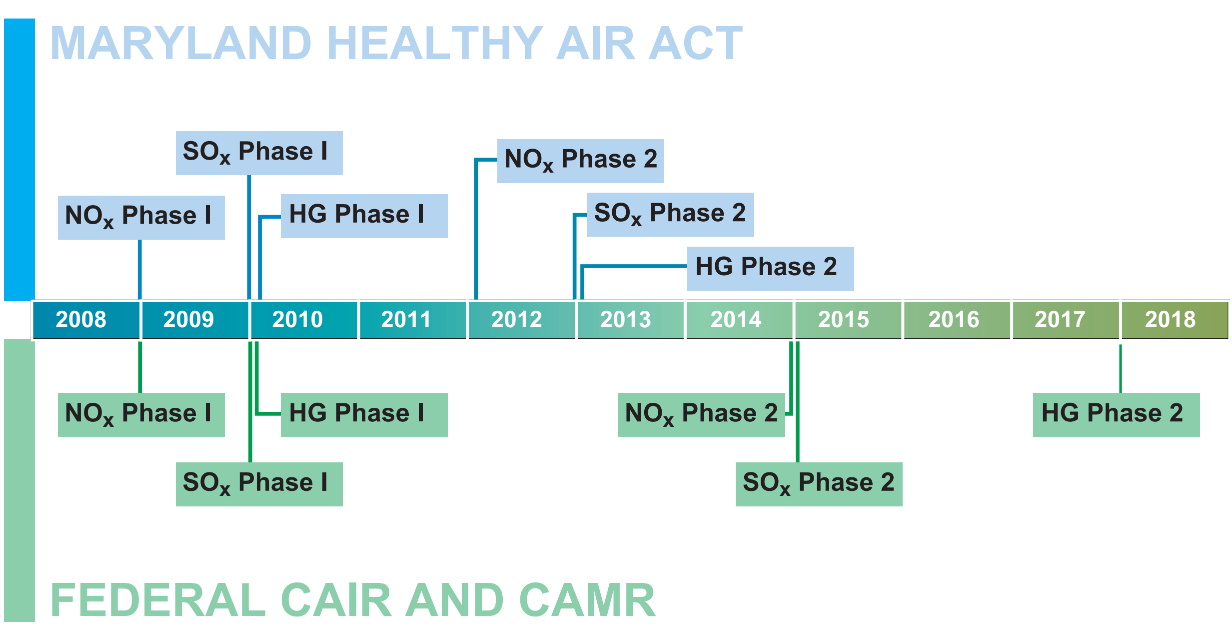
Table 4-9. Comparison of Emission Reduction Requirements under the Federal CAIR/CAMR Regulations and under Maryland's HAA

	EPA CAIR/CAMR	Maryland HAA
NO_x	▼ 42%	▼ 70% in 2009
	▼ 27,000 tons per year	▼ ~45,000 tons per year
SO_2	▼ 50%	▼ 80% in 2010
	▼ 120,000 tons per year	▼ ~200,000 tons per year
Mercury	▼ 46%	▼ 80% in 2010

and is designed to reduce formation and downwind transport of PM2.5 and ozone by limiting emissions of precursor pollutants SO_2 and NO_x. There will be two phases for emissions reductions; the first phase will begin in 2009 for NO_x and 2010 for SO_2; the second phase for both pollutants will commence in 2015. By 2015, expected emission reductions are 70 percent and 60 percent for SO_2 and NO_x power plant emissions, respectively (compared with 2003 levels).

Similar to the Acid Rain Program, states will be able to comply with the rule by either participating in a cap-and-trade program or by implementing other measures, such as state-defined and EPA-approved emission limits. Under the cap-and-trade program, EPA has set emissions "budgets" — tons of pollutants per year — for SO_2 and NO_x for each state affected by the rule. Each state will then distribute the available emissions to affected power plants. The power plants can reduce emissions to meet the cap, or purchase emissions credits, or "allowances,"

Figure 4-19
HAA Schedule v. Federal CAIR/CAMR Schedule



from power plants that have over-controlled and banked excess emissions reductions for sale. Once the rule is fully implemented in 2015, Maryland will have NO_x and SO_2 emissions caps of 12,000 and 24,000 tons respectively, which reflects a reduction of 82 percent and 91 percent from 2003 levels.

Clean Air Mercury Rule

CAMR is the first-ever federal action designed to regulate mercury from electric generating units. Finalized by EPA in March 2005, the rule is similar to CAIR in that it creates a market-based cap-and-trade program that will be implemented in two phases. The first phase, effective in 2010, will cap nationwide mercury emissions at 38 tons per year (34 metric tons per year). The second phase, effective in 2018, will cap emissions at 15 tons per year (14 metric tons per year). Also like CAIR, EPA has established mercury limits for each state for both phases. States must submit revised State Implementation Plans to EPA explaining how these mercury budgets will be met.

In addition to being subject to the mercury caps, coal-fired plants that begin construction after January 2004 must meet stringent mercury performance limits. Performance limits vary according to the type of coal unit because different raw materials and energy conversion processes yield different mercury emission rates. Coal-fired plants in Maryland all burn bituminous coal, and thus would be subject to a mercury emission limit of 21×10^{-6} pounds/MWh.

Maryland's HAA is more stringent than EPA's CAIR and CAMR programs in several key ways:

- *HAA generally requires greater pollutant reductions than CAIR (see Table 4-9).*
- *HAA reductions schedules are more aggressive than the federal schedule (see Figure 4-19).*
- *HAA prohibits the affected power plant from acquiring allowances from outside the State of Maryland.*
- *To date, there are no federal programs regulating GHGs emissions from power plants or other sources, while the HAA requires Maryland to participate in RGGI.*

Climate Change

Gases that trap heat in the atmosphere are known as greenhouse gases (GHGs). Some GHGs, such as CO_2, occur naturally and are emitted to the atmosphere by both natural processes and human activities. Other GHGs, such as fluorinated gases, are created and emitted solely through human activities. Increased levels of GHGs in the atmosphere have been linked to the relatively rapid increase in the Earth's average temperature over the past century. This temperature change has influenced human health, agriculture, forests, weather, and water resources. Collectively, this process is called "climate change."

GHG emissions are typically expressed in metric tons of carbon dioxide equivalent (CO_2e). The CO_2e is calculated using the global warming potential (GWP) of each GHG in comparison to CO_2. For example, methane (CH_4) traps 21 times more heat than CO_2, so an emission of 1 molecule of CH_4 can also be expressed as 21 molecules of CO_2 equivalent.

Climate change has entered into the United States political debate, with many businesses and organizations calling on Congress for action. The 110th Congress included a record number of proposed bills calling for cap and trade systems, United States participation in international climate change negotiations, and funding for research programs.

Regional Greenhouse Gas Initiative

To inhibit climate change worldwide, GHG emission reductions must be achieved. Absent any Federal regulation, various regions are adopting their own initiatives to reduce GHG emissions. One such effort is the Regional Greenhouse Gas Initiative (RGGI). RGGI is a cooperative effort by several Northeastern and Mid-Atlantic states to implement a CO_2 emissions budget and market-based emissions trading system. This program will regulate CO_2 emissions from fossil fuel-fired electric generating stations that have a rated capacity equal to or greater than 25 MW.

In August 2006, participating states issued a model rule for implementing RGGI. The model rule serves as the basis for participating states to pass regulations aimed to cap CO_2 emissions equal to that state's baseline emissions budget starting in 2009, and to decrease the cap by 2.5 percent each year starting in 2015 until a 10 percent reduction is achieved. Each state's baseline shall be set per the RGGI program.

Maryland became the tenth state to join RGGI in April 2007. As a participating state, Maryland commits to implementing an emissions budget and emissions trading system. The State continues to develop plans for implementation. Additionally, on 20 April 2007, the Governor of Maryland signed an Executive Order to establish a Climate Change Commission. The objective of the Commission is to develop a Plan of Action to address climate change issues, including potential mitigation strategies.

Methane - The Greater Cause for Concern?

Of all of the greenhouse gases, carbon dioxide is the one that has received the majority of public attention. Methane is a potent greenhouse gas with a high global warming potential. While concentrations of methane in our atmosphere are less than those of CO_2, methane is able to trap 21 times more heat than CO_2. Other GHGs include nitrous oxide, ozone, water vapor, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF6). These are all able to trap more heat that CO_2, but their concentrations are very low.

Increases in livestock farming and rice cultivation have led to an increase in methane, and there is concern that as the population grows so will methane emissions. Methane is also produced as a result of decomposing solid wastes in landfills. Methane can be used for electricity generation by burning it in a gas turbine or steam boiler (see further discussion of landfill gas-to-energy projects on page 39). While burning methane to produce energy does release CO_2, it reduces the greenhouse effect by substituting a less potent GHG (carbon dioxide) in place of a stronger GHG (methane).

CO_2 Reduction Strategies for Power Plants

With Maryland's becoming a member of RGGI and with the potential for federal legislation, the reduction and mitigation of CO_2 is currently a major issue. Some of the strategies for utility companies on the forefront include geologic sequestration, terrestrial sequestration, and the use of lower carbon fuels such as biogas.

Geologic Sequestration

The Midwest Regional Carbon Sequestration Partnership (MRCSP) is a public/private consortium that was established in 2003 to assess the technical potential, economic viability, and public acceptability of carbon sequestration within seven contiguous states, including Maryland. MRCSP recently released a Phase I report that detailed the initial findings of its geologic sequestration research. It found numerous sequestration options in the region, including deep saline formations that are available across most of the region, both active and depleted large oil and gas fields, and one of the nation's largest accumulations of coal in the North Appalachian Basin. Ultimately, they estimated that there are more than 500 gigatons of potential geologic CO_2 storage within the MRCSP region. Currently, MRCSP is moving forward with geologic sequestration field tests at a FirstEnergy power plant near Shadyside, Ohio, and underneath the Gaylord parcel forest in northern Michigan.

The Canadian energy provider SaskPower had announced plans to develop the world's first commercial scale geologic sequestration project as part of a 300 MW clean coal project. The facility in Saskatchewan would utilize underground carbon sequestration along with injection for enhanced oil recovery to capture over 90 percent of total CO_2 emissions. However, in September 2007 the utility announced that projected costs had increased to the point where the near-zero emission facility had become uneconomic, and it is putting the plans on hold.

Terrestrial Sequestration

Terrestrial sequestration of carbon using biological processes is being investigated by the MRCSP and may qualify for offset allowances under RGGI. The goal of the states participating in RGGI is to stabilize emissions from power generators of 25 MW or greater at current levels from 2009 through 2015, then to achieve a 10 percent reduction in emissions by 2019.

Terrestrial biological processes that remove carbon dioxide from the atmosphere and store it in vegetation (e.g., photosynthesis) can be important tools for managing carbon. Another biological strategy for managing carbon is to offset emissions of CO_2 by substituting biomass fuels, known as biofuels, for fossil fuels. Biofuels include ethanol, wood, other fuels derived from vegetation, and methane released during the decomposition of animal waste and other organic material (i.e., biogas). Growing and burning biofuels recycles carbon that is already in the environment, thereby reducing the amount of fossil carbon (contained in coal, oil, or gas) that is extracted from the ground and added to the atmosphere. PPRP has identified a number of strategies for increasing biological sequestration of carbon and production of biofuels in Maryland, including strategies for increasing carbon sequestration in forests, agricultural areas, wetlands, and ecologically degraded zones.

In particular, PPRP has been evaluating actions that could be undertaken or supported by power companies to acquire carbon sequestration credits under RGGI and other programs. Two terrestrial sequestration approaches that are especially relevant to Maryland's economy and natural resource strengths are forestry and wetlands restoration. Carbon management in forested areas combines harvest practices that maximize the carbon benefit of the forest with carbon sensitive uses of the harvested wood and scrap material. This set of strategies may be used in commercial and recently disturbed forest areas, where the soil carbon reservoir is already depleted, and in restored forest after new trees have reach their peak growth rate. Wetlands restoration will be particularly effective in the large estuarine wetlands of Maryland's Eastern Shore, which have been shrinking because of both human and natural factors. A third strategy that may produce benefits is to plant more trees in urban areas. In total, a large city may be able to support

Massachusetts v. Environmental Protection Agency

On April 2, 2007, the Supreme Court ruled that the U.S. Environmental Protection Agency (EPA) not only has the authority to regulate motor vehicle emissions, including carbon dioxide, but that EPA must provide adequate rationale for not regulating emissions. Prior to the ruling, the EPA Administrator indicated that even if the agency had such authority it would decline to regulate carbon dioxide in relation to global warming. Massachusetts argued that the EPA has the authority and, in fact, the obligation to regulate carbon dioxide under Section 202(a)(1) of the Clean Air Act, which requires EPA to set emission standards for motor vehicles that contribute to air pollution.

as many trees as a small patch of forest, and proper management can create a sizeable carbon reservoir.

Forest Management

The three carbon management elements of an effective forestry project are (1) a tree management/harvest cycle that maintains a high rate of carbon removal from the atmosphere; (2) a wood-product mix that maximizes long-lived products; and (3) maximum conversion of harvest scraps to biofuel. The first of these elements entails balancing the growth rate of the trees (which slows as trees mature) with the amount of usable lumber that can be obtained (which increases as trees grow larger). The second is important because the carbon in wood that is used in building materials, furniture, and recyclable products can be sequestered for decades, and ideally for 100 years or more. The third represents a way of offsetting or reducing the fossil-fuel costs of timber management by extracting energy from the half of the forest biomass that is unsuitable for lumber, instead of letting that biomass decay and release its carbon right back to the atmosphere.

PPRP has used a carbon accounting model to simulate the rate at which carbon is sequestered in forests managed by Maryland's Department of Natural Resources. Table 4-10 shows the results for three different species that are common in Maryland forests: red maple, white oak, and loblolly pine. These species cover the range of growth rates typically found in Maryland, and hence the results indicate the level of carbon sequestration that could be expected under different conditions and management practices.

Table 4-10 Carbon Sequestration Under Various Timber Management Scenarios

Scenario	Description	Carbon Dioxide Equivalent (lbs/acre/yr)
Loblolly Pine		
1	Harvest at 43 years with two thinnings	6551
2	Harvest at 43 years with no thinnings	6871
3	Harvest at 60 years with two thinnings	7202
4	Harvest at 60 years with no thinnings	6201
5	Natural death at 85 years, no harvest, no thinning	5062
Red Maple		
1	Harvest at 58 years with one thinning	7500
2	Harvest at 58 years with no thinnings	7306
3	Harvest at 73 years with one thinning	6796
4	Harvest at 73 years with no thinnings	6495
5	Natural death at 100 years, no harvest, no thinning	5429
White Oak		
1	Harvest at 74 years with one thinning	7566
2	Harvest at 74 years with no thinnings	7375
3	Harvest at 93 years with one thinning	7686
4	Harvest at 93 years with no thinnings	7395
5	Natural death at 140 years, no harvest, no thinning	6301

These results demonstrate that harvesting trees under typical management practices sequesters carbon at a faster annual rate than unmanaged natural growth, even though half of the biomass of the harvested plot ("slash") is left in the forest to decay. Net sequestration is on the order of three tons of CO_2 per acre per year, including allowance for long term sequestration in lumber. Additional gains could be made by collecting and using the slash to produce biofuels.

Wetlands Restoration

Some kinds of wetlands are also highly effective carbon scrubbers that serve, in addition, as ecological refuges, water-purification plants, and buffers for floodwaters. The potential of wetlands to sequester carbon dioxide from the atmosphere follows from their typically high productivity and low decomposition rates. As undecayed organic material accumulates in wetland soils, a large pool of stored carbon is produced. What happens to this carbon depends on several factors. Upland wetlands that dry out intermittently may convert most of it to the greenhouse gas methane, which has a warming potential 21 times larger than carbon dioxide, and release it to the atmosphere. On the other hand, evidence suggests that cool, acidic non-tidal wetlands with fairly constant water levels may sequester carbon effectively. Tidal saltwater marshes, such as found on the eastern shore of the Chesapeake Bay, appear to emit relatively little, if any, methane compared to the carbon that they sequester.

Maryland has both abundant wetland resources and many drained wetland areas that could be restored. A particularly interesting restoration project is being managed by the U.S. Fish and Wildlife Services at Blackwater National Wildlife Refuge on the Eastern Shore. Up to 20,000 acres of this ecologically important area have been lost to the effects of navigation channels, subsidence, and the rising sea level. The restoration approach involves installing low-cost dikes (basically hay bales) in shallow, flooded areas and filling them to the water level with clean sediment dredged from navigational channels in Chesapeake Bay. Filled areas are then planted with wetland plants that stabilize the dredged material and lay down an annual layer of biomass from the summer growing season. Once re-established and protected from the effects of wave erosion, the wetlands become self-sustaining, such that the annual accumulation of peat compensates for subsidence and sea-level rise. Preliminary estimates from experiments funded by PPRP have indicated that carbon sequestration rates may be similar to forests, at around one to three tons of CO_2 per acre per year, for an indefinite period. Thus, in addition to its ecological benefits, restoring the whole 20,000 acres could absorb as much as 60,000 tons annually of CO_2 emissions produced by fossil-fuel power plants.

Lower Carbon Fuels

An example of switching to lower carbon fuel might be the conversion of a coal plant to a state-of-the-art gas turbine, which emits much less CO_2 during operation. Co-firing a traditional fossil fuel with biomass, which is considered a zero carbon fuel, is another example (see

IGCC Power Plant Technology

Integrated gasification combined cycle (IGCC) technology is an alternative means of generating power and producing fuels and other chemical products using coal or other solid fuels such as petroleum coke and biomass. PEPCO proposed the first IGCC project in Maryland at the Dickerson Generating Station in the late 1980s. Due to PEPCO's plan for phased development of the Station H project – simple cycle combustion turbines to be constructed first, then a steam cycle added, then IGCC – the CPCN that PEPCO received in 1990 only covered the initial simple cycle turbines. PEPCO later dropped its IGCC plans due to economic and market considerations.

In recent years, IGCC has become a more attractive generating option and is currently being considered by several power plant developers due to its demonstrated environmental performance, thermal efficiency, feedstock flexibility, and byproduct marketability. The technology allows for power production with significantly less emissions (i.e. SO_2, NO_x, particulates, and mercury) and more favorable thermal efficiency than conventional coal-fired plants, even when employing lower grade coals – for instance, high sulfur eastern bituminous coals. An IGCC plant bears resemblance to a chemical process plant, in that gasification is used to convert the solid or liquid fuels to a synthetic gas (syngas), which is then processed to remove sulfur compounds, tars, particulates, and trace contaminants like mercury prior to combustion. The sulfur removed from the syngas can be sold for further use. Clean fuel gas is then converted to electricity via a combustion turbine (CT) operating in a combined cycle configuration with a heat recovery steam generator (HRSG) and steam turbine.

<table>
<tr><th rowspan="2">Power Generation Technology</th><th rowspan="2">Heat Rate (MMBtu/ MWh)</th><th rowspan="2" colspan="2">CO_2 Emissions (tons/MWh)</th><th colspan="2">Potential Maximum CO_2 Emissions (tons/year)</th></tr>
<tr><th>Proposed 900 MW Plant</th><th>Proposed 1600 MW Plant</th></tr>
<tr><td>Polk IGCC Plant (Tampa Electric Co.)</td><td>9.35</td><td>0.935</td><td rowspan="2">Average CO_2 Emissions (tons/MWh) 0.9125</td><td rowspan="2">7,194,150</td><td rowspan="2">12,789,600</td></tr>
<tr><td>Wabash River IGCC Plant (Wabash Valley Power Assn.)</td><td>8.9</td><td>0.89</td></tr>
<tr><td>Natural Gas CCT Plant (based on proposed Catoctin Power facility)</td><td>6.79</td><td colspan="2">0.44</td><td>--</td><td>6,173,349</td></tr>
<tr><td>Conventional Pulverized Coal Plant with FGD (U.S. DOE data)</td><td>9.8</td><td colspan="2">1</td><td>7,884,000</td><td>14,016,000</td></tr>
</table>

further discussion on page 40). Methane produced at landfills can be captured and used to replace fossil fuels for heating or power generation, creating climate change benefits (see page 39).

Utilizing fuel switching or co-firing projects may also qualify a utility company for carbon offset credits under the RGGI agreement. Reducing CO_2 emissions with qualified offset projects may count toward reducing the net CO_2 emissions from a given plant, bringing it into compliance with the limitations set by the cap and trade program under RGGI.

Biogas recovery is another type of alternative fuel that is already well established in power generating applications. Biogas is a mixture of methane and carbon dioxide that is released from decaying organic matter in the absence of oxygen. It can be used in any energy application that would normally use natural gas. Because the carbon in the organic matter comes from atmospheric carbon dioxide, burning biogas as fuel simply recycles carbon. Moreover, the methane produced naturally during decomposition of organic waste is burned for energy instead of being released to the atmosphere, where it would have a warming capacity about four times as great as carbon dioxide.

The primary process used for generating biogas is anaerobic digestion of organic matter. In the absence of oxygen, some bacteria extract energy and nutrients from organic material while producing methane instead of carbon dioxide. Methane generation occurs spontaneously in landfills, wetlands, and other low oxygen environments. Almost any organic matter can be used as raw material for generating biogas. Concentrated source materials are readily available at landfills, wastewater treatment plants, and livestock farms, feedlots, and dairies. Using animal manure to generate biogas is particularly beneficial, since the manure is also a primary source of water pollutants in agricultural watersheds.

On-farm biogas recovery systems have proven themselves, but are not yet widely deployed in the United States. With a modest investment in facilities and operational procedures, biogas can be recovered from animal manure and other agricultural waste and used to generate electrical power for the farm or for sale to the power grid. Unfortunately, the average size of dairy farms in Maryland (about 100 cows) is too small to support individual digesters on each farm economically, but private or public construction of centralized digesters that could handle the aggregated waste of about 1000 cows could afford efficient and profitable energy production. For example, a county-scale digester producing 1.8 million cubic feet of biogas (about 900,000 cubic feet of methane) per day could generate 60 to 90 MWh of energy per day, which is equivalent to the output of a small power plant capable of supplying several thousand homes. A recent PPRP-sponsored analysis of the feasibility of biogas recovery in Maryland concluded that the total potential of dairy farms in the state was approximately four to eight times as large as this (three to six million cubic feet of methane per day).

PPRP has evaluated the use of poultry litter as fuel for power generation, either as a source of biogas or in solid pelletized form. Allen Family Foods proposed a biogas project utilizing poultry litter, and although the company received a CPCN in 2001, the plans never became economically viable.

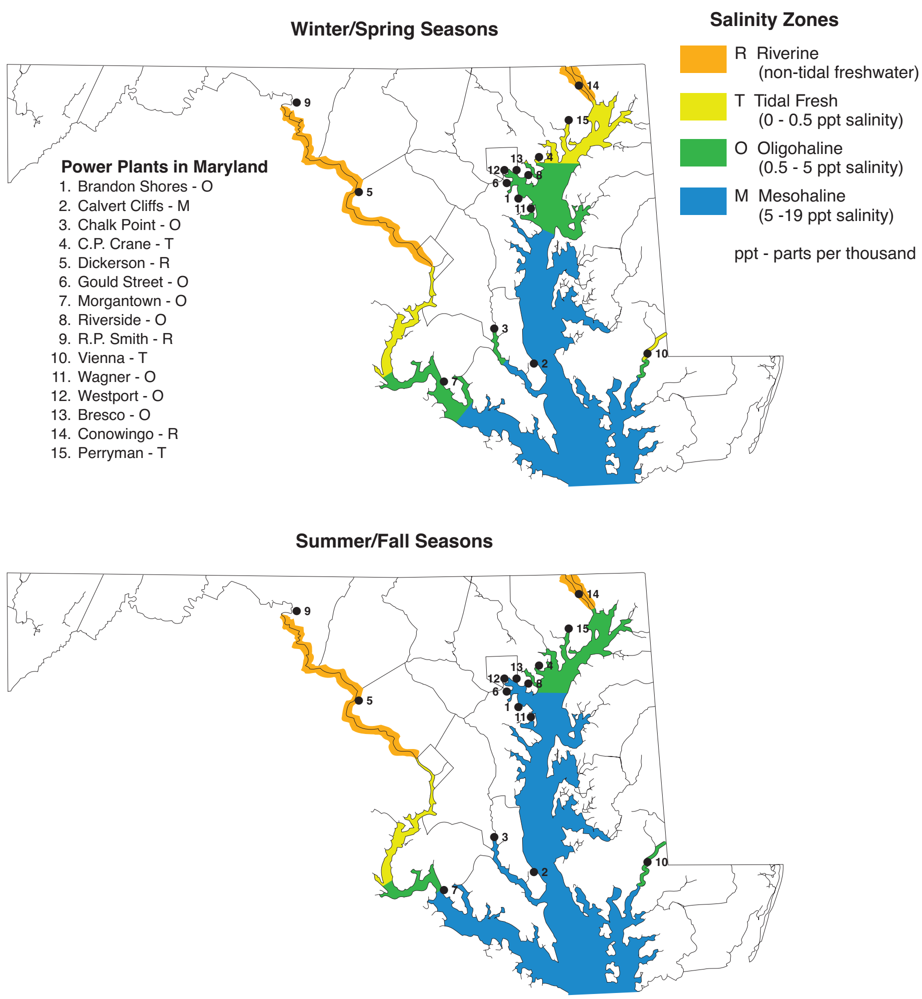
Water Impacts

Other than a small segment of western Maryland and small estuarine water bodies of the Atlantic Shore, the bulk of Maryland's drainage system feeds the Chesapeake Bay. All of Maryland's primary rivers drain into the Chesapeake Bay: Potomac, Patuxent, Patapsco, Susquehanna, Chester, Choptank, Nanticoke, Blackwater, and Pocomoke Rivers. Together, these rivers and the Bay extend over a large geographic area and encompass a broad range of aquatic habitat types, including marine, estuarine, and freshwater rivers and lakes.

All steam electric power plants in Maryland are located in the Chesapeake Bay watershed. As depicted in Figure 4-20, the power plants occupy various physiographic and habitat types, including upland, riverine, and estuarine.

Power plants are significant users of water in Maryland, and their operation can affect aquatic ecosystems as well as the availability of water for other users. This section describes the volume of water used in Maryland for power plant operation, potential resource impacts, and methods for minimizing any adverse impacts.

Figure 4-20
Salinity Zones of the Maryland Chesapeake Bay



Withdrawal and Consumption Impacts

Most electricity is produced in Maryland by four types of generating technologies: steam-driven turbines, combustion turbines, combined cycle facilities (a combination of steam and combustion turbine units), and hydroelectric facilities. Power plants with steam cycles have the largest water withdrawals because of the need to cool and condense the recirculating steam. Typically, a power plant will obtain cooling water from a surface water body. The other, much smaller water needs of the power plant, such as boiler makeup water, are met by on-site wells or municipal water systems.

Table 4-11 lists all major steam generating power plants in Maryland (excluding self-generators) and quantifies their water withdrawals and consumption for 2006. Most steam plants in Maryland use once-through cooling, in which cooling water is continuously drawn from a water source, used, and then continuously returned to (usually) the same source. While water losses within the cooling system are negligible, the release of heated water results in elevated evaporative losses in the receiving waters. According to work conducted by the Interstate Commission on the Potomac River Basin (ICPRB), the in-stream evaporative loss caused by heated discharges can range up to 2.5 percent of the discharge volume,

Table 4-11. Surface Water Appropriations and Use at Maryland Power Plants with Steam Cycles

Power Plant	Surface Water Appropriation (average, mgd)	2006 Actual Surface Withdrawal (average, mgd)	Estimated Consumption (mgd)[1]	Water Source
Once-through Cooling				
BRESCO	62.2	20	0.1	Patapsco River
Calvert Cliffs	3,500	3,235	18	Chesapeake Bay
Chalk Point[2]	720	604	N/A	Patuxent River
C.P. Crane	475	323	2.2	Seneca Creek
Dickerson	400	366	1.5	Potomac R. (non-tidal)
Morgantown	1,500	1,154	2.5	Potomac River
Riverside	40	4	0.03	Patapsco River
R.P. Smith	70	52	0.6	Potomac R. (non-tidal)
H.A. Wagner	940	414	1.7	Patapsco River
SUBTOTAL		**6,172**	**26.6**	
Closed-cycle Cooling				
AES Warrior Run[3]	0.021	N/A	N/A	City of Cumberland
Brandon Shores	35	6.1	3.0	Patapsco River
Panda Brandywine[3]	3.0	N/A	N/A	Mattawoman WWTP
Montgomery Co. Resource Recovery Facility	1.3	0.87	0.6	Potomac R. (Dickerson Station's discharge canal)
Vienna	2.4	1.1	0.7	Nanticoke River
SUBTOTAL		**8.07**	**4.3**	
TOTAL	**7,753.6**	**6,180**	**30.9**	

Sources: MDE WMA

1 For facilities with once-through cooling, the estimated consumption was derived from ICPRB's 1986 report, Evaporative Loss from Receiving Waters Due to Heated Effluent Discharges.

2 Chalk Point has two units on once-through cooling and two on closed-cycle cooling. The appropriation of 720 mgd covers all four steam units; data on each cooling system individually are not available.

3 AES Warrior Run and Panda Brandywine do not have direct surface water appropriations for their total water use, since their cooling water needs are met indirectly through third parties (the City of Cumberland and the Mattawoman wastewater treatment plant, respectively). 2006 water use data for these power plants was not available.

with an average of about 0.6 percent during the summer and 0.5 percent during the winter.

PPRP used ICPRB's calculation methods, applying them to facilities' 2006 water use data, to estimate the amount of water lost to evaporation as a result of thermal discharges from Maryland power plants. The calculations indicate that an estimated 27 mgd of water statewide is lost to in-stream evaporation as a result of heated discharges from once-through cooling. While most of this evaporation occurs in tidal waters, with negligible impacts to other water users, approximately 2 mgd of that loss represents freshwater losses in the Potomac River as a result of heated discharges from Mirant's Dickerson plant and Allegheny Energy's R. Paul Smith facility. For comparison, the historic minimum flow in the Potomac at Point of Rocks, near the Dickerson Plant, was 342 mgd, measured in September 1966.

Four steam power plants in Maryland — AES Warrior Run, Brandon Shores, Panda Brandywine, and Vienna — use closed-cycle cooling (cooling towers) exclusively instead of once-through cooling. (Chalk Point has multiple steam boilers, two of which use once-through and two of which use closed-cycle cooling.) Closed-cycle systems recycle cooling water and contact less than one-tenth of the water required for once-through cooling; however, depending on plant design and operating parameters, 50 to 80 percent of the water evaporates from the cooling tower and does not return to the source, thus representing a consumptive use. According to data reported by the Electric Power Research Institute (EPRI), closed-cycle cooling systems consume about 1.5 times more water per megawatt-hour compared to once-through systems, on average.

Cooling water withdrawals at steam electric facilities represent the majority of surface water usage in Maryland. In 2006, combined water withdrawal for all steam generating power plants in Maryland is estimated at 6.2 billion gallons per day (see Table 4-11). All other non-power plant users in the state have a combined appropriation of less than 4 billion gallons per day. By comparison, the Potomac River has an average discharge of roughly 7 billion gallons per day, while the Susquehanna River discharges an average of about 23 billion gallons per day (actual daily flows in both the Susquehanna and the Potomac fluctuate greatly, both seasonally and from year to year).

Nuclear power plants fall within the steam generating category; however, they use nuclear reactions instead of fossil fuel combustion to create the thermal energy. Nuclear facilities generate more waste heat than fossil fuel-fired plants of the same capacity, and require 10 to 30 percent more cooling water to produce the same energy, according to data from the U.S. Nuclear Regulatory Commission. Existing nuclear stations generally operate at a lower steam temperature and pressure compared to fossil fuel fired generating plants, which causes a somewhat lower efficiency in the conversion of thermal energy to mechanical and, ultimately, electrical energy. Consequently, more thermal energy is rejected to the cooling system, per megawatt-hour generated, than would be in a fossil fuel plant, and more cooling water is needed to absorb that waste heat.

Maryland has one nuclear power plant operating on the western shore of the Chesapeake Bay, Calvert Cliffs, which withdraws an average of 3.3 billion gallons per day from the Bay. This is the largest single appropriation of water in the State of Maryland, 13 times more than the municipal supply for the Baltimore City metropolitan area of 250 million gallons per day. While the majority of this water is returned to the Bay, an estimated 18 mgd of Bay water is lost to evaporation as a result of the heated discharge (see Table 4-11). Plans for an expansion at Calvert Cliffs indicate that evaporative cooling towers will be used for the proposed Unit 3.

Low-Flow Issues

In the nontidal portion of the Potomac River, consumptive users of water (withdrawing more than 1 mgd) must comply with Maryland's consumptive use regulations for the Potomac River Basin (COMAR 26.17.07). Consumptive water use refers to that portion of a water withdrawal that, as a result of evaporation, interbasin diversions, or other means, is not returned to the source to be available for subsequent use. The main focus of this regulation is to ensure that upstream users do not withdraw too much water during low-flow periods, and that sufficient water is present downstream to supply municipal water to the Washington, D.C., metropolitan area.

The consumptive use regulations require users consuming more than 1 mgd of water from the Potomac River to maintain low-flow augmentation storage, and to release water from storage to offset their consumption during low-flow periods. Alternatively, users can comply with the rules by reducing consumptive use to less than 1 mgd during low-flow periods. Users can provide low-flow augmentation storage, if necessary, by developing new water storage facilities or by purchasing storage space in existing water storage facilities, or both. The regulations specify the amount of augmentation storage that must be secured to avoid the potential for curtailment of water withdrawals during low-flow periods.

A power plant developer can build ponds or tanks to store cooling water, which could carry the facility through a short-term drought. However, based on current conditions, it is prohibitively expensive for plant developers to construct on-site storage that could supply enough water to support operations through a prolonged period of withdrawal restrictions. Plants that propose to withdraw cooling water from nontidal waters of the Potomac therefore accept the risk that, occasionally, severe drought conditions will require them to curtail their operations. It is recognized that severe drought conditions correlate quite well with conditions of heavy electricity consumption, but the goal of providing on-site water storage is to reduce the risk of curtailment, not entirely eliminate it.

As an example, part of the 2007 licensing case to modify the Dickerson Generating Station to install a wet scrubber, Mirant agreed to incorporate on-site water storage to meet Potomac River low-flow requirements. Approximately 85 percent of the water used in a wet scrubber is consumptively lost through evaporation out of the stack. Mirant projected that operating at peak load for 24 hours could create a consumptive use of water slightly over 1 mgd. In addition, Mirant operates two combustion turbines at Dickerson that consume additional water under certain operating conditions. To comply with the consumptive use regulations, Mirant proposed to limit Potomac River water consumption to 1 mgd for the FGD unit and the two combustion turbines. In addition, Mirant proposed to use an on-site pond with a capacity of 4.5 million gallons to supplement the water supply during periods of low flow to ensure generation would not be curtailed. In response to the State's recommendations, the PSC accepted this approach to comply with consumptive use requirements through the issuance of a CPCN with conditions reflecting the approach.

Another water storage alternative has been identified as part of Catoctin Power's plans to build a combined cycle power plant in Frederick County. Catoctin Power proposed to comply with the regulations by providing almost 470 million gallons of water in augmentation storage at one of two potential quarry sites upstream of the power plant to maintain a minimum flow during low-flow conditions. The two quarry sites are located along the Shenandoah River in Jefferson County, West Virginia.

Cooling System Alternatives and Advances

With increasing pressures to minimize water withdrawals, power plant developers are finding more efficient means of cooling. Once-through cooling, once standard for power plants, is not a viable option for new power plants, particularly in light of EPA's newly promulgated regulations under the Clean Water Act Section 316(b), which target ecological effects of cooling water withdrawals (see discussion on page 89). Closed-cycle cooling towers have become standard on new steam generating power plants, which reduce water withdrawals substantially compared to once-through cooling systems, although their consumptive use is somewhat higher.

The reuse of treated wastewater treatment plant (WWTP) effluent is also becoming more acceptable and viable for power plants. The Panda Brandywine combined cycle facility, located in Prince George's County, currently utilizes about 1.5 mgd of treated effluent from the Mattawoman WWTP. The 2005 licensing proceeding for Catoctin Power, a proposed Frederick County facility, also included WWTP effluent as an alternative in its facility plans.

In 2007, Constellation and Mirant agreed to use treated effluent to supply the FGD units being installed at the Brandon Shores and Morgantown power plants, respectively. Constellation plans to use treated effluent from Anne Arundel County's Cox Creek WWTP, which is ideally located adjacent to the Brandon Shores power plant. At Morgantown, Mirant agreed to obtain treated effluent from the LaPlata WWTP to minimize Mirant's proposed use of ground water and mitigate long-term withdrawal impacts to sensitive Southern Maryland aquifers.

Effluent reuse has been established as an alternative that can be economically attractive and technically viable for sites located near large WWTPs. With respect to environmental impacts, effluent reuse still represents a consumptive loss of freshwater resources, since the treated effluent that is used and evaporated in the cooling towers would otherwise be discharged to surface water. However, aquatic impacts are reduced because effluent reuse does not involve direct withdrawals from a surface water body. In the case of Mirant's use of the LaPlata WWTP effluent, the elimination of the discharge from the WWTP to the Port Tobacco River will reduce nutrient loading to the river, thus improving water quality.

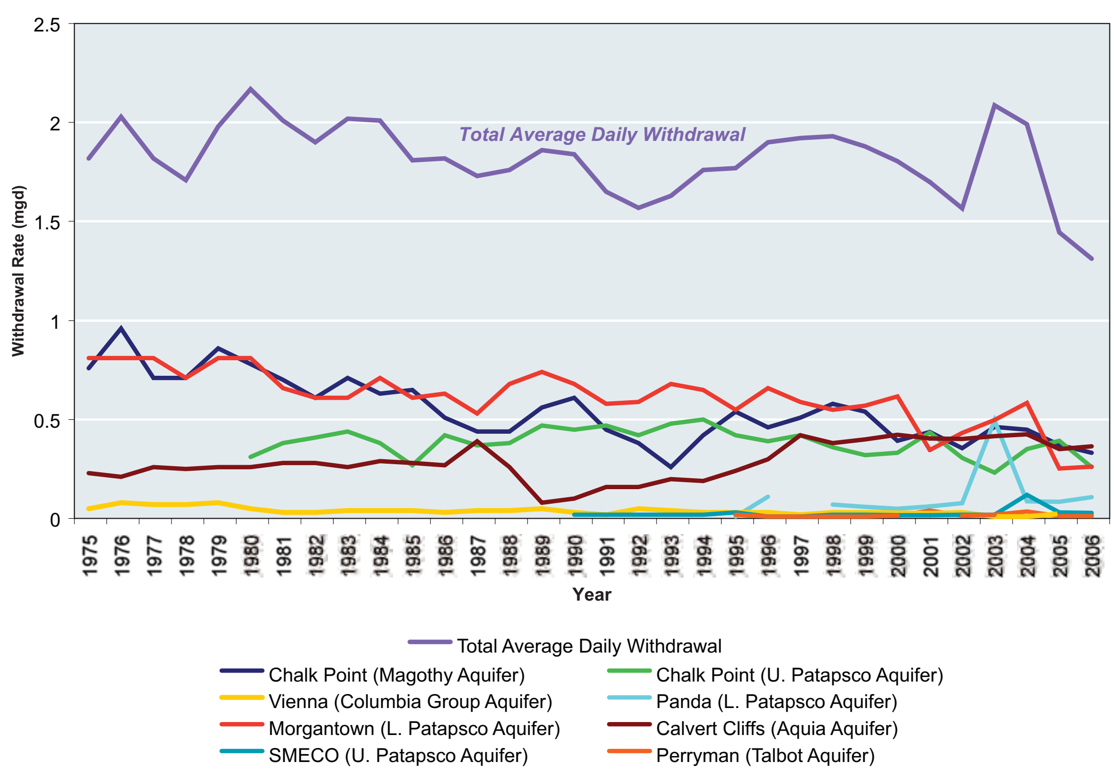
Dry cooling systems are also making significant inroads to the power industry. Once thought infeasible due to their large size (aesthetics, parasitic power use, required land, capital outlay), dry cooling towers are now being seriously evaluated as potential alternatives to wet cooling systems. Although currently there are no facilities in Maryland using dry cooling systems at major power plants, this option is being considered by a developer for a generating project in Charles County. As appropriations for cooling water become more restricted, dry cooling becomes more attractive.

Ground Water Withdrawals

Some of Maryland's power plants are also significant users of ground water. Ground water is used for boiler feedwater in coal-fired power plants, inlet air cooling and emissions control in gas- and oil-fired combustion turbines, and potable water throughout the power plants. However, use of ground water for process cooling is severely restricted in Maryland. High-volume ground water withdrawals from aquifers have the potential to lower the water level of an aquifer, reduce the amount of water available for other users, lower the water table of an area, or, in the case of Coastal Plain aquifers, cause intrusion of salt water into the aquifer. The impact of these withdrawals has been a key issue in southern Maryland, where there is a significant reliance on ground water for public water supply. Although large volumes of ground water are available in the Coastal Plain aquifers, withdrawals must be managed over the long-term to ensure adequate ground water supplies are available in the future.

Currently seven power plants in Maryland withdraw ground water from Coastal Plain aquifers for plant operations. These plants include: Constellation's Calvert Cliffs Nuclear Power Plant and Perryman combustion turbine facility, Mirant's Chalk Point and Morgantown power plants, NRG's Vienna power plant, SMECO's combustion turbine facility (located at the Chalk Point plant), and Panda-Brandywine's combined cycle power plant. All of these plants are located in the Coastal Plain of Maryland, and with the exception of the Perryman and Vienna facilities, all are located in southern Maryland. Perryman, located in Harford County northeast of Baltimore, withdraws ground water from the Talbot

Figure 4-21
Average Daily Ground Water Withdrawal Rates at Maryland Power Plants



Aquifer; Vienna, located in Dorchester County on the Eastern Shore, withdraws ground water from the Columbia Group Aquifer. An eighth power plant, the Rock Springs combustion turbine facility in Cecil County, withdraws ground water under certain conditions.

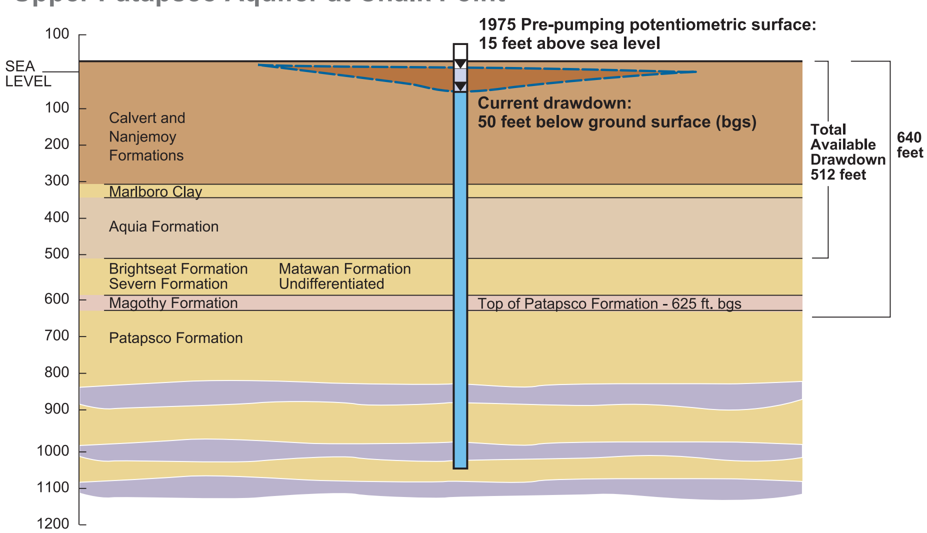
Five power plants located in southern Maryland (Calvert Cliffs, Chalk Point, Morgantown, SMECO, and Panda) withdraw ground water from three aquifers: the Aquia, the Magothy, and the Patapsco. Recently, Morgantown has been granted approval to pump from the Patuxent aquifer on an interim basis until a pipeline from the La Plata wastewater treatment plant can be completed and subsequently used to supply water to a planned wet FGD scrubber. Figure 4-21 shows the ground water withdrawal rates expressed as daily averages from 1975 to 2006 for each of these five power plants, in addition to the Perryman and Vienna facilities; the rates are also listed in Table 4-12. The power plants typically withdraw amounts of water well below their appropriation permit limits. The average withdrawal for all seven power plants in 2006 was 1.30 mgd compared to a combined daily appropriations limit of 2.66 mgd. The amount of ground water withdrawn by power plants has fluctuated between about 1.5 and 2.1 mgd over the past 30 years.

Three government agencies — the Maryland Geological Survey, the U.S. Geological Survey, and PPRP — jointly operate a ground water monitoring program to measure the water levels in these aquifers to ensure the long-term availability of ground water. MDE WMA, which has permitting authority over all ground water appropriations, uses the data from the joint monitoring program to assess the significance of impacts to these aquifers when reviewing additional appropriations requests.

Evaluating Drawdown Impacts

Long-term monitoring data show how pumping from a ground water aquifer affects the water level over time. MDE regulations define "available drawdown" in an aquifer as 80 percent of its historic pre-pumping level. The significance of the current drawdown can then be estimated by comparing current drawdown to the total available drawdown (see drawing below for an illustrated example).

Upper Patapsco Aquifer at Chalk Point



Long-term monitoring indicates a steady decline in water levels in the Aquia, Magothy, and Patapsco aquifers. However, these declines are not solely due to withdrawal from power plants, and are considered acceptable by MDE when compared to the amount of water available in the aquifers. The amount of water available is expressed as the aquifer's "available drawdown," which is defined in MDE regulations as 80 percent of the distance from the historic pre-pumping water level to the top of the pumped aquifer.

Also, although power plants have contributed to the decline in the water levels in these aquifers, increased withdrawals from municipal well fields in southern Maryland have caused most of the recent declines. Water quantity impacts to each of the three aquifers are summarized below.

- ***Aquia Aquifer at Calvert Cliffs*** *– Water levels in the Aquia Aquifer at Calvert Cliffs have declined approximately 58 feet over the period 1982 to 2006, with most of the decline occurring since 1990. This acceleration in water level declines is due to the withdrawal from municipal well fields at Lexington Park in St. Mary's County and Solomons Island in Calvert County. The water levels at Lexington Park and Solomons Island have declined nearly 18 feet since 1997 and approximately 108 feet since 1982. The impacts from the water level declines are considered acceptable given the 315 feet of available drawdown currently estimated in the Aquia Aquifer at Calvert Cliffs.*

- ***Magothy Aquifer at Chalk Point*** *– MDE has required industrial users of the Magothy Aquifer to use deeper aquifers like the Patapsco to allay concerns over water level declines in the Magothy. As a result, the Chalk Point power plant reduced its ground water withdrawal from the Magothy during the time period 1990 to 2005 by about 44 percent compared to the period before 1980. This reduction has resulted in a commensurate reduction in the rate of water level decline at the facility during this same period; however, water levels continue to decline in the aquifer due to the extensive continued use in Annapolis and Waldorf. The drawdown at Chalk Point between 1975 and 2006 has been approximately 39 feet, and a total of about 82 feet since pumping at Chalk Point began in 1964. Prior to pumping in 1962, the elevation of the potentiometric head in the Magothy Formation was 28 feet above msl; thus the available drawdown is 80 percent of 600 feet plus 28 feet, approximately equivalent to 500 feet. Consequently, the total drawdown of 82 feet is small compared to the estimated total available drawdown of approximately 500 feet for the Magothy Formation in the vicinity of Chalk Point.*

- ***Upper Patapsco Aquifer at Chalk Point*** *– The water level surface in the Upper Patapsco Aquifer declined up to 21 feet at Chalk Point between 1990 and 2006. Recent measurements indicate a total drawdown of nearly 63 feet between 1975 and 2006 at Chalk Point. These declines will not impact the approximately 512 feet of available drawdown in the Upper Patapsco Aquifer at Chalk Point.*

- ***Lower Patapsco Aquifer at Morgantown*** *– The water level surface of the Lower Patapsco Aquifer in the vicinity of the Morgantown power plant has declined up to 36 feet between 1990 and 2006. Since 1997, water levels in the vicinity of the Morgantown power plant have remained relatively constant.*

Table 4-12. Average Daily Ground Water Withdrawal Rates at Maryland Power Plants (in mgd)

	Chalk Point (Magothy Aquifer)	Chalk Point (U. Patapsco Group Aquifer)	Vienna (Columbia Aquifer)	Panda (L. Patapsco Aquifer)	Morgantown (L. Patapsco Aquifer)	Calvert Cliffs (Aquia Aquifer)	SMECO (U. Patapsco Aquifer)	Perryman (Talbot Aquifer)	Total Average Daily Withdrawal
Current Appropriations Limit:	**0.66**	**0.66**	**0.05**	**0.064 ***	**0.82**	**0.45**	**0.02**	**0.1**	**2.66**
1975	0.75		0.04		0.8	0.22			1.81
1976	0.95		0.07		0.8	0.2			2.02
1977	0.7		0.06		0.8	0.25			1.81
1978	0.7		0.06		0.7	0.24			1.70
1979	0.85		0.07		0.8	0.25			1.97
1980	0.77	0.3	0.04		0.8	0.25			2.16
1981	0.69	0.37	0.02		0.65	0.27			2.00
1982	0.6	0.4	0.02		0.6	0.27			1.89
1983	0.7	0.43	0.03		0.6	0.25			2.01
1984	0.62	0.37	0.03		0.7	0.28			2.00
1985	0.64	0.26	0.03		0.6	0.27			1.80
1986	0.5	0.41	0.02		0.62	0.26			1.81
1987	0.43	0.36	0.03		0.52	0.38			1.72
1988	0.43	0.37	0.03		0.67	0.25			1.75
1989	0.55	0.46	0.04		0.73	0.07			1.85
1990	0.6	0.44	0.02		0.67	0.09	0.01		1.83
1991	0.44	0.46	0.01		0.57	0.15	0.01		1.64
1992	0.37	0.41	0.04		0.58	0.15	0.01		1.56
1993	0.25	0.47	0.03		0.67	0.19	0.01		1.62
1994	0.41	0.49	0.02		0.64	0.18	0.01		1.75
1995	0.53	0.41	0.02	0	0.54	0.23	0.02	0.01	1.76
1996	0.45	0.38	0.02	0.1	0.65	0.29	0	0.001	1.89
1997	0.5	0.41	0.01	Not Available	0.58	0.41	0	0.001	1.91
1998	0.57	0.35	0.02	0.06	0.54	0.37	0.01	0	1.92
1999	0.53	0.31	0.02	0.05	0.56	0.39	0.01	0	1.87
2000	0.382	0.322	0.019	0.04	0.606	0.412	0.008	0.005	1.79
2001	0.427	0.426	0.017	0.051	0.337	0.395	0.007	0.031	1.69
2002	0.346	0.296	0.020	0.067	0.423	0.392	0.009	0.004	1.56
2003	0.454	0.222	0.022**	0.486	0.489	0.407	0.009	0.010	2.08
2004	0.439	0.341	0.008***	0.076	0.575	0.415	0.11	0.025	1.98
2005	0.362	0.382	0.013	0.074	0.243	0.34	0.02	0.002	1.44
2006	0.322	0.249	0.009	0.097	0.251	0.354	0.018	0.002	1.30

Source: U.S. Geological Survey, MDE

* Panda was granted a higher appropriation during construction of its pipeline for conveying treated effluent.

** No report was submitted to MDE for the period July-December 2003. The amount shown was estimated using the total volume withdrawn of 4,131,683 gallons reported for the period January-June 2003.

*** No report was submitted to MDE for the period January-June 2004. The amount shown was estimated using the total volume withdrawn of 1,505,770 gallons reported for the period July-December 2004.

Impacts to Water Quality and Aquatic Biota

Potential impacts from steam-electric power plants on rivers and estuaries may include a reduction in river flow volumes due to evaporative water loss in the plant's cooling system, mortality of aquatic organisms as a result of entrainment in the cooling system, impingement of larger organisms on cooling system screens, and elevated temperatures of receiving waters after power plant discharge.

Water usage and the resulting environmental impacts have been monitored by various agencies and organizations; these issues have been a major responsibility of PPRP since it was established in 1972. In systems where multiple sources of potential impacts can affect water quality and aquatic habitats, the combined effects may compound or intensify the effects of the individual sources, and accumulate in downstream areas. Although permit requirements and regulations may not require an assessment of cumulative effects, the health of the contiguous system is determined by the impact of multiple influences. PPRP has conducted aquatic impact assessment studies at all of Maryland's existing plants and has identified no measurable cumulative adverse impacts. MDE issues discharge permits, in accordance with the Clean Water Act, and uses aquatic impact assessment data to monitor continued performance of power plants in minimizing these impacts.

In addition to minimizing impacts, several power plants have instituted cooperative aquatic enhancement measures at their facilities, such as constructing and operating game fish hatcheries where fish are released under the direction of Maryland DNR. Power plants have also established funds to remove fish migration obstructions caused by low-head dams no longer in use. The types of impacts identified by PPRP, along with the steps that have been taken to minimize and mitigate these impacts, are discussed in greater detail below. The impacts associated with cooling water withdrawals in the state are currently being re-evaluated for regulatory compliance because of the new U.S. EPA Section 316(b) of the CWA regulations for new and existing power plants.

Cooling Water Withdrawal Impacts

Cooling water withdrawals can cause adverse ecological impacts in three ways:

- ***Entrainment*** *– drawing in of plankton and larval or juvenile fish through plant cooling systems;*
- ***Impingement*** *– trapping larger organisms on barriers such as intake screens or nets; and*
- ***Entrapment*** *– accumulation of fish and crabs (brought in with cooling water) in the intake region.*

In the 1970s and early 1980s, PPRP evaluated aquatic organism impacts at 12 major power plants. The studies were used to evaluate the relative impacts of power plant operations on the aquatic environment, with special emphasis on the Chesapeake Bay. Results of the studies showed that while power plant operations affect ecosystem elements, the cumulative impacts have no significant consequence to Maryland's aquatic resources.

Although entrainment losses for aquatic organisms have been measured, they did not reveal consistent depletions of populations. Even though power plant activities have not substantially decreased populations, the plants are still modifying their operating procedures and have constructed on-site hatchery facilities for fish stocking operations. They have also provided funding to remove blockages to migratory fish and developed improved intake technologies and other modifications to reduce entrainment or impingement.

Clean Water Act Section 316(b)

The EPA's implementation of Clean Water Act Section 316(b), has resulted in updated assessments of the impacts of cooling water withdrawals. EPA phased in the regulation in three steps: **Phase I:** Applies to *new* facilities with a cooling water intake, constructed after January 17, 2002; **Phase II:** Applies to *existing* power-producing facilities, effective September 7, 2004, with a cooling water intake design greater than 50 million gallons per day (mgd) and applies to each facility as its NPDES permit is renewed; **Phase III:** Applies to non power producing facilities.

Maryland has eleven existing steam electric power plants with an NPDES permit and a cooling water intake and discharge. Of these, two plants are below the 50 mgd design threshold for Phase II facilities (Warrior Run and Vienna), one is classified as exempt from the new regulations (BRESCO), and the remaining nine (Calvert Cliffs, Chalk Point, C.P. Crane, Dickerson, Gould Street, Morgantown, Riverside, R.P. Smith, and Wagner-Brandon Shores) are or will undergo a Phase II evaluation.

The Phase II regulations established specific performance standards for reduction of impingement and entrainment (I&E). There were five compliance alternatives for using best technology available to minimize adverse environmental impact at facilities. However, as a result of a lawsuit by several environmental groups, states, and industry groups, the US Court of Appeals made a ruling on the Phase II rule, rejecting many of its provisions (Riverkeeper et al. v. USEPA, decided January 25, 2007).

In March 2007, EPA suspended the Phase II 316(b) rule due to the court ruling. Most power plants with once-through cooling water intakes, including those in Maryland, were required to submit a comprehensive study by the January 2008 deadline, to demonstrate how they would meet its requirements. These facilities were already in the process of collecting the necessary information. The suspension means that 316(b) permit conditions will be developed based on best professional judgment. Thus, studies and analyses will proceed that can be used for either best professional judgment and for the EPA rule, if and when it is reinstated. This includes any impingement and entrainment studies already undertaken to update the biological data for each facility, including Calvert Cliffs, Chalk Point, C.P. Crane, Dickerson, Gould Street, Morgantown, Riverside, R.P. Smith, and Wagner-Brandon Shores. Analyses of field data (where required) is also expected to proceed to show the impact of current level of I&E relative to the calculation baseline and in comparison with historical data. MDE and PPRP will evaluate these analyses as part of each facility's NPDES permit renewal process.

Cooling Water Discharge Impacts

Impacts to aquatic biota from power plant cooling water system discharges include elevated temperatures, discharge of chemicals used for biofouling treatment (e.g., chlorine), discharge of metals eroded from internal plant structures (e.g., copper), and, in the case of Maryland's only nuclear power plant, discharge of radiological materials. Each of these impacts is discussed below.

Thermal Changes

Biological impacts from heated effluents depend upon the magnitude and duration of the temperature difference between discharge water and river water. Small organisms that pass through a plant's cooling system experience the greatest temperature stress, both in magnitude and duration. Exposed organisms in the receiving waters are more likely to experience smaller increases in temperature of shorter duration due to dispersion of the thermal plume and mobility of most of the exposed aquatic biota (e.g., fish, blue crabs). PPRP conducted studies to determine the effects of thermal discharges at each existing power plant in the state. Because different aquatic biota occupy different habitat types in Maryland waters, study results are presented here according to the habitats where power plants are located (see Figure 4-20). The following pages present a brief summary of the findings in those studies.

Mesohaline Habitat – The largest power plants (in megawatts) in the state discharge into mesohaline habitat during all or part of the year. PPRP studied thermal discharges from Chalk Point, Morgantown, Calvert Cliffs, and H.A. Wagner power plants as part of extensive fieldwork in the 1970s and 1980s. Thermal plume dimensions for these power plants varied with season, tidal stage, wind velocity and direction, and plant operating levels.

The effects of thermal discharges from the power plants located in the mesohaline habitats of the Chesapeake Bay have been localized and are not considered significant. PPRP found no cumulative adverse impacts to the habitats of the Chesapeake Bay ecosystem. However, PPRP will continue to evaluate the habitats if additional power plant discharges are proposed; new technology would then be considered to reduce thermal discharges.

Tidal Fresh and Oligohaline Habitat – Two plants, Vienna and C.P. Crane, discharge into tidal fresh and oligohaline waters. PPRP studies showed that the thermal plume at Vienna was small and its discharge effects were negligible. The thermal plume at C.P. Crane affected about 40 percent of the volume of the receiving water embayment. C.P. Crane effluents also resulted in a slight increase in nearfield salinity due to plant-induced changes in the nearby bay circulation pattern, but these factors did not affect nearfield dissolved oxygen.

Recently, MDE required studies at C.P. Crane to repeat some of the historical fishery surveys conducted in the late 1970s, as a condition for NPDES permit renewal. The purpose of the surveys was to demonstrate that the fish populations in the vicinity of the Crane power plant remain unaffected by its thermal discharge. The study showed that differences in the fish community apparent between the 2003-2005 results and the results of the 1979-1980 study reflect long-term changes in the upper Bay fish community and are not suggestive of a plant discharge effect. The results also suggest that there is no consistent effect of the thermal discharge on the fish community composition or distribution.

Findings at the plants in these tidal fresh and oligohaline habitats were consistent with those at facilities in mesohaline areas. Thermal discharge effects were small and localized. PPRP studies found no evidence that fish movements were blocked by thermal plumes in the plants' receiving waters in these particular habitats.

Nontidal Freshwater Habitat **–** Only R.P. Smith and Dickerson power plants are located in nontidal riverine habitat in Maryland. The thermal impact of their discharges on the Potomac River ecosystem was assessed in a long-term freshwater benthic study conducted by PPRP over an 8-year period. While this long-term study documented that the thermal discharges from these two plants had an adverse impact on benthic communities in the immediate area of the discharges, these effects were localized. The affected percentage of the total river bottom is very small. To assess whether these localized impacts on benthic communities may be affecting fish populations within the river, the discharge permit for the Dickerson facility included a requirement for a multi-year study of growth and condition of several fish species in the vicinity of the plant. Based on data on fish condition collected over a 21-year period near the plant and at reference locations, there was no indication that fish near the plant were affected by the localized discharge effects on benthic communities.

Chemical Discharges

Concerns regarding the impacts of copper and chlorine discharged into sensitive waters of the Chesapeake Bay watershed in the late 1970s and early 1980s led to extensive studies by PPRP as well as others.

Copper **–** In the late 1970s and early 1980s, oysters in the vicinity of the Chalk Point, Calvert Cliffs, and Morgantown power plant discharges were found to be bioaccumulating copper that was present in the effluent discharge. The copper resulted from erosion of the copper condenser tubes within the plants' cooling systems. While PPRP studies showed that oyster growth and survival were not adversely affected, the elevated levels of copper concentrations in oysters posed a potential risk to the health of individuals who might consume them. Power plants replaced the copper condenser tubes with titanium tubes where this problem was most significant, primarily in estuarine waters. The titanium tubes eliminated the metals erosion, which also resulted in less maintenance on the condenser tubes. Currently, NPDES permitting for all power plant discharges includes an evaluation of maximum discharge levels for copper (as well as other metals) to protect human health and the environment.

Chlorine **–** This substance is sometimes used by power plants to control bio-fouling of condenser tubes in cooling water systems. While it may be an effective means of controlling biological organisms within the cooling system, it can also cause mortality in the aquatic biota of the receiving water body. Presently, the NPDES permits for all power plants in Maryland require that chlorine not be discharged into the state's waters for more than two hours in any one day from any one unit, and no more than one unit may discharge at any one time. An exception may be granted if a facility demonstrates that more chlorination is needed to control macroinvertebrates. Chlorinated discharge impacts are now considered resolved and no further action is needed.

Impacts of Hydroelectric Facilities

While only two large-scale hydroelectric projects (greater than 10 MW capacity) are present in Maryland, seven additional small-scale facilities also generate electricity within the state (see map and table on pages 43-44).

Hydroelectric facilities may present special environmental concerns that are not encountered at steam electric power plants. Development and operation of hydroelectric facilities can cause three main types of impacts:

Changes in water quality – Impoundments created for hydroelectric dams significantly alter river flow from free-flowing streams to deep water flow. This alteration causes changes in natural water clarity, thermal stratification, and lower dissolved oxygen concentrations upstream of the dam, which, in turn, may result in low dissolved oxygen levels in the water discharged from the dam. To mitigate these impacts, a procedure known as turbine venting was implemented at Conowingo Dam on the Susquehanna River. This venting allows air to be entrained into the water passing through the turbines and increases the oxygen content of the water. Similarly, an aeration weir was constructed in the Deep Creek Station tailrace to increase oxygen in water from the dam's discharge.

Changes in water quantity – Operating hydroelectric facilities in a peaking mode (in response to peak electrical demand) produces unnatural, and frequently extreme water level fluctuations in impoundments as well as downstream from

Deep Creek Hydroelectric Station: Balancing Multiple Resource Uses

The 3,900-acre Deep Creek Lake was formed in 1925 by the construction of a rockwall dam across Deep Creek, a tributary of the Youghiogheny River. The Deep Creek Hydroelectric Station (DCHS) includes two turbines with a combined generating capacity of about 20 MW. Operation of the facility affects recreational users of the lake and the river. The Youghiogheny River is Maryland's only designated "wild" river. It supports a trout fishery and is one of the most challenging whitewater runs in the country. In 1994, the owner of DCHS agreed to develop the conditions required under a water appropriations permit administered by MDE. Working with PPRP and MDE, conditions were designed to achieve two objectives: 1) to provide a reliable and economical source of electricity; and 2) to enhance Deep Creek Lake's and the Youghiogheny River's natural and recreational resources.

Lake Water Levels — Recreational lake users typically want minimal and consistent drawdown of the lake during summer, with a higher than historic level in the autumn to extend the boating season. Historically, the power company lowered the water level in the fall and winter to prevent ice damage to the spillway. To help evaluate possible alternative operating strategies, a computer model of historical lake inflow, storage, and electricity generation was developed. The model was used to create monthly operating rules for the DCHS that balanced electricity generation with the maintenance of desirable lake water levels.

Downstream Fisheries — Naturally high water temperatures in the Youghiogheny River and low dissolved oxygen (DO) levels in the hydroelectric station's discharge historically limited trout habitat. The discharge from the hydroelectric station tends to be cooler than the river because it draws cooler water from the bottom of the lake. PPRP developed a protocol for station operators that regulates the timing and volume of water discharges during periods of peak temperatures in the Youghiogheny River, such that downstream trout habitat is enhanced. The protocol uses river flow and temperature changes, and available predictions of maximum air temperature and cloud cover for the region. The goal is to maintain the river temperature below 25°C. The plant owner also installed structures to aerate discharge water to alleviate the low DO problem.

Whitewater Recreation — The Youghiogheny River is an exceptional whitewater recreation resource that depends on releases from the DCHS for adequate flow volume in most summer months. Whitewater boaters rely on timed and dependable releases from the hydroelectric facility to plan trips in advance. Operation of the facility is scheduled around providing: 1) suitable flow for boating at fixed times on all Fridays and Mondays during the whitewater recreation season (April 15 through October 15), except when lake levels are too low; and 2) suitable boating flow on at least one Saturday per month and during other special events on a prearranged basis.

Deep Creek Station's water appropriations permit was renewed in 2007 for another 12-year period. MDE, with assistance from PPRP, working with affected stakeholder groups, reviewed the permit conditions and made minor adjustments to the permit with the goal of continuing to promote optimal use of Deep Creek Lake and affected downstream natural resources.

Jennings Randolph Hydroelectric Project

In July 2006, Fairlawn Hydroelectric Company, LLC filed an application with the Federal Energy Regulatory Commission (FERC) for a three-year preliminary permit to study the feasibility of a proposed 10.5-megawatt project at Jennings Randolph Dam. The project would be located on the Potomac River, in Mineral County, West Virginia, and Garrett County, Maryland.

The proposed project would use the Jennings Randolph Dam, owned by the U.S. Army Corps of Engineers (COE), and would:

- *Construct a powerhouse containing two generating units with a total installed capacity of 10.5 megawatts*
- *Construct a 4-mile-long, 14.7-kilovolt transmission line*
- *Produce an annual generation of 48 gigawatt hours, which would be sold to a local utility*

Potential issues at the proposed project, based on the preliminary application and issues identified from earlier proposals are as follows:

- *Location of transmission line right-of-way and access roads*
- *Construction activity and appropriate sediment controls*
- *Water flow during installation of the project*
- *Project operation and impacts on water flow and other users*
- *Impact on resident reservoir fisheries, particularly due to turbine entrainment*
- *Impact on downstream biota, especially the existing trout rearing facilities in the tailwater*
- *Coordination of construction and operational activities with the COE*

As of December 2007, Fairlawn planned to submit a license application to FERC in the summer of 2008.

Conowingo Hydroelectric Project Relicensing

Susquehanna Power Company and PECO Energy Power Company, owned by Exelon Generation Company, are licensed by the Federal Energy Regulatory Commission (FERC) to operate the 549.5-megawatt (MW) Conowingo Hydroelectric Project. The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014. Exelon intends to submit an application to the FERC for continued operation of the project. This application for the new license must be submitted to the FERC by September 1, 2012. Exelon will use the FERC's Integrated Licensing Process to relicense the Conowingo Project; this process has a minimum 5-year schedule to complete by the date of license expiration.

FERC will complete a full review of Exelon's new license application and determine the appropriate terms and conditions for the new license. PPRP will coordinate all MAryland agency reviews and input on the license application, which FERC must consider as part of its review. Review of the license application typically results in a new license order and an Environmental Assessment or Environmental Impact Statement.

The project currently operates two fish lifts. The west lift is currently operated under a settlement agreement with the United States Fish and Wildlife Service, with funding provided by Pennsylvania Fish and Boat Commission and Maryland Department of Natural Resources for American shad egg production and other research purposes. The newer east lift, which uses regulating gate bays for attraction flow, is used primarily to pass American shad and other migratory fishes during the April – June migration season.

Preliminary issues Exelon expects to address as part of this process include: fish passage (including a West side passage when needed), flow management, recreation and land management, and cultural resources and archeology. Dissolved oxygen and minimum flows as currently required will also be addressed. Exelon's goal is to reach a settlement agreement with all the resource agencies on these issues, prior to submitting its final license application to FERC, which is due before September 2012; conceptual settlement discussions would likely occur starting in mid-2010. Outreach efforts to non-agency groups and to the public will be undertaken as part of these settlement negotiations.

Holtwood Hydroelectric Project Redevelopment

Summary of Proposed Project:

PPL Corporation has proposed to expand and upgrade the Holtwood Hydroelectric Project in Lancaster County, Pennsylvania, on the Susquehanna River just upstream of the Conowingo Pond. The redevelopment proposal includes:

- *Improvements to migratory fish passage facilities*
- *Construction of a new 125 MW hydroelectric generating plant adjacent to the existing facility*
- *Extensive in-river rock excavation to create additional passage routes for American shad*

Project Issues:

Holtwood has been a "bottleneck" to migration of American shad up the Susquehanna River. Despite the installation and operation of state-of-the-art fish lifts at the dam, on average only about 20% of fish passing the Conowingo Dam have made it upstream past Holtwood over the past several years (see Figure 4-22). Passage is especially low when river flows are high; it was only 3.1% in 2004, a high flow year. The new turbines to be installed at the dam would contribute to a redirection of river flows that, combined with excavation of selected river channels, are expected to significantly enhance shad movement to and into upstream passage facilities, while at the same time providing additional generation capacity. Additionally, the turbine design of the new units would enhance survival of juvenile fish and other anadromous fish that have spawned and are migrating downstream, as compared with the existing turbines.

the dams. Additional small-scale projects may also divert some flow away from the natural streambed. Fluctuations in water level and flow may reduce fish abundance as well as food sources important to fish growth and survival. Several studies, initiated in the early 1990s and completed in 1998 were conducted at Conowingo Dam to determine the minimum flow necessary to protect and enhance aquatic biota as well as whether a continuous flow is needed.

Direct adverse effects on fish populations – Dams prevent the natural upstream and downstream movement of both resident and anadromous fish species. Entrainment of fish attempting to move downstream past the dam may cause mortality due to the turbines. Factors that affect fish mortality include the type of turbine, the proportion of flow diverted through the turbine, and the size of fish. Restoration activities at Conowingo, such as fish lifts, have proven effective in enhancing fish populations and reducing fish mortality.

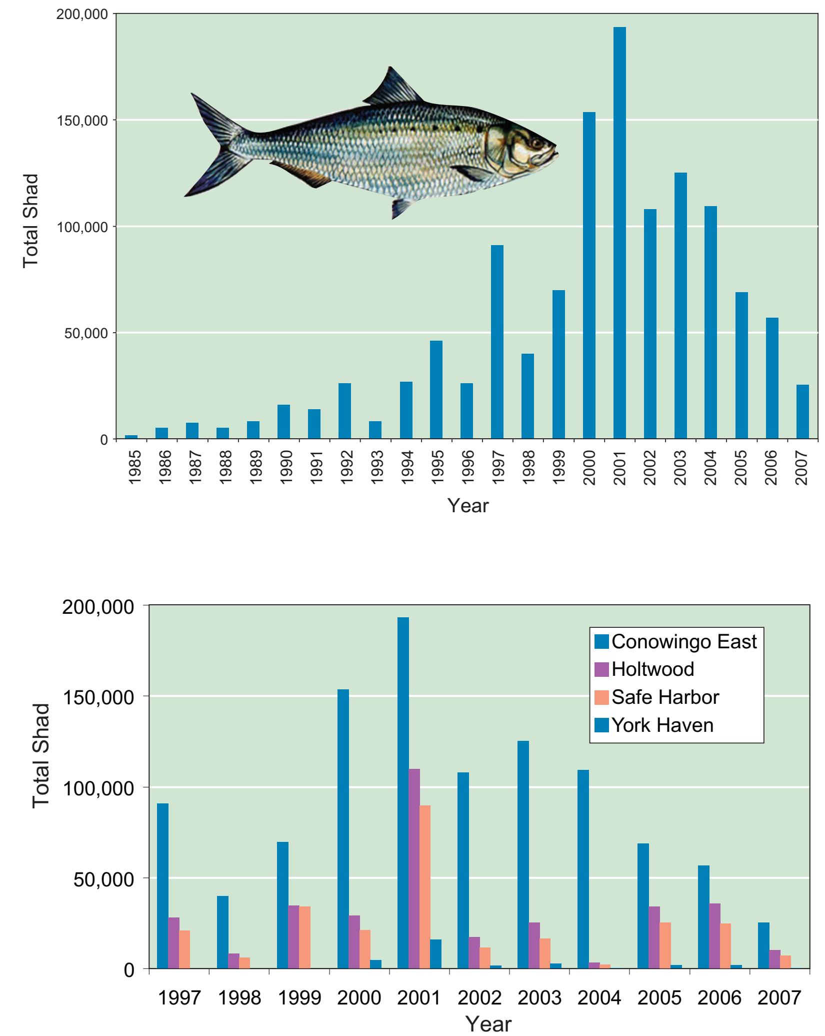
Historically, the Susquehanna River supported large spawning runs of anadromous species such as American shad, river herring, and striped bass. The massive anadromous fish runs that generated migrations extending as far upstream as Cooperstown, New York, however, were eliminated with the construction of four major hydroelectric facilities on the lower Susquehanna in the early 1900s (Maryland's Conowingo Dam, and Holtwood, Safe Harbor, and York Haven dams in Pennsylvania).

When the FERC licenses for the four Susquehanna River hydroelectric facilities were being considered for renewal in the early 1970s, a major issue that arose was restoration of anadromous fish to the Susquehanna. Participants in the FERC license proceedings included PPRP, on behalf of the state of Maryland; the state of Pennsylvania; the state of New York; the U.S. Fish and Wildlife Service; and several non-governmental organizations (NGOs). The ultimate goal of the resource agencies and NGOs was to restore migratory fish runs throughout the Susquehanna River basin. This goal was pursued through an active restoration program (e.g., trapping and trucking adult fish to areas above the dams, hatchery rearing of larval and juvenile shad for stocking in the river) and the installation of fish passage devices at all four dams.

By the year 2000, restoration programs had been operating for nearly thirty years, and fish passage devices had been installed at all four hydroelectric facilities. For the first time since the dams had been constructed, the entire Susquehanna River had been re-opened to migratory fish. This has created the potential for shad and other species to move as far upstream as New York State, representing well over 400 miles of new habitat.

Growth of the Susquehanna River shad stock in response to the restoration efforts and installation of fish passage devices has been dramatic. This growth peaked in 2001, when nearly 200,000 American shad passed over Conowingo Dam (see Figure 4-22). On-going monitoring of restoration progress, however, revealed some issues that need to be addressed. The primary concern at the present time is the low percentage of shad that are able to move past the Holtwood Dam during high flow years once they have successfully moved past the Conowingo Dam. In 2004, only 3.1 percent of the shad passing over Conowingo Dam succeeded in moving beyond Holtwood Dam. Concerns also exist regarding the percentage of shad that move past York Haven Dam. A more thorough assessment of that issue may not be possible until a higher passage efficiency is achieved at Holtwood Dam. PPRP, working with dam owners and other state and federal agencies, is continuing efforts to enhance upstream migratory fish passage as well as downstream passage of juveniles through operational and/or engineering modifications. The FERC licenses for three of the four lower Susquehanna facilities expire at the end of 2014, and agency consultation on relicensing is already underway. Fish passage and flow issues will be further addressed as part of this process.

Figure 4-22
Number of American Shad Passed at Conowingo Dam (Susquehanna River), 1985-2007 and at Conowingo East, Holtwood, Safe Harbor, and York Haven Dams, 1997 - 2007



Terrestrial Impacts

For a relatively small state, Maryland contains a surprising number of natural habitats, which vary with physiographic region, geology, and other factors. From east to west, different habitats are present in the coastal marshes and forests along the Atlantic Ocean and Chesapeake Bay, the mixed-agricultural areas and wetlands over much of the Eastern Shore, the deciduous forests and riparian ecosystems in the agricultural and urbanizing matrix of the Piedmont, and the mostly contiguous mixed-deciduous forest in the Highlands of western Maryland. Habitats in each of these environments possess a suite of flora and fauna that is definitive (but not necessarily unique); many also contain rare, threatened, or endangered species.

The State of Maryland has enacted the following regulations (COMAR 08 and 26) that afford protection to habitats and species in terrestrial and wetland environments:

- *Waterway Construction*
- *Water Quality and Water Pollution Control*
- *Erosion and Sediment Control*
- *Nontidal Wetlands*
- *Tidal Wetlands*
- *Forest Conservation*
- *Threatened and Endangered Species*

Construction and operation of power generation and transmission facilities (i.e., power plants; pipelines for water, natural gas, and oil; electric transmission lines; roadways and railways) can have significant effects on terrestrial environments and wetlands. Specifically, these facilities can:

- *physically change or eliminate existing habitats;*
- *disturb or displace wildlife;*
- *emit particulate matter or gases to the atmosphere that later deposit on the landscape; and*
- *release toxic material through permits or inadvertent spills.*

Construction of a new power generating facility may occur entirely within an existing developed area or it may require the clearing of dozens (rarely hundreds) of acres of natural habitat. Transmission lines must also be maintained in an open or shrubby condition, fragmenting the forest habitat through which they cross. Forest organisms are lost from these areas, while open field or shrub species will colonize cleared areas that are allowed to revegetate. Power plant emissions can change the soil chemistry of natural habitats through acidic and nutrient deposition.

PPRP's role in the CPCN process is to facilitate compliance with these regulations and natural resource objectives, even when the CPCN supersedes individual statutes. The Waterways Construction, Water Quality and Water Pollution Control, and Erosion and Sediment Control laws require best management practices

(BMPs) to eliminate or minimize disturbance in and discharges to Maryland waters. These BMPs are uniformly included as conditions in CPCNs. CPCNs also include specific conditions to avoid, minimize, or mitigate adverse impacts to wetlands, forests, and species habitats.

Wetlands

In the 1780s, Maryland had about 1,650,000 acres of wetlands (24.4 percent of the surface area); two hundred years later, in 1989, Maryland had only about 440,000 acres of wetlands (6.5 percent of its surface area), a reduction of 73 percent. To address such losses the State developed regulations under Maryland's 1991 Nontidal Wetlands Protection Act, with the goal of no net loss of nontidal wetlands. Similarly, the 1994 Tidal Wetlands Regulations were developed to regulate activities in tidal wetlands. Under Maryland's nontidal wetlands regulations, permanent impacts to nontidal wetlands must be mitigated at various ratios depending on the type of wetlands affected. For example, a ratio of 3:1 is applied to scrub/shrub and forested wetlands of special State concern; a ratio of 2:1 is applied to other scrub/shrub and forested wetlands, and to herbaceous wetlands of special State concern; and a ratio of 1:1 is applied for emergent wetlands. Mitigation ratio requirements are similar for State tidal wetlands. Temporary impacts and impacts to wetlands buffers do not usually have replacement mitigation requirements but may require compensatory or enhancement measures.

The CPCN process includes assessing potential wetlands impacts and developing appropriate mitigation equal to or greater than those required by these regulations. While wetlands are present at nearly all Maryland's power facilities, impacts to these wetlands are rare. Where especially valuable wetlands are present, the CPCN process can identify special conditions to ensure their protection. For example, the CPCN to construct the Kelson Ridge generating facility in Charles County included the following conditions to protect the Zekiah Swamp Natural Environmental Area, a Nontidal Wetland of Special State Concern:

- *preparation of a protection plan that ensures the wetland recharge rates to Piney Branch Bog are maintained at or below current conditions through the use of shallow infiltration beds and vegetated terraces; and*
- *establishment of a permanent protection buffer with no vegetation clearing, earthworks, or other disturbances allowed within 300 feet of Piney Branch Bog.*

Forests

Similar to the wetland concerns, historical losses of Maryland's forest resources prompted enactment of the 1991 Forest Conservation Act (FCA). With the exception of projects located in heavily forested Allegany and Garrett Counties, all construction developments of greater than 40,000 square feet must comply with the FCA. Under the FCA, existing forest condition and character became an integral part of the development planning process, including power plant and transmission line siting, across the State. Applicants must provide information on the condition of the existing forest and a strategy for conserving the most ecologically valuable areas of the forest. The FCA requires submittal of both a Forest Stand Delineation (defining the nature of the existing forest) and a Forest Conservation Plan (for protecting the most ecologically valuable areas of forest). Under the

FCA, tree conservation, replanting, and other environmental parameters must be considered before any development disturbs forest resources.

If the applicant demonstrates that the clearing of forest will be minimized, an exemption from FCA requirements for rights-of-way and land for construction of electric generating facilities can be granted by the PSC. To date, however, all CPCNs issued since the FCA was enacted have included conditions that ensure applicants comply with the FCA where applicable. The CPCN process also considers the quality of forest resources lost as conditions are developed. For example, the CPCN to construct the Rock Springs generating facility in Cecil County included restoration conditions to compensate for values of mature forest lost and some of the nitrogen deposition caused by the facility's emissions. Specifically, the applicant was required to plant 50 acres of young trees to replace 20 acres of mature forest. The reforestation was directed to riparian areas to increase the likelihood that deposited nitrogen would be intercepted before reaching Chesapeake Bay tributaries.

Threatened and Endangered Species

Regardless of the kind of habitat involved, areas that support State-listed threatened and endangered flora and fauna are protected under the Maryland Threatened and Endangered Species regulations. Table 4-13 lists the number of protected species by taxonomic group that the CPCN process considers when evaluating potential adverse effects and developing protective conditions.

Table 4-13. Types of State-Listed Rare, Threatened, and Endangered Species

Group	Number of listed species
Plants	841
Planarians	5
Mollusks	22
Crustaceans	27
Spiders	3
Insects/Collembola	1
Insects/Coleoptera	23
Insects/Diptera	1
Insects/Ephemeroptera	1
Insects/Homoptera	2
Insects/Lepidoptera-Butterflies	39
Insects/Lepidoptera-Moths	23
Insects/Odonata	109
Insects/Trichoptera	1
Fishes	27
Amphibians	11
Reptiles	15
Birds	78
Mammals	31

Although few applications for power generating or transmission facilities affect threatened and endangered species, individual cases have considered potential impacts to bald eagle, Delmarva fox squirrel, carpenter frog, purple pitcher plant, New Jersey rush, and winterberry. Some projects, however, have the potential to cause significant adverse effects to several threatened or endangered species. For example, the Roth Rock Windpower Project proposed by Synergics for western Maryland's Backbone Mountain would have adversely affected a number of state-threatened or endangered species. The mourning warbler, a state-endangered breeding bird, is known from only a few sites in the state but has been recorded most reliably in the northern portion of the project area. Species that rely on rocky habitats including the state-endangered Allegheny woodrat, southern rock vole, and small-footed bat, would likely have suffered severe impacts from construction in the southern portion of the project area. To avoid impacts to these state-endangered and other species, DNR recommended two exclusion zones within the project area, in which no construction of wind turbines or access roads would occur.

Wind Power Impacts to Birds and Bats

Wind power development can adversely affect birds and bats in two ways. The first is through the direct loss of habitat from the construction of facility infrastructure, such as wind turbines and service roads. As indicated above, habitat loss can lead to the eradication or displacement of species that live in the area. To date, three wind power projects have been approved or recommended for approval in Western Maryland (see Figure 3-2). All three are located on mountain ridges that historically have been densely forested. The forest habitat in the region is considered to be a southern extension of the northern hardwood forests that extend more broadly to the north, and historically included pure stands of white pine, eastern hemlock, and red spruce. At present, however, logging, coal mining, and home construction have fragmented much of these forests. Where contiguous forest exists, wind power development could increase fragmentation. Fragmentation affects birds and bats as well as other terrestrial species through direct loss of forested habitat, the encroachment of species that can have direct (e.g., brown-headed cowbirds that parasitize songbird nests) or indirect (e.g., raccoons that can be disease vectors for rare mammals) detrimental effects, the potential disruption of corridors for daily movement or seasonal migration, and the failure of the resident species to adapt to the wind power facility.

Wind power development also kills birds and bats that collide with turbines and turbine blades. After more than a decade of study at a number of wind power facilities in the U.S. and abroad, there is evidence that the numbers of bird fatalities are small at most locations. Per turbine, two to three birds are killed annually on average. Studies at facilities constructed on eastern Appalachian ridges in West Virginia and Pennsylvania report similar rates of bird fatality. In contrast, the numbers of bats killed at these regional facilities are among the highest ever reported for birds or bats, and annual estimates range into the thousands for each project. It is currently believed that most of the bat fatalities occur during the late summer to fall migration period as bats move to their over-wintering habitat.

The cumulative impact of bird fatalities, at present, is not considered to be severe for any one species, as no single species appears to be disproportionately affected. In addition, operational (e.g., lighting that can attract birds) and design (e.g., guyed structures) circumstances that can contribute to higher fatalities are better understood and new wind power facilities are constructed with reduced lighting and no guy wires to minimize impacts. Birds considered most at risk are songbirds that migrate nocturnally. High fatality events for these species often coincide with nights that have a low cloud cover resulting in birds flying closer to ground level. Although the Migratory Bird Treaty Act prohibits the "take" of any birds, the U.S. Fish and Wildlife Service, in practice, only requires that good faith efforts be employed to avoid fatalities.

The cumulative impact to bat species is of greater concern. The high level of recorded bat fatalities has been distributed among only a few species, predominantly red and hoary bats. These two species undertake long distance seasonal migrations and typically roost in trees, whereas most other species have shorter seasonal movements to and from caves in which they over-winter. While the specific population characteristics of these species are uncertain, they are relatively long-lived and they produce few offspring annually, both characteristics that make them less able to sustain a high level of fatalities. Recent PPRP-funded studies of bat activity in Western Maryland have recorded high numbers of these two species during spring monitoring.

Wind turbines have killed several other species of bats, but so far none have been identified as a threatened or endangered species. Western Maryland provides year-round habitat to the federally endangered Indiana bat, and the state listed as In Need of Conservation small-footed bat. Most records of these two species come from winter cave surveys when the bats are hibernating. Much less is known of their habits during the flying season as they disperse throughout the landscape; however, a recent radio-tracking study followed a single female Indiana bat from a Pennsylvania cave to Carroll County, Maryland. The seasonal and daily activity patterns of these rare species must be investigated further before concerns about the risks posed by proposed wind turbines can be dismissed.

To address the issue of wind power impacts to birds and bats, the Maryland General Assembly required that the PSC establish a technical advisory group (TAG) to develop siting guidelines that would seek to minimize the risk to birds and bats. The TAG produced Siting Guidelines to Mitigate Avian and Bat Risks from Wind Power Projects, which addressed five aspects related to wind power development:

- *Standards that will avoid or minimize impacts on birds and bats from the construction and operation of wind-energy generating facilities.*
- *A tiered system of standards that vary with the size of the wind-energy generating facility and the associated generating capacity.*
- *Assessments of avian and bat populations before issuance of a Certificate of Public Convenience and Necessity.*
- *Additional monitoring studies of avian and bat populations and behavior during and after construction of a wind project.*
- *Mitigation appropriate to address any impact on avian and bat populations above a threshold level.*

In support of the siting guidelines, PPRP has developed model monitoring protocols for birds and bats during pre- and post-construction phases. Pre-construction monitoring for birds and bats should employ radar and acoustic techniques (for bats) during appropriate seasons. Additional studies for birds should include a breeding bird survey and Phase 1 Avian Risk Assessment. For bats, the project site should be evaluated for habitat suitability. Post-construction monitoring should entail of a study of bird and bat fatality over a period of three years.

PPRP anticipates that new wind power applications will be submitted for other mountain ridges in Western Maryland. To better understand the migratory movements of birds and bats in this area, PPRP is funding several studies through the University of Maryland's Appalachian Laboratory. One study is using a mobile, marine-grade radar system to track migratory movements during spring and fall and to obtain information on the height of passing migrants. Microphones have been deployed to monitor the calls of night passing migrant birds. A new study will use remote acoustic bat detectors to examine the use by bats of forested areas that have recently been logged in Allegany and Garrett Counties, in an effort to understand how bats respond to the forest clearing caused by wind power development. These research efforts, coupled with pre- and post-construction studies at wind power facilities, will allow PPRP to better assess risks posed by projects proposed in the future, and to develop mitigation, such as curtailing operations at the seasons and wind speeds when bats are most vulnerable.

Transmission Line and Pipeline Rights-of-Way

More than 2,000 miles of electric power transmission line rights-of-way are located throughout Maryland. These rights-of-way are constructed and maintained as long, linear corridors that are often quite different from the surrounding environment. The corridors may cross streams and rivers, split patches of forest, slice across farms and open areas, run alongside roads and through residential areas, or span wetlands and other sensitive habitats, resulting in a variety of effects. To provide public review and to ensure that environmental and other concerns are addressed, CPCN applications for new corridor construction and for modifications in existing corridors must be made to and approved by the PSC. PPRP coordinates the review of these applications to identify both temporary construction effects and potential long term impacts in the same manner as proposed power generating facilities.

Transmission line corridors vary from one to several hundred feet wide, depending on the power-carrying capacity of the line and the number of lines routed through the corridor. Because they are linear they are bound to cross natural linear features such as streams and floodplains, but because of their relatively narrow width they potentially can be sited to avoid valuable wetlands, forests, rare species, historical and archeological sites, and viewsheds. In recent years, only small lengths of new transmission lines and enhancements to existing lines have been proposed and approved by the PSC. It is expected, however, that one or more major new interstate transmission line will be proposed for Maryland in the near future as part of a regional effort to increase transmission capacity and reliability. Should offshore windpower facilities be built near Maryland, construction of additional large capacity transmission lines may be needed. These potential major transmission projects raise many unique environmental or other issues, e.g. fragmenting forests in Western Maryland, protecting the views and vulnerable stream habitats of suburban Central Maryland, perturbing the sensitive bottom habitats of the Chesapeake Bay, or insuring the security of power delivery to populations and facilities in urban areas.

In 2007, the Trans-Allegheny Interstate Line (TrAIL) was proposed from southwestern Pennsylvania to Virginia with an alternate route through Garrett County in Maryland. Two additional transmission line proposals, one through Kemptown in Central Maryland and one across Southern Maryland and the Chesapeake Bay, are expected in 2008 or 2009 (for more details on these interstate lines see page 29). PPRP has already coordinated with the Natural Heritage Program to identify rare, threatened, and endangered species potentially at risk from the TrAIL line. In addition, PPRP is actively preparing for new interstate transmission line proposals by studying the model process for engaging stakeholders in choosing new line routes that minimize environmental and other impacts that has been developed and tested by the Electric Power Research Institute in cooperation with the Georgia Transmission Corporation. PPRP is enhancing the quantitative spatial evaluation tools that have been used in past line evaluations to compare the impacts of alternate routes. In addition, the stakeholder engagement procedures that were recommended in the EPRI-GTC study are being further developed and tested by PPRP to provide better ways of bringing Maryland citizens who live near proposed routes, local and county government officials, and other stakeholders into the PPRP review process. The impact evaluation process used by PPRP to address the siting, construction, and maintenance of transmission line and pipeline rights of way are described below.

Siting

The most effective way to avoid adverse impacts from transmission and pipeline rights of way is to site them so that they avoid valuable resources. PPRP derives quantitative comparisons of alternate routes from digital maps, aerial photographs, and other data sets, and supplements them with field inspections. The purpose of these comparisons is to identify the types of impacts that may occur along each possible corridor and to find the route with the lowest overall impact. Where undesirable impacts cannot be avoided, recommendations may include compensating for the damage and maintaining certain conditions in the corridor after construction.

Because of their linear nature, it is rare that a new transmission lines will not cross some forested areas. While the area of forest eliminated may not be great, the impact of fragmenting contiguous forest areas, by removing trees and other native vegetation in the right of way, can have severe deleterious effects on many species. Most trees in the right-of-way are not permitted to grow beyond the sapling stage, so that both sides of the cleared corridor are kept separated by a man-made, maintained feature. The size and shape of the forest bisected by the corridor, and the sizes and shapes of the remaining fragments, directly determine the intensity of fragmentation effects. Species' sensitivities to parcel size and edge effects will determine whether forest fragmentation by right-of-way corridors can be tolerated; for example, areas of forest that are less than 300 feet wide are too narrow to support sensitive interior-dwelling species, such as migrating songbirds.

In many cases the process of reviewing the CPCN application results in modifications or conditions that make the construction of the transmission line acceptable to all stakeholders. Occasionally, however, the PSC determines that a proposed line is not required, poorly sited, or has unacceptable impacts, and therefore denies the application. During the review of a 230 kV line recently proposed for a location near Urbana, in Frederick County, PPRP found that there were environmental problems with the proposed route, the location was inconsistent with local development plans, and there were superior alternate routes. Although the line was well justified by providing an important power delivery upgrade, PPRP recommended (on behalf of the State of Maryland) that the application be denied, and the PSC concurred. A new application proposing a better route is expected in the near future.

Construction

Construction of transmission and pipeline rights of way normally involve short-term environmental damage that can be minimized with good planning and mitigated by post-construction restoration. If there is unavoidable permanent damage, the utility company is usually required to provide environmental compensation by creating an equal or larger amount of equivalent habitat elsewhere.

Freshwater streams in Maryland are known to be affected during the clearing of rights-of-way and construction of transmission towers. Tree removal during construction can result in immediate as well as long-term soil erosion that produces increased sediment loads in streams. Left uncorrected, increased sediment can lead to changes in stream morphology and diminished water quality, ultimately degrading the biological condition of the stream. Removing vegetation from the riparian area also reduces the amount of shading provided to the stream. Shading along a stream reduces the rate of warming from the sun, allowing cooler water temperatures that are necessary for species, such as native reproducing brook trout. The removal of riparian vegetation also decreases the amount of leaf litter, woody debris, and rootwads present in the stream system, thereby reducing critical habitat for many stream species.

Some construction impacts to forests can be avoided by careful placement of the transmission line towers. PPRP has worked with power companies during field reviews of proposed projects to protect wooded areas containing large native trees by re-aligning tower locations. During field reviews of the proposed New Market project, PPRP input led to minor adjustments in the alignment of two transmission towers that avoided impacts to large trees and several forest patches. Effective mitigation plans were also developed for unavoidable tree losses at other places along the right-of-way.

Maintenance

The primary goals of right-of-way maintenance are to retard the growth of woody vegetation and to assure emergency access. Trees or branches that grow too close to power lines can fall on the lines, especially during adverse weather conditions, causing power interruptions and safety hazards. Herbicides used to remove vegetation typically pose little danger to the terrestrial environment if they are properly applied; for example, glyphosate herbicides persist in the environment for less than two months and are generally not toxic to wildlife when applied appropriately. Improper use of chemical herbicides, however, can result in excessive amounts being carried by water runoff or wind into areas outside the right-of-way, and may damage untargeted vegetation and wildlife. Mechanically cutting vegetation in rights-of-way is not necessarily a benign alternative; it can disturb and kill wildlife, and has the potential for encouraging erosion and polluting surface waters, depending on the type of equipment used.

To encourage the implementation of environmentally friendly maintenance in rights-of-way, PPRP has compiled information on innovative practices that reduce adverse effects on local wildlife and plant communities. Most Maryland utilities indicate that they now use a combination of selective herbicide application and mechanical cutting rather than exclusively one or the other. Several of Maryland's utilities also have maintenance programs to improve wildlife habitats in rights-of-way. Certain rights-of-way can be maintained or enhanced to act as corridors that connect isolated patches of ecologically valuable forest or other habitats. The introduction of desirable species into the right-of-way through "right tree/right place" plantings or wildlife habitat enhancement projects is often possible. Utilities report that such programs have created better, more stable habitats for wildlife, and have saved thousands of dollars in annual maintenance costs.

There can be special maintenance problems when trees are in or near transmission line rights-of-way. While it is environmentally desirable to remove as few trees as possible, the PSC has estimated that fallen trees and branches are the largest cause of power outages in Maryland, accounting for almost two-thirds of the 6.5 million customer-hours of electric service interruption in the state in 2006. To address this issue, PPRP has joined with the Maryland Electric Reliability Tree Trimming (MERTT) Council to develop a clear picture of trees that cause power outages in Maryland. Utility foresters, using equipment and data collection procedures provided by PPRP, are identifying each instance of a tree-caused power outage and recording the location, type of tree, and other details in computer files. PPRP is assembling the data from utilities throughout the state into a common data base and analyzing the data to provide the PSC with accurate information on the causes of such outages. The results will be used by MERTT Council members and PPRP to develop improved maintenance practices that identify and remove hazardous trees while maintaining the maximum possible protection for valuable tree resources and forest habitat.

Another potential impact of transmission lines is bird collisions and electrocutions. The U.S. Fish and Wildlife Service and the Avian Power Line Interaction Committee (APLIC), which included involvement from the Edison Electric Institute, have cooperatively developed guidelines to help prevent injuries to birds that contact power lines. PPRP uses the voluntary guidelines, which were released in 2005, to help utilities develop Avian Protection Plans that meet the specific needs of their facilities, protecting birds from electrocution and collisions as well as reducing the likelihood of power outages caused by bird collisions.

Sociological and Land Use Issues

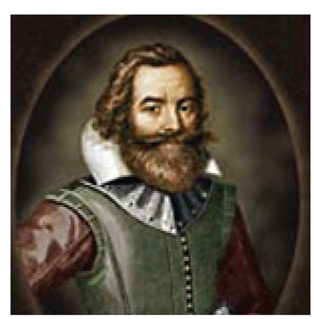
Cultural Resources

State assessment of the effects of power plant construction and operation on cultural resources is codified under Maryland State law (Article 83B, 5-617 & 5-618 of the Annotated Code of Maryland), which requires state agencies to consider the effects of their undertakings on properties included in or eligible for inclusion in the National Register of Historic Places and the Maryland Register of Historic Properties and to consult with the Maryland Historical Trust (MHT) prior to final action by the agency on a request for a permit, license, or financial assistance. The MHT is the principal operating unit within the Division of Historical and Cultural Programs of the Maryland Department of Housing and Community Development, and is responsible for identifying, studying, evaluating, preserving, protecting, and interpreting the state's significant prehistoric and historic districts, sites, structures, cultural landscapes, heritage areas, cultural objects, and artifacts, as well as less tangible human and community traditions. Maryland's State Historic Preservation Officer (SHPO), appointed by the Governor pursuant to the National Historic Preservation Act of 1966, is a member of the Trust staff.

Federal involvement is governed by Section 106 of the National Historic Preservation Act, which requires federal agencies to take into account the effects of their undertakings on historic properties. Since "undertaking" includes not only projects funded by a federal agency, but also those requiring a federal permit, license or approval, power plants that traverse or otherwise occupy federal land can be subject to "Section 106" review.

In recent PPRP environmental reviews, cultural impact assessments have also considered local, state and federal heritage initiatives, since most include National Register or state historic properties within their programmatic frameworks. This is clearly exemplified in PPRP's environmental reviews of a proposed barge unloading facility and air pollution control system at Mirant's Morgantown Generating Station in Charles County where federal heritage initiatives considered in the assessments included:

- ***The Chesapeake Bay Gateways Network (CBGN)*** *– a system of parks, refuges, museums, historic sites and water trails within the Chesapeake watershed region,*
- ***The Potomac Heritage National Scenic Trail*** *– an evolving network of locally managed hiking trails in a 425-mile corridor between the Chesapeake Bay and the Allegheny Highlands,*
- ***The Captain John Smith Chesapeake National Historic Trail****, the first water trail in the United States, which commemorates the voyages of Captain John Smith on the Chesapeake Bay and its tributaries during 1607-1609, and*
- ***The Thomas Stone National Historic Site*** *– located north of Port Tobacco, which honors the life and work of Thomas Stone, signer of the Declaration of Independence.*



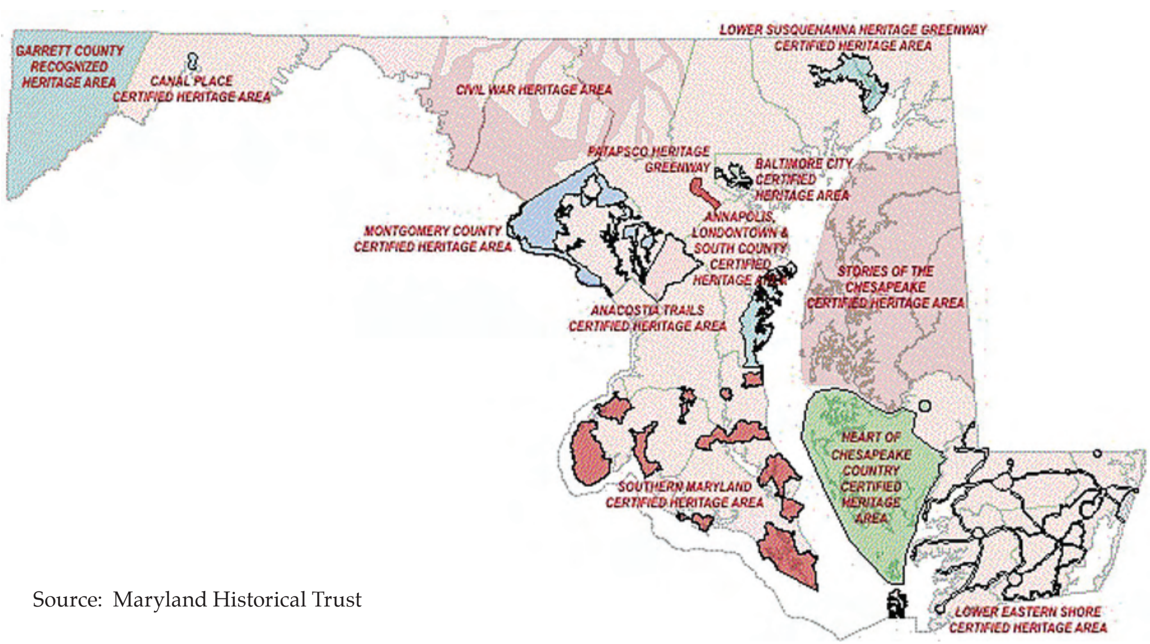
A consideration of growing importance in PPRP's environmental reviews is the Maryland Heritage Areas Program, governed by the Maryland Heritage Areas Authority (MHAA), an independent unit of State government housed within the Maryland Department of Planning. Created by legislation in 1996, the MHAA oversees a system of heritage areas, which are geographic areas demonstrated to contain high concentrations of cultural resources and where local partnerships commit to protect them for economic development through heritage tourism. Each Certified Heritage Area (CHA) is governed by a management plan, which defines economic development goals for the area, an area-specific interpretive strategy, rehabilitation and conservation needs, and the partnerships and financing needs required to achieve these goals. Currently, there are eleven certified heritage areas in Maryland (see Figure 4-23). Another two Recognized Heritage Areas are preparing management plans to enable them to become certified heritage areas.

In addition to being eligible for funding and support from the MHAA, Certified Heritage Areas are programmatically supported by State agencies. Specifically, when carrying out activities in a Certified Heritage Area, a State agency must:

- *consult, cooperate and, to the maximum extent feasible, coordinate their activities with the unit or entity responsible for the management of each CHA,*
- *ensure that the activities are consistent with the CHA's management plan, and*
- *ensure that activities will not have an adverse effect on the resources of the heritage area unless there is no prudent and feasible alternative.*

Although recent PPRP environmental reviews of proposed modifications to three Maryland power plants — Chalk Point, Dickerson, and Morgantown — considered certified heritage areas, the issue was brought most clearly into focus at Morgantown, which is near some components of the Southern Maryland Heritage Area (SMHA). Certified by the MHAA in July 2003, the SMHA Certified Heritage Area consists of eleven distinct clusters containing a concentration of heritage resources, existing or proposed interpretive facilities, and significant lands protected by federal, state, and county ownership or easements. These clusters are connected by corridors comprising scenic byways, trails and water-

Figure 4-23
Maryland Heritage Areas



Source: Maryland Historical Trust

ways. The plan identifies key themes to guide visitors through Southern Maryland's history and identity and, importantly, stewardship principles for sustaining and enhancing the region's heritage tourism initiative.

As an example of potential impacts, PPRP's visibility analysis determined that at all times the FGD vapor plume from Morgantown would be either continuously or intermittently visible from three designated corridors, and would probably be visible much of the time from the southernmost parts of one of the clusters within SMHA, primarily in the vicinity of the Zekiah Swamp Natural Environmental Area.

With the expansion of certified heritage areas throughout Maryland, coordination with heritage management entities will continue to be an important element of PPRP's evaluations. The process is complicated by the structure of the heritage areas program, which is a locally focused, bottom-up system. Furthermore, there is great variety in the types of entities that manage local heritage programs including a state unit (Canal Place), local government units, private non-profit corporations, or private unincorporated associations assisted by a multi-county public agency, all with varying levels of technical expertise. Recent licensing proceedings have revealed a need to improve the communication and coordination between all units of state government, especially within the Heritage Program itself, to satisfy the consultation provisions of the Maryland Heritage Law.

Visual Impacts

Adverse effects from power plants include a visual component that varies by technology. One of the more recognizable features of some power plants is the natural draft cooling tower, a sight often associated with nuclear power plants. Additionally, coal-fired power plants usually have tall stacks, and buildings that house the boilers and turbines for generating electricity can be highly visible under certain conditions. High voltage transmission lines add towers and wires to both rural and urban views. Technologies such as combustion turbines have a lower profile than coal and nuclear power plants. This reduces their visual intrusion into the surrounding environment, but facilities such as these are often located closer to public facilities and or roads and communities because of their smaller "footprint". An example of these are the visual impacts from the Rock Springs combustion turbine facility on nearby properties and historic structures. This was a major issue during those licensing proceedings.

Vapor Plume

More recently, the potential for visual impacts from vapor plumes exiting from flue gas desulfurization (FGD) systems, or scrubbers, has engendered controversy. The predominant visual externality from scrubber operations at Maryland's coal-fired power plants would be the plume from a 400-foot stack and the stack itself. Composed primarily of water vapor, the plume would be visible at virtually all times the FGD system is in operation. Plume dimensions would vary by season, with higher and longer plumes in the fall and winter, and by direction, with plumes of greater heights and lengths depending on wind direction.

In the context of the existing Morgantown Generating Station, the vapor plume from its FGD modification was projected to exceed the height of the two existing 700-foot stacks at Morgantown about 23 percent of the time, varying from

13 percent in the summer to 36 percent in the winter. For much of the time the vapor plume would be contained within the boundaries of the Morgantown property itself or immediately offshore from the facility. Nevertheless, the vapor plume would be visible from selected locations along the Maryland shore of the Potomac River, from shoreline locations on the Northern Neck of Virginia, from the Governor Harry W. Nice Memorial Bridge, and from the surface of the Potomac River, itself. Given the region's emphasis on cultural heritage, recreation and ecotourism, it was necessary to address whether plume visibility would alter visitor perceptions of Charles County.

Plume blight is defined as a coherent, identifiable plume that can be seen as an optical entity against the background sky or distant object. Plume blight occurs when pollutants are emitted into a stable atmosphere and transported in some direction with little or no vertical mixing and the pollutants take a long time to disperse. Plume blight typically appears as a narrow band or layer across the horizon, much like smog. A vapor plume from a stack is a form of plume blight even though its visual form is very localized. The size of the plume, which looks like a cloud, will depend on atmospheric conditions, particularly temperature and humidity. The primary component of a vapor plume is water vapor, which usually dissipates quickly in the atmosphere.

Haze

Scenery is an integral part of the recreational and tourism experience. Degradation of views has been shown to affect tourist perceptions of scenic vistas and visitation levels. Visibility impairment is a serious problem, not only in Class I areas, but also in cities and other areas where views are valued. In fact, substantial visibility impairment is a frequent occurrence in even the most remote and pristine areas of the Northeast and Mid-Atlantic. However, vapor plume visibility is of a substantially different nature than visual impairment from haze.

Haze is the consequence of air pollution that originates from a multitude of sources and impairs visibility in every direction over a large area. In contrast, a plume is a form of air pollution, consisting of smoke, dust, or point source gaseous plumes that obscure the sky or horizon and is emitted from a single source or small group of sources.

Haze is caused when light is scattered and absorbed by atmospheric particles and gases that are nearly the same size as wavelengths of light, typically smaller than 2.5 micrometers, that are suspended in the air. Regional haze pollution results in poor visibility as well as negative human health impacts. These particles originate from a variety of sources, including power plant and automobile emissions. Haze is generally composed of five major components: sulfate aerosol, nitrate aerosol, organic carbon aerosol, elemental carbon, and dust from the earth's crust. While much of the haze experienced in the western United States is due to dust and nitrates, in the eastern U.S. over 70 percent of the reduction in visibility can be traced to sulfates, created when power plants emit sulfur dioxide. Haze is exacerbated by high humidity, which expands the size of nitrate and sulfate particles. The term "regional" haze is used because pollution can travel long distances from many sources. It is widely accepted that sulfur dioxide and sulfate can travel hundreds of miles before being removed from the atmosphere. Sulfur dioxide, and subsequent sulfate aerosol formation, is still the major cause of visibility impairment.

Haze should also not be confused with mist and fog. During the early morning or after rain showers when temperatures are low and humidity is high, mist and sometimes fog forms in valleys and lowlands, gradually clearing when the sun reappears. Mist and fog are formed as a result of the condensation of water vapor on particulates suspended in the atmosphere. Meteorologically, mist is defined as being present if diminished visibility occurs (with no other weather condition being present) and relative humidity of the atmosphere at the surface of the earth is above 95 percent. When the horizontal visibility falls below 1000 meters, mist is classified as fog.

Transportation

Transportation is an important input to the power generation process. During construction of generation facilities, traffic from construction workers and from trucks delivering goods and services to the site increases the number of vehicles on local roads, sometimes causing congestion at nearby intersections during peak periods. Congestion issues are typically addressed through licensing conditions attached to a CPCN.

Materials transport has been an important consideration in several recent environmental reviews in Maryland. In the case of the Catoctin Power facility in Frederick County, PPRP identified an issue associated with the transport of aqueous ammonia, classified as a Class 8 (corrosive) hazardous material by the U.S. Department of Transportation. Analysis of potential impacts from a spill during transport resulted in a recommendation for a designated truck route for hazardous waste, which resulted in a recommendation to route truck traffic away from residential neighborhoods and public schools.

Both Constellation Power Source Generation (CPSG) and Mirant Mid-Atlantic applied to the PSC to construct coal barge unloading facilities — at the C.P. Crane and Morgantown power plants, respectively — to diversify coal supplies and develop a competitive modal alternative to rail transport. Proposed FGD modifications to all of Maryland's coal-fired power plants required careful consideration of transportation impacts from the consumption of limestone of limestone and production of gypsum by-product.

Barge transportation issues associated with the C.P. Crane Generating Station concerned the introduction of barge traffic into a waterway that was traditionally used for recreational fishing and boating, and visual impacts from docked barges and conveyers on residences across Seneca Creek. Mitigation of these adverse effects, required the scheduling of barge deliveries around regattas and implemention of a lighting distribution plan to minimize light trespass on neighboring properties.

Mirant's proposed coal barge unloading facility encountered considerably more scrutiny because it represented the first industrial intrusion into the Potomac River below the Governor Harry W. Nice Memorial Bridge, and would increase commercial river traffic through the Middle Danger Area of the Potomac River Test Range, under the command of the Naval Surface Warfare Center. Because of its relatively low profile, PPRP found that the visual footprint of the facility would be restricted to nearby shoreline locations, the Potomac River between Swan Point and the Governor Harry W. Nice Memorial Bridge. But PPRP also concluded that the facility would have an adverse aesthetic effect upon certain heritage designations that overlay the Potomac River, such as the Chesapeake Bay Gateways Network and the Potomac River Water Trail, and could restrict recreational boaters from freely traveling along the Maryland shore of the river.

The Department of the Navy became involved because of the proximity of the barge unloading facility with the Potomac River Test Range. Following consultation with PPRP and the Department of the Navy, Mirant agreed to collaborate with the Navy to establish operating protocols and develop communications processes in order to minimize the impact of Navy's operations on the river to commercial water traffic.

An FGD system removes sulfur dioxide from the stack gas of a coal-fired power plant by injecting limestone slurry into the exhaust stream. The by-product of the chemical reaction of limestone with sulfur dioxide is synthetic gypsum, which can be utilized as a construction material, such as wallboard. FGD systems consume and generate significant quantities of limestone and gypsum. For example, operation of the FGD system at CPSG's Brandon Shores Generating Station is expected to require up to 740,000 tons of limestone to be delivered to the facility annually, and the export of up to 1.2 million tons of gypsum. Mirant's Dickerson Generating Station will consume 190,000 tons of limestone and generate 310,000 of gypsum, while projected annual tonnages of limestone and gypsum for Morgantown are 429,000 and 703,000 tons, respectively.

Generation facilities serviced by coal barges (Morgantown and Brandon Shores) are expected to also import limestone using barges. Where barge is not an option (Dickerson, Chalk Point), limestone is delivered by rail. Rail is a secondary limestone delivery option for Morgantown, but the rail spur to Brandon Shores has been out of service for several years. Except for Brandon Shores, where barge would be used, the primary transport option for exporting gypsum by-product would be rail. In all cases, truck is a backup transport option for both limestone and gypsum.

In the environmental review of the proposed FGD modification to Brandon Shores, it was concluded that increased barge traffic from hauling limestone and gypsum would not congest commercial river traffic in the Patapsco River. The same conclusion was reached in the Morgantown case, where fewer barge transits are expected.

Table 4-14. Traffic Impacts for Trucking Alternative, Brandon Shores FGD Project

	Limestone	Gypsum	Other	Total	Total Truck Trips (In/Out)
Direction:	In	Out			
Commodity:	Limestone	Gypsum			
Weight Unit:	Short Tons	Short Tons			
Truck Sizes Used: (Short tons)	20	20	20		
Operating Hours Per Day:	12	12			
Throughput Per Year:	740,000	1,200,000			
Trucks Per Year:	37,000	60,000	42,900	139,900	279800
Trucks Per Week:	712	1,154	825	2,691	5382
Trucks Per Day:	143	231	165	539	1,078

Truck traffic was another matter, however. Given a maximum carrying capacity of 20 tons, hauling limestone or gypsum by truck could add significantly more truck traffic to local roads (see Table 4-14). A Traffic Impact Study (TIS) to evaluate the effects of additional truck traffic from Brandon Shores on local road segments and intersections was conducted. The TIS concluded that even with the addition of nearly 1,080 round-trip truck trips per day destined for or originating from the Brandon Shores facility, nearby intersections would continue to operate at acceptable levels of service during the morning and afternoon peak hours.

For the FGD projects at Dickerson, Chalk Point, and Morgantown, local roads in the vicinity of these facilities were inadequate for carrying high volumes of truck traffic transporting limestone or gypsum over extended periods, and this required conditioning the licensing of each project on the use of trucks only in the event of an emergency and only upon notification to the Maryland State Highway Administration. The conditions included provisions for consultation with the Maryland State Highway Administration and appropriate county authorities to identify truck routes to minimize the impact of truck traffic on the public and for halting the trucking of limestone and/or gypsum when the emergency conditions no longer exist.

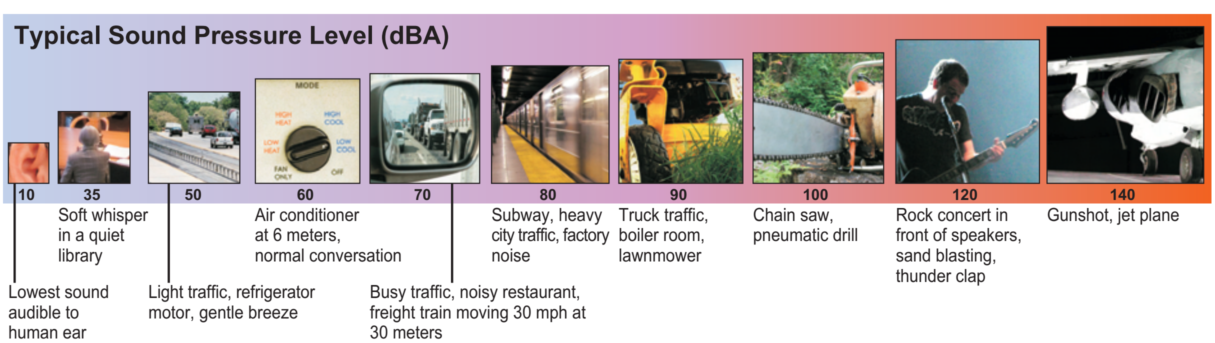
Noise

Noise consists of vibrations in the air that gradually decrease, or attenuate, the farther they travel. For people who live or work near a power plant, the noise impacts, along with visual and traffic impacts can be the most significant type of effect caused by the facility.

Noise is made up of many components of different frequency (pitch) and loudness. The decibel (dB) is a measure of sound energy; three decibels is approximately the smallest change in sound intensity that can be detected by the human ear, this varies according to the individual. An additional 10 units on the decibel scale is perceived subjectively as a doubling of the loudness. Ranges of typical A-weighted sound levels for various common sounds are shown in Figure 4-24.

The sensitivity of the human ear varies according to the frequency of sound; consequently, a weighted noise scale is used when discussing noise impacts. This A-weighted decibel (dBA) scale weights the various components of noise based on the response of the human ear. For example, the ear perceives middle frequencies

Figure 4-24
Ranking of Comparative Noise Levels



better than low or high frequencies; therefore, noise composed predominantly of the middle frequencies is assigned a higher loudness value on the dBA scale.

The State of Maryland has adopted noise pollution standards, found in COMAR 26.02.03, which are adopted from the draft federal standards on noise. The maximum allowable noise levels specified in the regulations vary with zoning designation and time of day, as indicated in Table 4-15.

The State regulations provide certain exemptions for specified noise sources and noise generating activities. For example, the regulations allow for construction activity to generate noise levels up to 90 dBA during daytime hours, but the nighttime standard may not be exceeded during construction.

Table 4-15. Maximum Allowable Noise Levels (dBA) for Receiving Land Use Categories

	Zoning Designation		
	Industrial	**Commercial**	**Residential**
Day	75	67	65
Night	75	62	55

Source: COMAR 26.02.03
Note: Day refers to the hours between 7 AM and 10 PM; night refers to the hours between 10 PM and 7 AM.

As sound waves radiate outward from a noise source, they lose intensity; thus, the sound decreases with distance. Ensuring adequate buffer distances is an effective method of controlling noise impacts. Structures such as berms and walls may also be constructed to provide noise control, and have been used in transportation applications for many years. Vegetative buffers may be used in conjunction with such structures for additional noise abatement.

In cases where developers propose new generating units on small sites — where the nearest residents may be less than a half-mile away — noise impacts to surrounding communities can be a serious concern. Modeling noise sources and nearest receptors is part of the review of impacts that both the applicant and PPRP conduct in order to assess the noise impacts of proposed facilities. When modeling shows that the threshold levels cannot be achieved, measures to meet the allowable levels are recommended and incorporated into the CPCN. For instance, in the licensing evaluation for the Rock Springs combustion turbine facility, a detailed noise mitigation evaluation was conducted because of the proximity of residential and commercial receptors and the generally low background noise levels. PPRP examined the mitigation measures, such as barriers, acoustical enclosures, vent fan mufflers, and silencers for the exhaust stacks, which ODEC was proposing to install. After negotiations with PPRP, local residents, and elected officials, ODEC agreed to enhance the noise reduction features, including upgraded silencers, improved vent muffling, and additional soundproofing material for the turbine enclosures. Ultimately, the plant was designed to meet the State nighttime noise limit of 55 dBA, but additionally will meet that standard even during daytime operation.

With the increasing interest in renewable energy sources, new generating technology is being developed for which there may be little quantitative information available regarding noise characteristics. Landfill gas and wind power projects are just two examples that have different noise characteristics than normal coal fired power plants.

In September 2007, PPRP conducted monitoring to obtain more specific information about the noise characteristics of landfill gas generators. These measurements helped PPRP to evaluate its current method for predicting noise impacts from proposed generating units. Day and night noise levels were recorded at two landfill gas generators in Maryland and compared to the predictions made during the licensing evaluating of those units. The noise measurements revealed that the predictive techniques used by PPRP are very conservative.

At residential receptors near the Eastern Landfill in Baltimore County, trucks, backup alarms, and traffic noise were audible; these noise sources are not associated with the operation of the landfill gas generator. Even with the presence of other onsite operations and road traffic the measured noise levels were well below the State's nighttime noise limit of 55 dBA.

The same circumstances held true at the Brown Station Road landfill in Prince George's County. During the day the primary audible noise source was road traffic traveling on Brown Station Road. Noise from the landfill gas generator was not audible over the traffic noise on Brown Station Road; during infrequent lulls in the traffic, noise from the site was just barely audible above the background. During the evening hours, the noise levels at the residential receptors were dominated by cricket/insect noise.

There are presently no operational wind turbines in the state where we could make direct noise measurements. Those windpower sites that have been approved have sufficient buffer distances from residences that noise is not expected to be an issue. However, noise concerns have been an issue at other communities outside Maryland that are in close proximity to operating wind turbines.

Property Value Impacts

The adverse effect of power plants and transmission lines on residential property values is an issue that has been increasingly raised in power plant permitting cases in Maryland. Although a considerable amount of research has been done to examine hazardous facilities, very little has been done in associating conventional generating facilities, high voltage transmission lines, and new technologies, such as wind farms, to property values. As a result, residential property value impact estimates have lacked the credibility needed to influence public policy decisions related to the siting of energy facilities.

Residential property value is dependent on many factors including the size and amenities of the property itself, improvements made to the property, and the attributes of the surrounding neighborhood. Previous research has suggested that distance to "environmental disamenities" is a contributing factor in adversely affecting property value. Property value declines have been more consistently observed in residential properties that are near higher-risk disamenities (e.g. hazardous waste facilities) or facilities that lack adequate land or vegetation buffers. Because risk is not strongly associated with most types of power plants, their influence on residential property values has been largely ignored.

PPRP sponsored a study to estimate property value impacts from power plants and comparable large industrial facilities in Maryland, using disamenity distance — the distance from a property to a disamenity — as one of the explanatory variables in econometric property value models for three industrial facilities in Maryland: Alcoa Eastalco Works in Frederick County, Calvert Cliffs Nuclear Power Plant in Calvert County, and the Dickerson Generating Station in Montgomery County. Ambiguous model results suggested that residential property values appeared to be influenced by proximity to the Alcoa Eastalco Works in Frederick County, but not by proximity to Calvert Cliffs or Dickerson.

The relationship between residential property values and distance to high voltage transmission lines is also ambiguous. Empirical research has generally found that properties with unencumbered direct views of transmission line towers experience a significant negative impact on price. However, adjacency to a transmission corridor alone does not necessarily cause residential property values to decline, or may even increase value, particularly when households value proximity advantages such as enlarged visual field and open space. A PPRP-sponsored study of property value effects in two Maryland subdivisions found similar ambiguities. In one subdivision, price appreciation of properties adjacent to a transmission corridor was less than non-adjacent properties, but in the other, no adverse effect was found.

Property value impacts are often cited in administrative proceedings for the licensing of generation and transmission facilities in Maryland. For example, property values were among the arguments considered in Allegheny Power's proposed Urbana Loop transmission line in Frederick County. At a Stakeholder Engagement Meeting sponsored by PPRP, property value was identified as one of the two most important criteria identified by local residents for route selection. Ultimately, it was one of the required considerations in the Hearing Examiner's Proposed Order which denied Allegheny Power's application. Concerns about property value impacts were also voiced during public hearings for wind energy projects in Western Maryland and proposed modifications to the Morgantown Generating Station in Southern Maryland.

As a consideration in its environmental reviews, PPRP is continuing its focus on property value effects from electric transmission and distribution facilities through both ongoing reviews of published literature and sponsored research. Advanced statistical tools and more comprehensive geospatial land use information from the Maryland Department of Planning suggest new insights into this issue will be forthcoming.

Health Implications of Electromagnetic Fields

Researchers have studied the health effects of powerline fields, also known as electric and magnetic fields (EMF), under various types of exposures and presumed health effects. The major public concern with regard to power generation and transmission facilities is the association between long-term exposure to weak EMF magnetic fields and disease, in particular childhood leukemia. This issue was first raised in 1979 and now, after 28 years, this issue is still being investigated by scientists without clear resolution.

In general, health agencies investigating the subject have failed to find sufficient scientific evidence to conclude that adverse health effects exist from long-term exposure to weak EMF fields, but at the same time they have been unwilling to dismiss the possibility of such effects. In 2002, the International Agency for Research on Cancer (IARC, part of the World Health Organization) classified EMF magnetic fields as "possibly carcinogenic to humans," based on limited evidence of its ability or tendency to produce cancer (carcinogenicity) in humans and less than sufficient evidence for carcinogenicity in experimental animals.

There have been few regulatory developments concerning EMF fields in the United States in recent years. Connecticut recently passed legislation that creates a rebuttable presumption that all new transmission lines (345 kV or more) be underground if it is technically feasible to do so, and establishing buffer zones for lines of 345 kV and above near residential areas, schools, and the like. In 2005 California issued a draft regulation that continued its policy of "prudent avoidance", mandating that up to 4 percent of the total project cost for new transmission lines be allocated for field mitigation options. There are indications that Connecticut may be moving towards a policy similar to that of California.

The most important recent scientific development was the release in May 2007 of the "Environmental Health Criteria No. 238 on Extremely Low Frequency Fields" by the World Health Organization. The World Health Organization concluded that evidence linking powerline fields with disease was weak and that "the benefits of exposure reduction on health are unclear." It recommended, among other measures, that "When constructing new facilities... low-cost ways of reducing exposures may be explored....Policies based on the adoption of arbitrary low exposure limits are not warranted."

Radiological Issues

Production of nuclear power in the United States is licensed, monitored, and regulated by the U.S. Nuclear Regulatory Commission (NRC). Provisions in the operating licenses of each plant allow utilities to discharge low levels of radioactive material to the environment. The kind and quantity of releases are strictly regulated and must fall within limits defined in federal law as protective of human health and the environment. The NRC regulates releases from power plants according to the principle that the exposure of the environment and humans to radiation be kept "as low as reasonably achievable."

Pathways of exposure to radioactive material in the environment are similar to those for other pollutants. An aqueous (water) pathway dose can be received internally or externally by ingesting contaminated water and seafood, or by exposure to contaminated sediments and water. An atmospheric pathway dose can result from exposure to or inhalation of radioactive gas or airborne particles, or ingestion of radionuclides deposited on or assimilated by terrestrial vegetation and animals.

Nuclear power plants are minor contributors to radiation exposure in the United States. As Figure 4-25 illustrates, natural radiation sources account for more than 80 percent of the average radiation dose to human beings. Of the approximately 18 percent of the radiation dose to human beings arising from man-made sources, only 1 percent is attributed to commercial nuclear power production.

Figure 4-26 shows the locations of nuclear power plants in and near Maryland. Calvert Cliffs Nuclear Power Plant, in Calvert County, is the only nuclear power station in the state. The next closest plant, Peach Bottom Atomic Power Station, is on the Susquehanna River just north of the Pennsylvania/Maryland border. Both these facilities release radionuclides into Maryland's environment.

PPRP, MDE, and the utility operators conduct environmental monitoring programs near both plants. These monitoring programs are used to assess the radiological effects on the environment attributable to each of the power plants.

Calvert Cliffs Nuclear Power Plant

Constellation Generation Group owns and operates the Calvert Cliffs facility, on the western shoreline of the Chesapeake Bay. Each of its two units is a pressurized water reactor with a generating capacity of approximately 830 MW. The units began service in May 1975 and April 1977.

Calvert Cliffs routinely releases low-level gaseous, particulate, and liquid radioactive material into the atmosphere and the Chesapeake Bay. The level of radioactivity of these materials at any given time depends on many factors, such as plant operating conditions and conditions of the nuclear fuel. Releases of radioactivity to the environment from Calvert Cliffs have been well within the regulatory limits since the beginning of its operation. PPRP has monitored radionuclide levels in the Chesapeake Bay and environment surrounding Calvert Cliffs since 1975, and biennially publishes the results of its environmental assessments.

Radioactive noble gases, primarily isotopes of xenon and krypton, constitute most of the radioactive material released to the atmosphere from Calvert Cliffs. Noble gases are chemically inert, are not readily incorporated into biological tissues, and are not bioconcentrated. They are readily dispersed in the atmosphere, and most have short half-lives, thus, decaying rapidly to stable forms. For these reasons, the noble gases do not represent a significant threat to human or ecological health. The most recently compiled results (for the years 2004 and 2005) from weekly air and annual vegetation monitoring conducted by Constellation Generation Group and independently by PPRP indicate that releases of radioactivity to the atmosphere by the Calvert Cliffs plant were not detectable in air, precipitation, or vegetation.

Figure 4-25
Estimated Effective Radiation Dose from Natural and Man-Made Sources

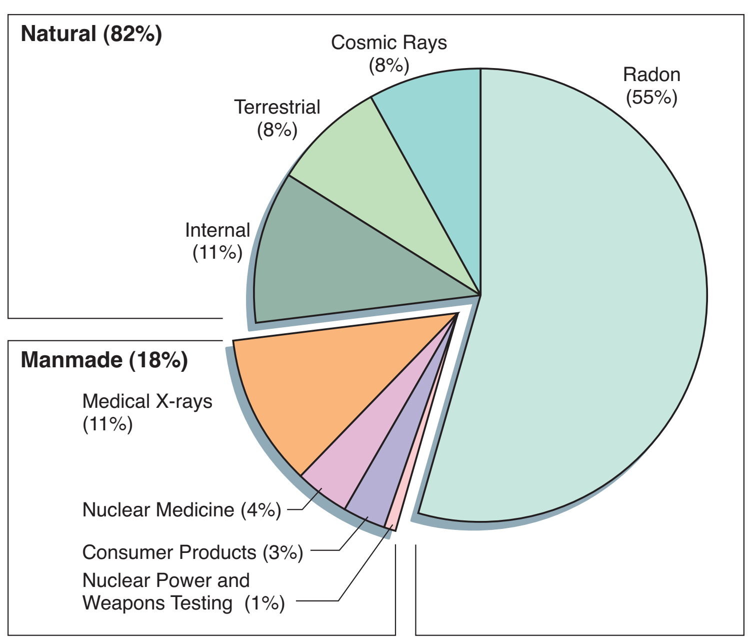
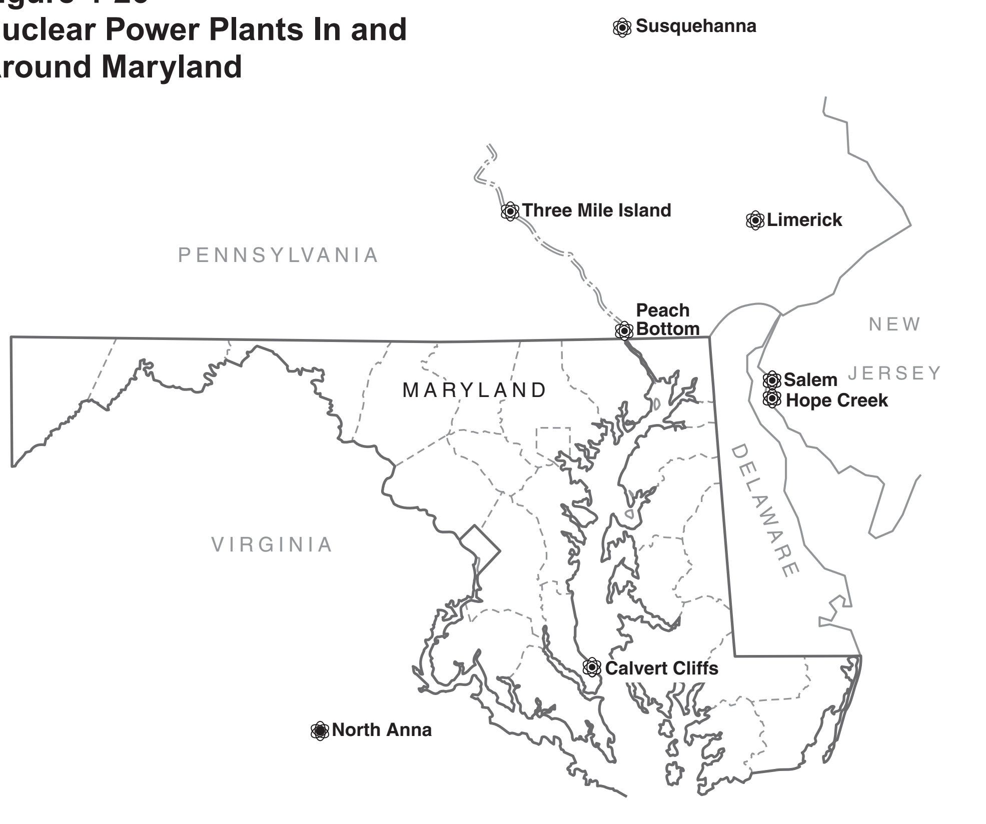


Figure 4-26
Nuclear Power Plants In and Around Maryland



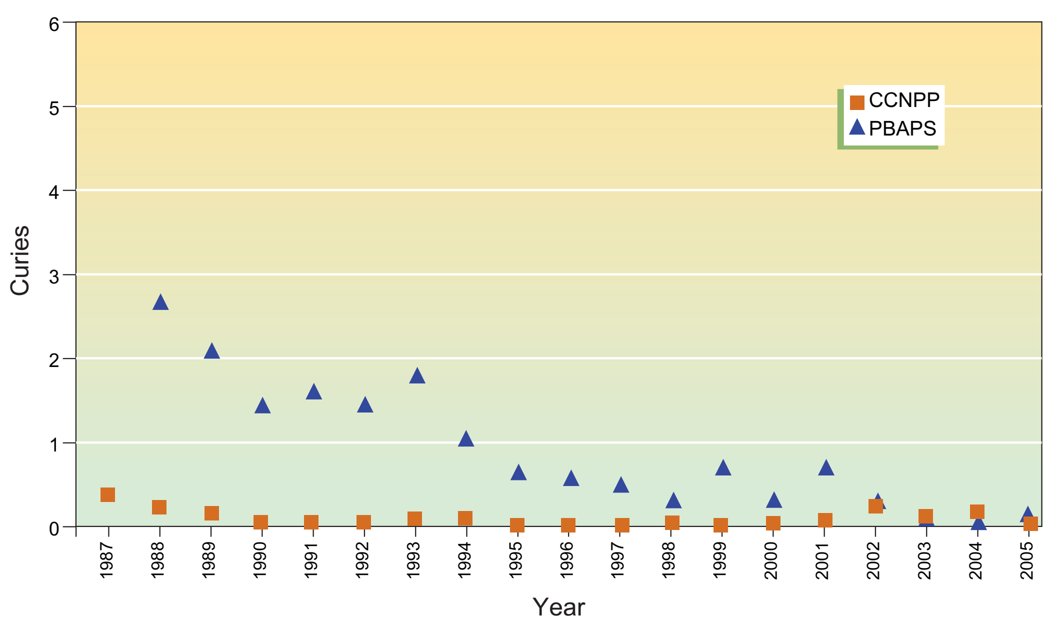
Although atmospheric releases consist mainly of radioactive noble gases, which have little environmental significance, aqueous discharges contain radionuclides that can be accumulated by biota or become trapped in sediments at the bottom of the Bay. Over time, these radionuclides may potentially contribute to a radiation dose to humans by being transported through the food chain. For CCNPP, the environmentally significant* radionuclides in 2004 and 2005 (see Figure 4-27) were primarily forms of radioactive iron, cobalt, nickel, and tellurium. Historically, the quantities of environmentally significant radionuclides released from Calvert Cliffs and subsequently detected in Bay sediments have been quite small (approximately one percent, or less, of all radioactivity detected in sediments, which includes historic nuclear weapons testing fallout and naturally occurring radionuclides). Total environmentally significant releases have declined over the past two decades due to improvements in coolant water filtration technology. Nevertheless, research programs conducted by PPRP investigate the fate of all releases from Calvert Cliffs and the results are published biennially. The monitoring program will continue throughout the licensed operating lifetime of Units 1 and 2 as well as the proposed Calvert Cliffs Unit 3, should that additional reactor be licensed.

* Environmentally significant refers to certain radionuclides that are known to be assimilated by biological organisms and are discharged in detectable amounts. Noble gases, tritium, or very short-lived radionuclides are not environmentally significant.

Bay oysters are ideal indicators of environmental radionuclide concentrations because they do not move and they readily ingest and concentrate metals. Oysters have been historically commercially harvested near Calvert Cliffs, and they have the greatest potential for contributing to a human radiation dose through seafood consumption. PPRP has monitored the uptake of radionuclides in test oysters placed seasonally on platforms on the Bay floor in the vicinity of the Calvert Cliffs discharge since 1996. The oysters are collected at scheduled time intervals and analyzed for radionuclide content in their tissues. Radiosilver (110mAg) has historically been the principal plant-related radionuclide accumulated by test oysters and oysters on natural beds. Because 110mAg has been the major contributor of radiation dose to humans via ingestion of oysters, PPRP continues to monitor its concentrations. Such monitoring satisfies NRC requirements to quantify dose to humans. Since the fourth quarter of 2001, concentrations of 110mAg in oysters have fallen below analytical detection limits. The lack of 110mAg detection reflects a recent downward trend in 110mAg releases, as well as other environmentally significant releases, from CCNPP (see Figure 4-28).

As part of its assessment program, PPRP estimates doses of radiation to individuals consuming seafood. The doses are calculated based on maximum or worst-case estimates of the amount of plant-related radioactive material potentially available in the seafood. Results indicate that radiation doses attributable to operations at Calvert Cliffs are well below federally mandated limits (see Table 4-16).

Figure 4-27
Environmentally Significant Annual Aqueous Releases, 1987-2005



Chesapeake Bay sediments are also useful indicators of environmental radionuclide concentrations because they serve as natural sinks for both stable and radioactive metals. PPRP collects sediment samples seasonally from eight transects extending bayward north and south of the Calvert Cliffs plant. There were no plant-related radionuclides detected in Bay sediments during the 2004-2005 reporting period (see Figure 4-29).

Results of analyses of environmental samples collected in the vicinity of Calvert Cliffs can be found in the periodic environmental reports referenced below. A comparison of radionuclide

Figure 4-28
Concentration of ^{110m}Ag in CCNPP Aqueous Effluent and 3-month Tray Oysters, 1996 - 2005

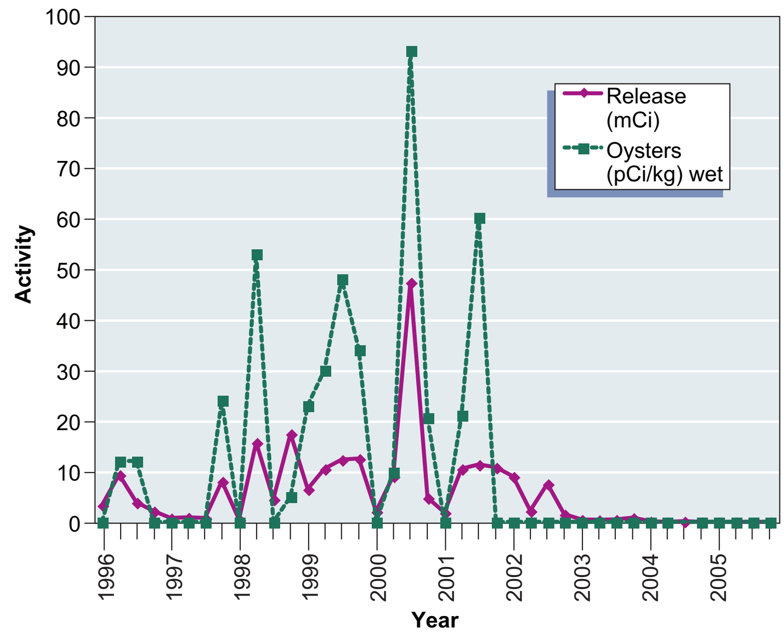


Table 4-16. Estimated Maximum Radiation Dose (mrem) Attributable to Calvert Cliffs and Peach Bottom

Exposure Route	Maximum Dose Estimate		EPA Regulatory Limit (40CFR190 Subpart B)	NRC Regulatory Limit (10CFR50 Appendix I)
Ingestion (mrem)				
Oyster ingestion, whole body dose (from CCNPP)	< 0.000321 (teen)[b]		25	3
Oyster ingestion, other organ dose (from CCNPP)	< 0.0051 (adult gastro-intestinal tract)[b]		25	10
Finfish ingestion, whole body dose (from PBAPS)	0.004 maximum (adult)[b]		25	3
Finfish ingestion, other organ dose (from PBAPS)	0.007 maximum (teen liver)[b]		25	10
Inhalation (mrem)				
	Maximum Dose Estimate (2004)	**Maximum Dose Estimate (2005)**		
Whole body dose (gaseous, from CCNPP)	0.00038 (child)[a]	0.00044 (child)[a]	25	3
Other organ dose (gaseous, from CCNPP)	0.0021 (skin, any age)[a]	0.0015 (child skin)[a]	25	10
Whole body dose (gaseous, from PBAPS)	0.0987 (child)[c]	0.351 (child)[c]	25	3
Other organ dose (gaseous, from PBAPS)	0.227 (infant thyroid)[c]	7.58 (infant thyroid)[c]	25	10

[a] Source: Annual Radiological Environmental Operating Reports for 2004 and 2005, Constellation Generation Group
[b] Source: PPRP
[c] Source: Annual Radiation Dose Assessment Reports for 2004 and 2005, Exelon Nuclear

concentrations in environmental samples collected in 2004 and 2005 with levels detected since 1978 shows the following:

- *Plant-related radionuclides were not detected in sediments or shellfish during 2004 and 2005.*
- *Although radionuclide concentrations fluctuate seasonally and annually, no long-term accumulation of plant-related radioactivity in Bay aquatic life and sediments is evident.*
- *The radioactivity introduced into the environment by Calvert Cliffs, when detected, is very small compared with background radioactivity from natural sources and weapons test fallout.*
- *Radiation doses to humans due to atmospheric and aqueous releases are well within regulatory limits (see Table 4-16).*

In summary, environmental, biological, and human health effects of releases of radioactivity from Calvert Cliffs are insignificant.

Peach Bottom Atomic Power Station

Exelon Generation Company, a subsidiary of Exelon Corporation, operates Peach Bottom Atomic Power Station (PBAPS), which began operations in 1974. Peach Bottom is located on Conowingo Reservoir just north of the Pennsylvania-Maryland border. The plant's two operating units are boiling water reactors, each with a generating capacity of approximately 1,100 MW. PPRP has monitored radionuclide levels from the plant since 1975.

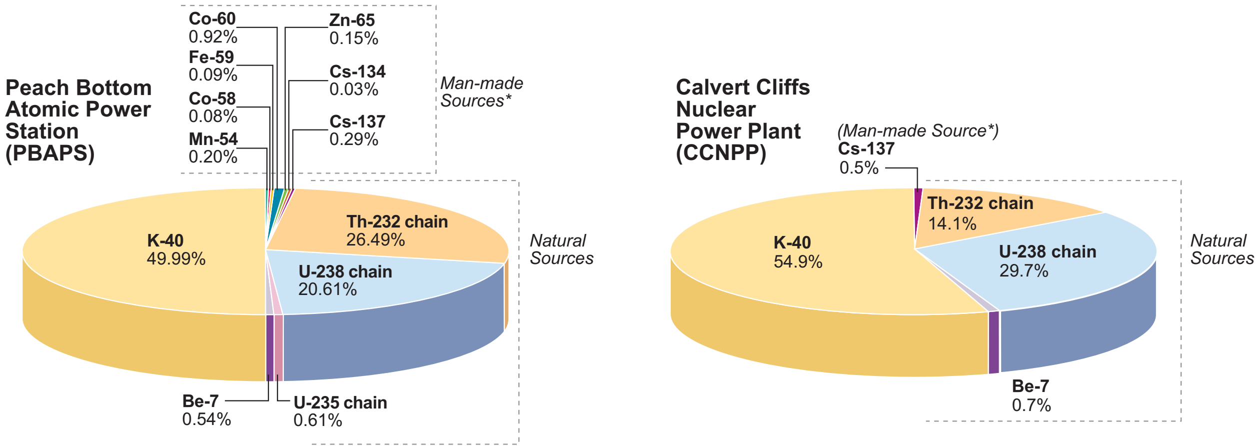
Like Calvert Cliffs, Peach Bottom routinely releases low-level gaseous, particulate, and liquid radioactive material into the atmosphere and the Susquehanna River. Estimated doses to humans, based on liquid and atmospheric releases of radioactivity from the plant, have been well within regulatory limits since the beginning of its operation (Table 4-16).

PPRP studies of the effects of nuclear power plant operations in the vicinity of Peach Bottom have been ongoing since 1979. PPRP publishes its environmental assessments biennially.

Information from Exelon's monitoring programs shows that in recent years, noble gases accounted for nearly all of identifiable radioactivity released to the atmosphere by the plant. The most recently compiled results from weekly air and annual vegetation monitoring conducted by Exelon Nuclear and independently by PPRP (for the years 2004 and 2005) indicate that releases of radioactivity to the atmosphere by the Peach Bottom plant were not detectable in air, precipitation, or vegetation.

Of the radionuclides released by Peach Bottom to the Susquehanna River in 2004 and 2005, 99 percent was tritium, which is not bioaccumulated and therefore not environmentally significant. Very small quantities of radioactive cobalt, zinc, iron, chromium, and manganese accounted for most of the remaining liquid radioactive material released. These particular radionuclides are environmentally significant (see Figure 4-27) because they can, if released in sufficient quantities, be readily accumulated by aquatic life such as mussels and finfish.

Figure 4-29
Proportion of Natural vs. Man-Made Radionuclides in Sediment Samples Near CCNPP and PBAPS



* Cesium-137 (Cs-137) in sediments in the vicinity of Calvert Cliffs is solely attributable to weapons test fallout as the radionuclide is released only in small quantities by the power plant. At Peach Bottom, however, releases of Cs-137 are larger. While the Cs-137 in sediments near Peach Bottom is primarily attributable to weapons test fallout, a power plant-related component is present as well.

Finfish collected semi-annually by PPRP from the Conowingo Reservoir area contained only historical, fallout-related radionuclides. Radioactivity related to Peach Bottom plant was detected in sediments collected semi-annually downriver of the plant (see Figure 4-29). It is estimated that historically, less than 20 percent of the radioactivity released in Peach Bottom water discharge is found in sediments of the Conowingo Reservoir. The remaining radioactivity is transported downstream to the Chesapeake Bay.

Similar to the studies at Calvert Cliffs, PPRP has estimated radiation doses to individuals consuming finfish using the maximum plant-related radionuclide concentrations found in the finfish. However, because the Susquehanna River is a source of drinking water, its ingestion, in addition to fish consumption, may potentially contribute to a human radiation dose. As shown in Table 4-16, the annual total body doses associated with the consumption of finfish and drinking water are well below federal limits.

Results of analyses of environmental samples collected in the vicinity of Peach Bottom can be found in the periodic environmental reports referenced below. Comparing PPRP's radiological monitoring of Peach Bottom-related radioactivity of aquatic life and sediments collected from 2004 and 2005 with monitoring results since 1978 shows the following:

- *The levels of plant-related radioactive material detected in aquatic life and sediments represent a small portion of the radioactive material in the Susquehanna River-Chesapeake Bay system compared with that from natural sources and weapons test fallout.*
- *No long-term accumulation of plant-related radioactive material in river biota is evident.*
- *Long-term operation of Peach Bottom Atomic Power Station has not caused signifi-*

cant accumulation of radioactive material within the Conowingo Reservoir.

- *Radiation doses to humans due to atmospheric and aqueous releases are well within regulatory limits (see Table 4-16).*

In summary, environmental, biological, and human health effects of releases of radioactivity from Peach Bottom are insignificant.

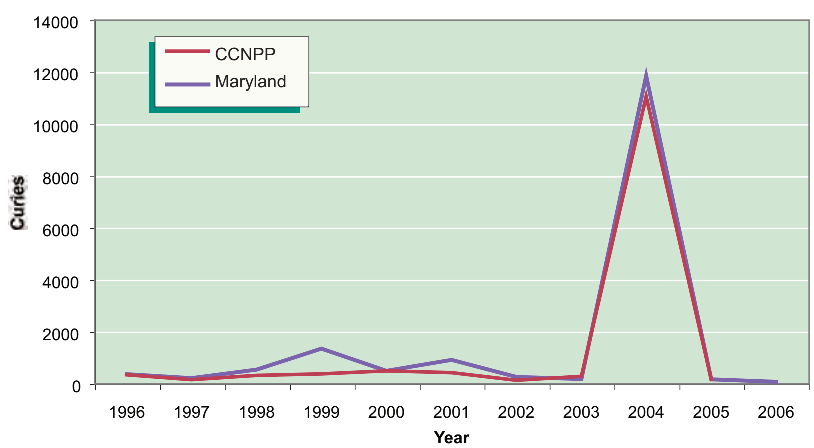
Radioactive Waste

In addition to the production of atmospheric and liquid effluent releases as a byproduct of normal power generation operations, both Calvert Cliffs and Peach Bottom generate radioactive waste products which require disposal.

Low-Level Radioactive Waste (LLRW)

This type of waste consists of materials such as contaminated gowns, toweling, glassware, resin, equipment, and reactor control rods that are used in the normal daily operation and maintenance of the power plant. Much of the waste is safety and testing equipment that have become contaminated through normal use. Resin is used to remove radioactivity from wastewater through an ion-exchange process. Depending on the waste type and radioactivity level, waste is dried, compressed, and sealed into high-integrity containers, metal boxes, or 55-gallon drums. These containers may in turn be sealed into shipping casks. Low-level radioactive waste from Calvert Cliffs, similar to LLRW from other industries, is transported by truck to licensed radioactive waste processing firms located in South Carolina and Tennessee, depending on the type of waste. Some of the waste's final destination is a burial site located in Barnwell, South Carolina. Other LLRW from Calvert Cliffs may be incinerated, supercompacted, or chemically reduced, depending on the waste processing vendor and type of waste. The proportion of LLRW produced by Calvert Cliffs in relation to total LLRW generated by Maryland is presented in Figure 4-30).

Figure 4-30
Low Level Radioactive Waste Generation in Maryland



High Level Radioactive Waste (Irradiated Fuel)

Spent nuclear fuel from both Calvert Cliffs and Peach Bottom are presently stored at each site within spent fuel pools for the recently discharged fuel or, in the case of older fuel generated in earlier years of plant operation, at dry storage independent facilities located within the protected plant area. These Independent Spent Fuel Storage Installations (ISFSIs) are licensed by the NRC for 20 years. ISFSI design and construction must conform to strict NRC specifications (10CFR72) that protect against unauthorized entry, earthquake, and other natural phenomena such as floods and hurricanes. The U.S. government expects to move irradiated fuel stored in ISFSIs at commercial power plants throughout the country to a central location beginning in 2017. The Yucca Mountain, Nevada, repository is currently the sole site under consideration as the central long-term storage facility. The U.S. Department of Energy is currently in the process of submitting a license application to the NRC to authorize construction. If the Yucca Mountain repository should not be available at the end of an ISFSI's 20-year license, nuclear power plant operators will be required to apply for a new license and modify their ISFSIs.

As of May 2007, Calvert Cliffs had 54 casks loaded with spent fuel in the ISFSI, 48 of which have a capacity of 24 spent fuel assemblies and six of which have a capacity of 32 spent fuel assemblies, for a total of 1,344 assemblies in dry cask storage. Constellation Energy plans to load three more of the 32-assembly capacity casks in 2007, six more in 2008, and then 24 more by 2012. Calvert Cliffs' currently licensed ISFSI will accommodate 3,456 assemblies and provide storage for spent fuel from both reactors for their lifetime.

Exelon's dry cask storage facility at Peach Bottom currently has 37 casks loaded with 68 fuel assemblies each, for a total of 2,516 assemblies. No more casks will be loaded in 2007.

Power Plant Combustion Products

Coal, like all fuels, produces gaseous and solid "by-products" during combustion. The solid by-products result from components of coal not consumed during combustion. This section of the report focuses on the solid coal combustion products (CCPs) produced by coal-fired power plants in Maryland. Specifically, the annual production of CCPs is reported, and more importantly, ways in which CCPs are used and disposed of are discussed. Much of the discussion focuses on beneficial industrial uses of CCPs and on-going research efforts to identify additional uses for CCPs. The ultimate goal is that all CCPs produced in Maryland, including those currently stockpiled, will be used in environmentally beneficial or at least in environmentally benign ways.

When properly engineered and correctly applied, CCPs can be put to multiple productive uses in civil engineering, mine restoration, and agricultural applications (Table 4-17). The beneficial use of CCPs as raw materials in applications that are environmentally sound, technically safe, and commercially competitive will lead to a reduction in the practice of landfilling these raw materials and contribute to reduced greenhouse

Reported TRI Releases Associated with CCPs

In 1986, the Toxics Release Inventory (TRI) was established under the Emergency Planning and Right to Know Act. The TRI is a database maintained by the U.S. EPA listing the quantities of toxic chemicals released to the environment annually by facilities in certain industries. Electric utilities became subject to TRI reporting requirements in 1997.

The TRI reporting for CCPs is based on the mass of the regulated chemical that was disposed, rather than the total mass of CCPs. There are currently 594 chemicals that require TRI reporting. Of these 594 chemicals, only 14 have been reported in the category of Electric Utility land-based waste disposal. The table below lists these chemicals along with the quantities disposed by Maryland electric utilities in 2005. The table shows that barium and vanadium compounds constitute the largest portion of TRI reportable chemicals disposed in CCPs in 2005. Overall, the mass of TRI reportable chemicals represents less than 1 percent of the total mass of CCPs produced annually in Maryland.

Chemical	Quantity Disposed in 2005 (pounds)	Off-site
Arsenic Compounds	34,678	32,870
Barium Compounds	1,049,224	1,012,473
Beryllium Compounds	—	—
Chromium Compounds	159,443	155,508
Cobalt Compounds	35,659	33,517
Copper Compounds	190,930	175,123
Lead Compounds	75,890	70,419
Manganese Compounds	233,562	227,113
Mercury Compounds	2,820	1,166
Molybdenum Trioxide	673	1
Nickel Compounds	184,216	152,526
Selenium Compounds	14,433	—
Vanadium Compounds	356,787	330,470
Zinc Compounds	165,963	153,049
Total Reported to TRI in 2005	**2,504,278**	**2,344,235**

Note: On and off-site disposal included.

Table 4-17. CCP Beneficial Use Options

	TYPE OF COAL COMBUSTION PRODUCT					
	FBC		Pulverized Coal			FGD
Potential Use	Fly ash	Bed ash	Fly ash	Bottom ash	Boiler slag	Sludge
ROADWAYS						
Cement/Concrete/Grout			X	X	X	X
Embankment/Structural fill			X	X	X	X
Flowable fill			X	X		X
Road base/Subbase			X	X	X	X
Snow and ice control				X	X	
Synthetic aggregate			X			X
Wetland liner						X
RECLAMATION USE						
Abandoned surface mine reclamation	X	X	X			X
Reclamation of existing surface mined lands	X	X	X			X
Subsidence remediation and control	X	X	X	X		X
Underground placement to mitigate AMD	X	X	X			X
Wetland and pond liner	X	X				X
Treatment of coal refuse	X	X				X
AGRICULTURE						
Agricultural liming substitute	X	X				X
Soil amendment	X	X	X	X		X
Pond & animal manure holding facility liner	X	X				X
Livestock feedlot and hay storage pad	X	X	X			X
New soil blends	X	X	X	X		
Commercial fertilizer	X	X	X			
Treatment of bio-solids	X	X	X	X		X
MANUFACTURING						
Paint			X			
Wallboard						X
Roofing granules				X	X	
Cement industry			X			X
Steel industry			X			X
Fillers (plastics, alloys and composites)			X			
Mineral wool insulation			X			
Ceramic products			X			
Recovery of metals			X			X
OTHER ENGINEERING USES						
Brick			X			
Concrete block			X	X		X
Landfill liner, daily cover, cap	X	X	X			X
Blasting grit				X	X	
Pipe bedding				X	X	
Water filtration					X	
Drainage media				X	X	
Waste stabilization/solidification	X	X	X	X		X
Treatment of sewage sludge	X	X				X
Pond liner			X			X
Dredged material stabilization	X	X	X			X

gas emissions. The most direct contribution to reducing greenhouse gas emissions occurs when fly ash is used as a supplementary material in concrete and concrete products. By substituting fly ash in place of cement for making concrete, the carbon emissions associated with cement production are avoided. For each ton of fly ash utilized, a reduction of approximately one ton of CO_2 is achieved. A continued increase in the beneficial utilization of Maryland CCPs will lead to:

- *Decreased need for landfill space;*
- *Conservation of the natural resources of the state;*
- *Reduction in the cost of producing electricity;*
- *Lower electricity cost for consumers; and*
- *Substantial savings for end-users of CCPs.*

Anticipated By-product to be Generated by FGD Units Installed on Maryland Power Plants in 2010

Plant	Mass (tons/year)	
	Maximum	Estimated Average
Brandon Shores	1,200,000	1,080,000
Dickerson	310,000	229,000
Chalk Point	382,000	309,000
Morgantown	703,000	520,000

CCP Generation

CCPs are produced during the combustion process necessary for the production of electrical energy at modern coal-burning power stations. In 2005, coal-fired power plants in Maryland generated an estimated 1.8 million tons of CCPs. These CCPs are the non-combustible mineral matter present in coal and any unburned carbon remaining as a result of incomplete combustion.

The two primary types of CCPs produced by Maryland's coal-burning power stations, fly ash and bottom ash, are differentiated by their physical characteristics. Fly ash is the finely divided residue or ash that is transported from the furnace along with emission gases. Fly ash is composed of very fine, and generally spherical, glassy particles. Conversely, bottom ash is collected from the bottom of the furnace and is composed of coarser, angular, porous, or glassy particles. There is little difference in the chemical makeup of fly ash and bottom ash. The principal difference is that the particles of bottom ash are much larger than particles of fly ash. During coal combustion, if temperatures are sufficiently high, a portion of the resulting ash will become molten and convert to boiler slag.

The chemical nature of CCPs depends upon the nature of the coal burned and the combustion process used. For the most part, power plants in Maryland burn bituminous coal from the eastern United States, which produces predominantly ASTM Class F fly ash. Class F fly ash is distinguished from Class C fly ash by having less than 10 percent calcium (expressed as CaO) by weight. The ash is typically composed of more than 85 percent silicon, aluminum, and iron oxides, much of which is present in glassy aluminosilcates. Class F fly ash may also contain trace metals such as titanium, nickel, manganese, cobalt, arsenic, and mercury. Electric utilities are required to include all applicable constituents of their CCPs when reporting chemical releases through EPA's Toxics Release Inventory (TRI) program.

B.B.S.S. Mine Reclamation Site

Since 1995, Constellation Energy Group (formerly Baltimore Gas & Electric) has provided Reliable Contracting Co., Inc. with approximately 200,000 to 400,000 tons per year of CCPs, primarily unstabilized Class F fly ash, to reclaim a former sand and gravel mine in Anne Arundel County owned by B.B.S.S., Inc. The site relies on soil cover and the underlying geology to minimize the potential for leachate to impact the regional ground water system. In October 2006, MDE requested that PPRP assist with an independent evaluation of the source of heavy metals and dissolved sulfate detected in residential wells surrounding the site. A statistical comparison of residential and monitoring well water quality data indicated that fly ash placement in the Turner and Waugh Chapel Pits at the site contributed to deterioration of ground water quality in the site vicinity. Constellation Energy Group has been operating a ground water recovery system downgradient of the Turner Pit since 2004 to mitigate impacts to ground water. In addition, Constellation and MDE entered into a Consent Decree in October 2007 that lays out an approach to resolve the impacts downgradient of the Waugh Chapel Pit.

Two clean coal technologies that are relatively new to Maryland are fluidized bed combustion (FBC) and flue gas desulfurization (FGD). Both of these technologies include the use of sorbents, such as limestone, during or after combustion to reduce air pollution by removing sulfur compounds from power plant emissions. FBC introduces the alkaline sorbent during combustion while FGD introduces the limestone sorbent in the flue (exhaust) gas. Whereas the use of sorbents improves air quality, the noncombustible sorbents significantly increase the volume of solid CCPs produced.

FBC by-products and FGD material resulting from these clean coal technologies contain many of the same chemical components as ordinary coal ash, but they contain much larger proportions of calcium sulfate and sulfite minerals due to reactions between the limestone sorbent and sulfur emissions. They may also contain free lime (unreacted sorbent), causing the ash to have cementitious properties when blended with water.

The AES-Warrior Run power plant in Cumberland is currently the only Maryland power plant that uses FBC. In FBC technology, coal and finely ground limestone are fed into the combustion chamber and mixed by forcing air into the chamber. The heat in the combustion chamber causes the limestone to decompose to an oxide that captures the SO_2 produced from burning the coal. FBC units can remove more than 95 percent of the sulfur that would normally be produced from burning coal. The resulting combined ash is a pozzolan: a silica, alumina, and calcium based material which, in the presence of water, will chemically combine with the free lime from the slurry spray and produce a cementitious material with excellent structural and engineering properties.

FGD scrubbers are scheduled to come online at the Brandon Shores, Dickerson, Chalk Point, and Morgantown power stations in 2010. After 2010, FGD scrubbers will introduce on average more than 2 million tons per year of FGD material to the CCP beneficial use stream. FGD material is produced when the flue gas enters the spray tower or absorber where it is sprayed with water slurry containing lime or finely ground limestone. The calcium in the slurry reacts with the SO_2 to form calcium sulfite or calcium sulfate which are removed by dewatering and settling. The resulting material is suitable for use as a natural gypsum substitute.

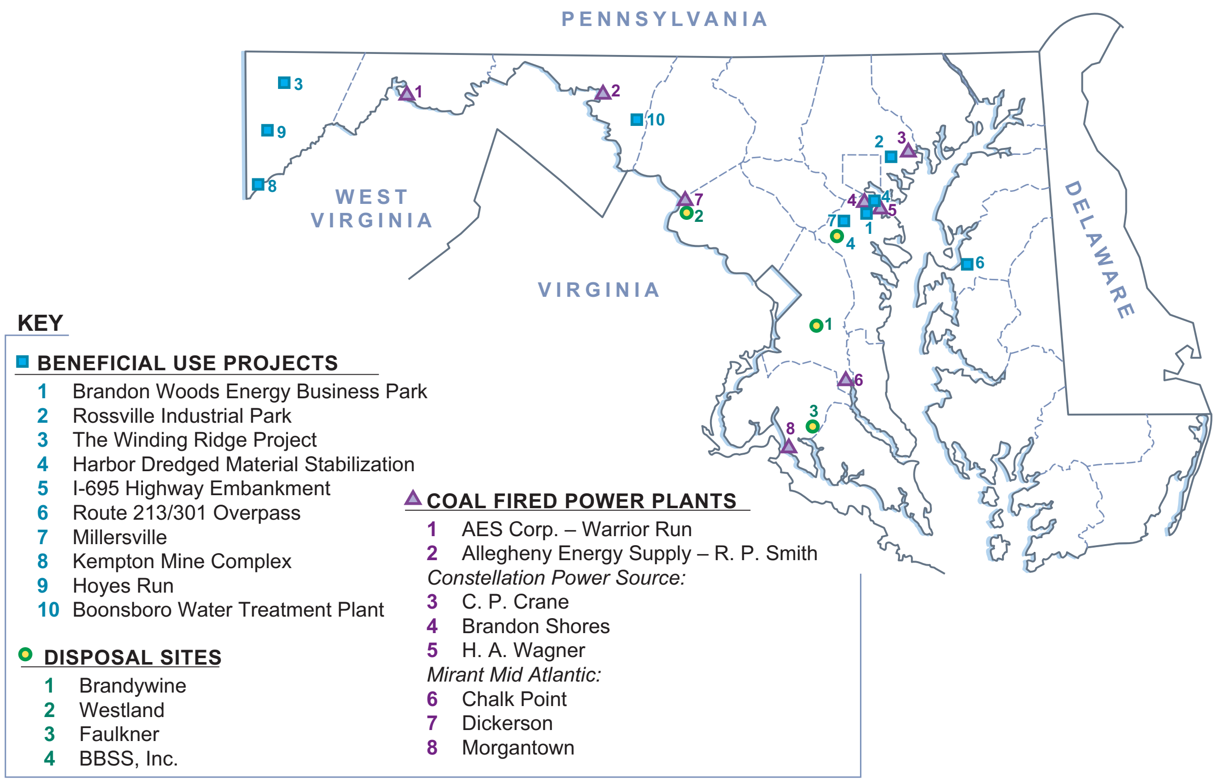
In the absence of sound engineering principles, landfilled CCPs have the potential to adversely impact Maryland's terrestrial and aquatic resources. To avoid adverse impacts, landfilled CCPs must be contained or properly engineered based on the environmental constraints of a specific location.

Disposition and Beneficial Use

Of the approximately 1.8 million tons of CCPs produced by Maryland plants in 2006, about 46 percent are placed in disposal sites (see locations in Figure 4-31) with the largest disposal site being the BBSS site. As the largest beneficial use CCP application, AES Warrior Run used all (312,000 tons in 2006) plant-generated CCPs for surface coal mine restoration in Western Maryland. In 2006, the remainder of the Maryland beneficial use stream was used in a variety of applications including:

- *Concrete, block, and cement manufacturing (560,000 tons of CCPs);*
- *Blasting grit (51,000 tons);*

Figure 4-31
Distribution of Beneficial Use CCP Projects in Maryland



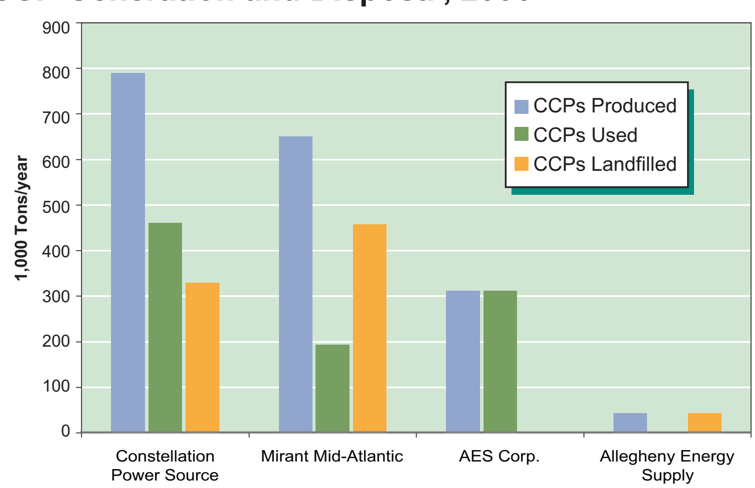
- *Flowable fill manufacturing (36,000 tons); and*
- *Snow and ice control (6,500 tons).*

Figure 4-32 highlights the quantity of CCPs generated and disposed by Maryland's coal-fired power plants annually.

Beginning in 2010, FGD by-product to be generated from the Brandon Shores plant will be provided to a wallboard manufacturer as a replacement for natural gypsum. The Dickerson, Chalk Point, and Morgantown plants will provide the FGD material to a third party for beneficial use applications such as wallboard, cement, and structural fill.

Fly ash, bottom ash, boiler slag, and FGD material have different primary beneficial uses because each component has distinct physical and chemical properties suited to a specific beneficial use application. Fly ash is used in the largest quantities and the widest range of applications among the CCPs (Table 4-17). Use in cement

Figure 4-32
CCP Generation and Disposal, 2006



and concrete production tops the list of leading fly ash applications, followed by structural fills and waste stabilization. The relatively uniform spherical shape and particle distribution of fly ash improves properties of flowable fill and the fluidity of grout. For waste stabilization, fly ash can act as a drying agent for wet materials such as sludge, sediment or dredged material.

The primary beneficial uses for bottom ash are road base/sub base, structural fill, and snow and ice control. Minor uses include concrete, mining applications, and cement clinker raw feed. Bottom ash can also is used as fine aggregate in asphalt paving mixtures. Owing to its considerable abrasive properties, boiler slag is used almost exclusively in the manufacture of blasting grit although use as roofing granules is also a potentially significant use area. Blasting grit and roofing granules account for nearly all beneficial uses for boiler slag. Primary beneficial use applications for FGD material are wallboard manufacturing, concrete, mining applications, and structural fill. Structural fill and concrete account for a majority of the remaining beneficial use of FGD by-product. Although agricultural use account for a small fraction of FGD material, the potential for using this material in agriculture to condition clayey soils exceeds even the volume used in wallboard manufacturing.

PPRP Demonstration Projects

While the 54 percent beneficial usage of CCPs in Maryland is above the national average of approximately 40 percent, as reported by the American Coal Ash Association in 2005, PPRP believes that this percentage can be increased even further even with the incorporation of the FGD material annual volumes beginning in 2010. For this reason, PPRP has supported research on both traditional and innovative beneficial uses of CCPs. Of particular interest are applications which use massive quantities of CCPs and can be adapted and adopted by both private and public enterprises to suit their particular needs.

Within the Potomac Basin, the Kempton Man Shaft Project conducted in 2003 demonstrated the viability of using CCPs in lieu of conventional cement in seepage barrier applications. The project demonstrated that CCPs, along with conventional mixing and pumping equipment can be used in place of traditional concrete for ground flow barriers, and for restoration of ground water flow patterns drastically disturbed by past coal mining. As a nationally recognized success, PPRP's Winding Ridge Mine Grouting Project conducted in 1996 demonstrates that CCPs can be used to effectively mitigate acid mine drainage (AMD) in abandoned underground coal mines.

PPRP is working on projects to address AMD and the protection of ground water in the Upper Potomac Coal Basin. In both of these basins, AMD exits abandoned coal mines and discharges into local streams and waterways, adversely affecting flora and fauna. PPRP currently has two projects in the Upper Potomac Basin and the Georges Creek Basin that are underway or in the planning stages investigating the beneficial use of CCPs to reduce acid formation. These projects include AMD abatement with CCPs at the Kempton Mine Complex in the Upper Potomac Basin.

Unique watershed restoration and mine injection projects are currently in the planning stages for the Upper Potomac Basin in the area of the Kempton Mine Complex. One of these projects will focus on a sub-watershed in an isolated section of the Kempton Complex. Building on previous PPRP studies indicating significant AMD production at upgradient mine spoil piles is infiltrating the mine complex and flowing along the mine pavement, a comprehensive plan to abate AMD with CCPs and restore watersheds will be developed. Suitable CCPs mix designs will be refined through previous mix design studies conducted by PPRP using local CCP materials.

The project objective is to mitigate AMD infiltration from the mine spoil piles, seal stream beds disturbed by surface mining with flowable CCP fill, and inject a CCP grout with appropriate flow characteristics to cover most of the mine pavement and entomb the mine floor debris. Once hardened, the grout would act as a barrier to prevent contact between pyrite, oxygen, and water seeping into the mine, thereby reducing or preventing acid formation within the tunnels. Stabilized CCP caps on the mine spoil piles will limit precipitation infiltration and AMD production while stream bed sealing will restore surface water flow lost to mine infiltration. The upper section of the Kempton Complex is representative of several hundred acres of exposed mine pavement in the Upper Potomac and Georges Creek Basins.

In addition to demonstration projects, PPRP also supports research that may lead to future projects or provide data that can be used by others in adapting CCP or waste-to-energy ash use technologies. The pozzolan stabilized material (PSM) weathering study is one such CCP research project. Other projects include:

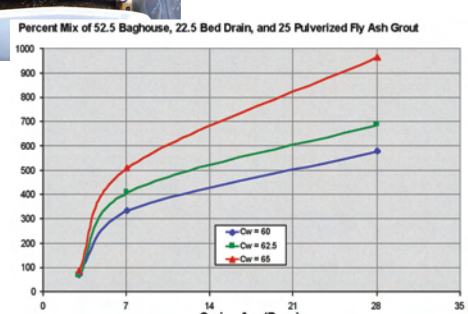
Dredged Material (DM) Stabilization – For the last few years, PPRP has been a member of the DM Innovative Reuse Committee (IRC) providing guidance on the beneficial use of massive amounts of material including DM and CCP blends. As an additive to DM, CCPs allow drying and conditioning of an otherwise poor engineering material for reuse as structural or flowable fill. Preliminary and ongoing laboratory tests of Baltimore Harbor DM blended with Maryland CCPs have resulted in a structurally stable material with excellent engineering properties.

Cost Optimization Study – PPRP developed a modular cost optimization and conceptual engineering plan to beneficially use the CCPs generated at the AES Warrior Run plant for deep mine restoration in the Georges Creek Basin. This deep mine restoration would reduce the risks of subsidence, mine out-gassing, mine fires and further disturbances of hydrogeology in this area. PPRP is adapting this modular study to other areas in western Maryland for surface and deep mine restoration applications, and in eastern Maryland for surface mine restoration.

Fly Ash Cement – PPRP is assisting MDE in evaluating fly ash and Portland cement blends for use in an AMD collection ditch and associated AMD holding ponds in the Georges Creek Basin. The stability of the fly ash cement mix relative to AMD attack is being evaluated based on

Weathering Studies of CCP-based Pozzolan Stabilized Materials

Initiated in June 2005, CCP weathering experiments document the physical and chemical degradation of CCP grout that could occur if placed as cover on abandoned underground mine pavement and exposed to AMD. To simulate abandoned mine conditions and determine environmental impacts, blocks of varying CCP composition were placed in flowing water ranging from pH 7 to pH 3.0. Partner organizations collected samples of the circulating water monthly (and now quarterly), to analyze for trace metals and selected contaminants of concern. Due to the inherent buffering capabilities of the CCP grout when exposed to AMD, water samples are analyzed daily for pH and must be adjusted weekly to the specified pH level. To date, monitoring has shown an increase in standard water quality parameters (i.e., calcium, potassium, sulfate, TDS) as expected from surficial CCP grout weathering under acidic conditions. However, no water quality constituents have shown increased concentration trends that would indicate continuing weathering and/or chemical dissolution of the blocks over time.



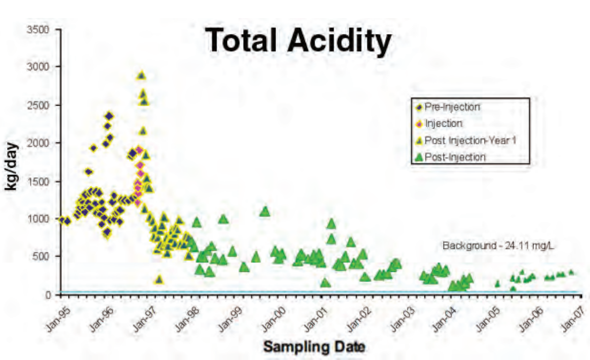
physical and chemical properties of the mix and results of bench scale studies. PPRP is evaluating results of laboratory tests related to durability of mix combinations based on the source and chemical composition of the fly ash to determine optimal blend ratios of fly ash and Portland cement.

In addition to successfully demonstrating potential massive CCP beneficial use projects in Maryland, PPRP supports the restoration of abandoned mine lands through the environmentally benign use of CCPs. Through the Geospatial Research Group at Frostburg State University (FSU) and the Maryland Bureau of Mines, PPRP supports the characterization of abandoned underground mines in western Maryland to define opportunities for mine restoration utilizing CCPs. PPRP also contributes support to the Ort Library at FSU to collect and catalogue historical information on abandoned Maryland mines to assist public and private agencies in the planning of mine restoration projects. PPRP has provided core and matching funds to Garrett College for the past six years to monitor the wetlands at the headwaters of the North Branch of the Potomac River. This monitoring provides a baseline understanding of the impact of abandoned mines and mine restoration on sensitive wetlands located at the headwaters of the Potomac River Basin. PPRP has also contributed to the soils laboratory at FSU for conducting stabilization studies of problem soils with Maryland CCPs, and stabilization of Baltimore Harbor dredged material with CCP blends. The soils laboratory and a supporting material testing laboratory are operated for PPRP at FSU by the Western Maryland Resource Conservation and Development Council, Inc. PPRP also supports research at the University of Maryland College Park concerning the unique material properties and potential use of relatively high carbon content CCPs.

The Winding Ridge Demonstration Project

PPRP and MDE Bureau of Mines initiated a cooperative effort in 1995 with the Winding Ridge Demonstration project. In 1996, 5,600 cubic yards of 100 percent CCP grout was injected into the Frazee Mine, a small abandoned coal mine in Garrett County, Maryland. The grout cured within the mine to a pozzolan stabilized material (PSM) and core samples retrieved from the mine one year after injection had compressive strengths above 1,000 pounds per square inch (psi). Additional core samples retrieved 10 years later showed that the PSM had retained its integrity over this time. A nationally recognized success, post-injection monitoring results show that the concentration of AMD-related parameters, including iron, aluminum, sulfate, total acidity, and trace metals in the mine discharge have decreased to well below pre-injection conditions. The pH of the mine discharge has also increased slightly, although it remains in the acidic range. While certain major ions (namely calcium, sodium, potassium, and chloride) do appear to have dissolved from the PSM surface into the mine discharge, their concentrations are decreasing with time and indicate that the PSM does not leach trace metals into the mine discharge water. In summary, the Winding Ridge Demonstration Project shows that CCP grout can be injected into underground coal mines to successfully reduce acidic mine water formation by sealing and encapsulating mine debris with a pozzolan stabilized material.

Acidity Reduction



Aerial view of the Winding Ridge project location