Impacts

Power Plants and Air Quality

The combustion of fossil fuels to generate electricity at power plants in Maryland results in the release of air pollutants that can potentially degrade air quality, both locally and regionally. Since the 1970s, the U.S. Environmental Protection Agency (U.S. EPA) has taken action through provisions of the Clean Air Act (CAA) to monitor and control the effects of air pollutants from power plants and other sources. The first comprehensive CAA was passed in 1970, and it has been amended significantly twice, once in 1977 and again in 1990.

The State of Maryland, and state and local organizations across the United States, develop air quality regulatory programs for power plants, other industrial sources, and mobile sources to address CAA requirements. Some air regulations target power plants specifically, such as the CAA's Acid Rain Program; other air regulations address specific pollutants that are emitted by power plants and other sources.

The goal of air regulations that affect power plants is to limit emissions of air pollutants to protect the public health and welfare. The following sections describe power plant air pollutant emissions, the impacts of those emissions, and recent pollution control trends and actions that affect power plants in Maryland and serve to reduce air pollution in the state.

Section Highlights

Air emissions from power plants have a significant impact on both local and regional air quality. The power plant air emissions of primary concern are carbon dioxide, sulfur dioxide, nitrogen oxides, and toxic substances (including such metals as mercury). PPRP is evaluating the impacts of these emissions on Maryland's environment and helping to develop methods to control such emissions.

Emissions from Power Plants

The air pollutants that power plants (and other fossil fuel combustion sources) emit can be classified into the following three types: criteria pollutants, hazardous air pollutants (HAPs), and greenhouse gases (GHGs). Each of these types of pollutants is described in the following sections.

Criteria Pollutants

The U.S. EPA has established National Ambient Air Quality Standards (NAAQS), which apply to six pollutants, known as criteria pollutants. These criteria pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2), lead, particulate matter (PM), sulfur dioxide (SO_2), and ozone (O_3). The U.S. EPA has developed both "primary" or health standards, and "secondary" or welfare NAAQS, representing the maximum pollutant concentrations that are allowable in ambient air. Primary standards are based on health risk assessments and are designed to protect the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards are set at levels designed to protect the public welfare by preventing damage to crops, animals and vegetation, and protecting against decreased visibility. The current NAAQS are listed in Table 3-1.

*Table 3-1 National Ambient Air Quality Standards (NAAQS)**

Criteria Pollutant	Averaging Period	Primary NAAQS*	Secondary NAAQS*
PM10 (particulate matter <10 microns)	Annual 24-hour	50 $\mu g/m^3$ 150 $\mu g/m^3$	50 $\mu g/m^3$ 150 $\mu g/m^3$
PM2.5 (particulate matter <2.5 microns)	Annual 24-hour	15 $\mu g/m^3$ 65 $\mu g/m^3$	15 $\mu g/m^3$ 15 $\mu g/m^3$
SO_2 (sulfur dioxide)	Annual	0.030 ppm (80 $\mu g/m^3$)	—
	24-hour	0.14 ppm (365 $\mu g/m^3$)	—
	3-hour	—	0.50 ppm, (1,300 $\mu g/m^3$)
NO_2 (nitrogen dioxide)	Annual	0.053 ppm (100 µg / m3)	0.053 ppm (100 $\mu g/m^3$)
Ozone	1-hour	0.12 ppm (235 $\mu g/m^3$)	0.12 ppm (235 $\mu g/m^3$)
	8-hour	0.08 ppm (157 $\mu g/m^3$)	0.08 ppm (157 $\mu g/m^3$)
CO (carbon monoxide)	8-hour	9 ppm (10 mg/m^3)	—
	1-hour	35 ppm (40 mg/m^3)	—
Lead	Quarterly	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$

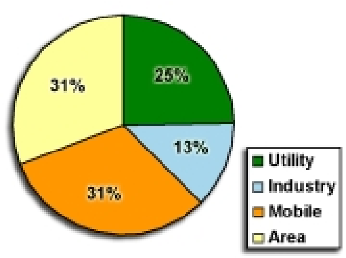
* 40 CFR 50

What Sources Emit NO_x?

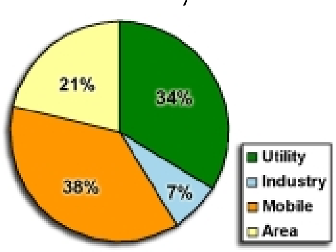
Burning fossil fuels, whether from stationary sources such as power plants, or from mobile sources, such as cars and trucks, produces emissions of nitrogen oxides (NO_x). NO_x is one of the precursor compounds — along with volatile organic compounds — that contribute to the formation of ozone smog. Because of its role in ozone formation, NO_x sources continue to be the focus of stringent pollution control efforts.

The U.S. EPA captures emissions information and publishes it in the National Emissions Trends (NET) Inventory. The NET inventory consists of close to 100,000 individual point or county-wide "area" sources with the emissions totaling close to 24.7 million tons of NO_x per year nationwide. As illustrated below, data from NET indicates that power plants account for 25 percent of total NO_x emissions nationally and about 34 percent in Maryland. Mobile sources and area sources (smaller sources not otherwise captured in the other source categories) each account for 31 percent of total annual NO_x emissions nationally; in Maryland, mobile sources contribute nearly 40 percent of NO_x emissions annually.

Nationwide NO_x Emissions: Contributions by Sector



Maryland NO_x Emissions: Contributions by Sector



Burning fossil fuels produces emissions of nitrogen oxides (NO_x), CO, and PM, and depending on the type of fuel, may also emit SO_2 and lead. Note that the nitrogen-based exhaust product from power plants and other combustion sources is termed "NO_x", which is composed of several compounds such as NO and NO_2. The criteria pollutant itself takes the form of nitrogen dioxide or NO_2, because this compound is particularly corrosive and can cause respiratory problems. NO_x emitted by combustion sources is primarily in the form of NO, which is partially converted to NO_2 in the atmosphere.

In the United States, nearly two-thirds of all SO_2 emissions and

Figure 3-1
NO_x Emissions from Maryland Power Plants, 1995-2001

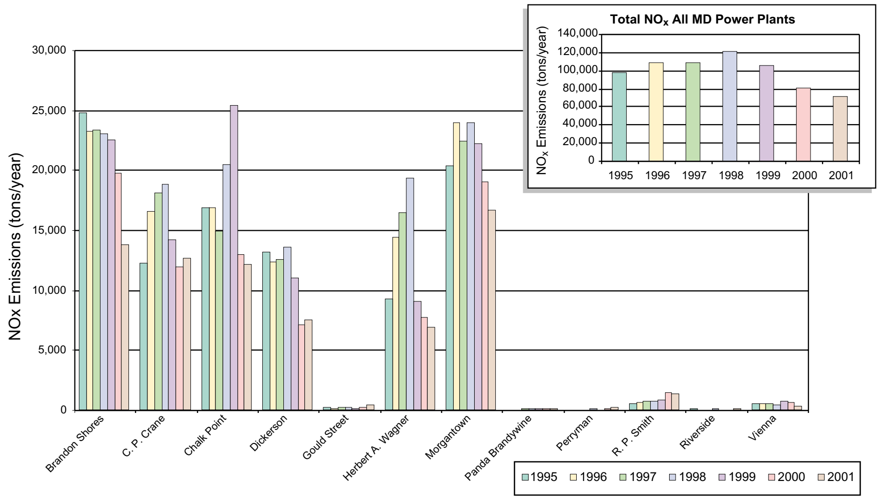
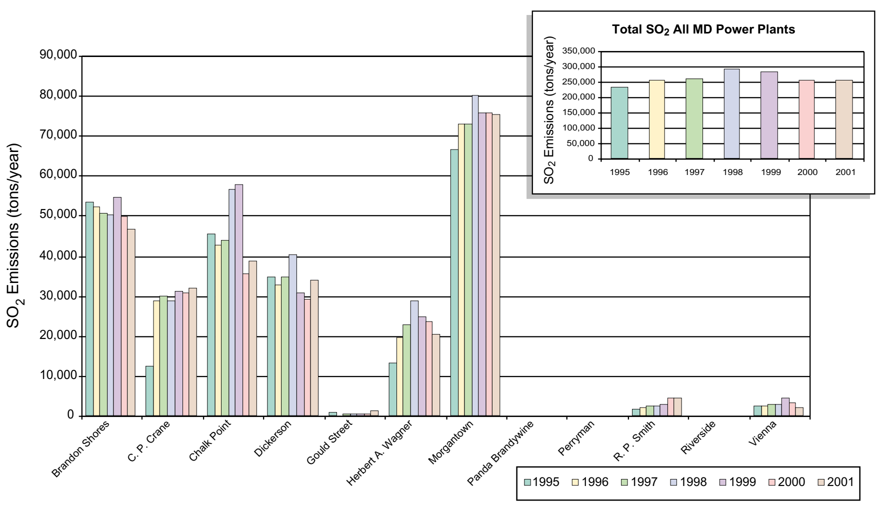


Figure 3-2
SO_2 Emissions from Maryland Power Plants, 1995-2001



one-fourth of all NO_x emissions result from power plants and large stationary combustion sources such as refineries that burn fossil fuels. Power plant emissions are the largest point-source contributor of NO_x emissions in Maryland; however, mobile sources of NO_x account for as much or more NO_x annually.

Figure 3-1 presents NO_x emissions from most power plants in Maryland during the period from 1995-2001; Figure 3-2 presents SO_2 emissions over the same time period. As discussed later in this chapter, all power plants in Maryland are subject to increasingly stringent NO_x emissions limits, and many larger plants in the state have implemented combustion modifications or post-combustion control devices to reduce NO_x emissions. In general, these NO_x reductions are evident in the emissions information in Figure 3-1, particularly when observing total NO_x emissions of all plants statewide (shown in the inset of Figure 3-1).

On the other hand, the trend in SO_2 emissions statewide is less clear. SO_2 emissions from the larger power plants in Maryland (and across the country) were capped under the Acid Rain program beginning in 1995, so the majority of SO_2 emission reductions occurred prior to 1995. Therefore, unlike NO_x emissions, the fluctuations in tons of SO_2 emitted from 1995-2001 reflect primarily variations in the amount of fuel burned (electricity generated) rather than changes in actual SO_2 emission rates.

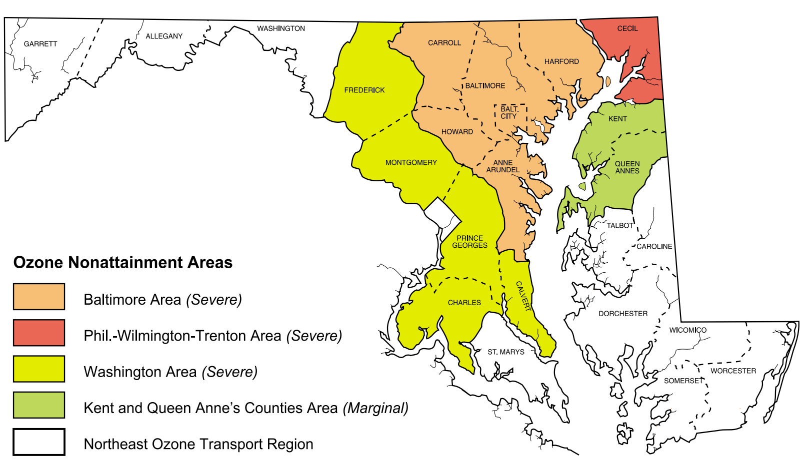
The 12 facilities shown in Figures 3-1 and 3-2 represent 93 percent of the fossil fuel-fired generating capacity in Maryland. The figures do not include smaller self-generation projects such as Bethlehem Steel or independent power producers in Maryland such as Trigen-College Park. Most of these smaller plants are not subject (because of their size or use) to the CAA Acid Rain program, and are therefore not required to monitor emissions continuously. These plants do calculate emissions (using emission factors, stack testing results, and engineering calculations) and report emissions annually or more frequently to the Maryland Department of the Environment.

Monitoring Criteria Pollutant Levels

The U.S. EPA and state and local agencies routinely monitor concentrations of the criteria pollutants near ground-level at various locations across the United States. If monitoring indicates that the concentration of a pollutant exceeds the NAAQS, 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 monitored concentration of a criteria pollutant is below the NAAQS is labeled an *attainment* area, indicating that the NAAQS is being met.

Because ozone smog has proven to be such a pervasive and persistent problem, as part of the Clean Air Act Amendments of 1990, the U.S. EPA further categorized ozone nonattainment areas based on the severity of the ozone problem. The categories range from "extreme" nonattainment (no areas in Maryland are in that category), to severe, serious, moderate, and marginal. Figure 3-3 shows the ozone attainment status for each county in Maryland.

Figure 3-3
Ozone Nonattainment Status in Maryland



The attainment/nonattainment designation is made separately for each of the criteria pollutants. Therefore, the air quality in an area of the country may be designated attainment for some pollutants and nonattainment for other pollutants at the same time. For example, the area around a particular power plant may be nonattainment for ozone, but attainment for the other criteria pollutants. Currently, all of Maryland is in attainment with the NAAQS for SO_2, NO_2, PM, CO, and lead. However, much of the urbanized portion of Maryland (along with much of the East Coast) is not meeting the NAAQS for ozone, making ozone "smog" an issue of particular concern in Maryland. Because ozone is recognized as a regional, rather than local issue, the entire State of Maryland is treated as an ozone nonattainment area, even though ozone monitoring indicates that many counties are actually in attainment with the ozone NAAQS.

State and federal air agencies regulate air emissions sources in nonattainment areas more stringently than in attainment areas to ensure that construction and operation of new industrial and power plant projects do not interfere with the State's progress in bringing the entire state into compliance with the ozone NAAQS. In fact, new source permitting requirements affecting large emissions sources in nonattainment areas, including new power plants in Maryland, require the most stringent levels of pollution control in the country.

Air pollutant emissions from power plants continue to be a major target of air quality legislation, given the volume of power plant emissions nationally. In fact, power plants are the primary target of the Bush Administration's recently proposed "Clear Skies Initiative" and other similar multi-pollutant initiatives that Congress may take up in 2003.

Hazardous Air Pollutant Regulations

Hazardous air pollutants (HAPs), also referred to as air toxics, are a list of 188 pollutants that the U.S. EPA has determined cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. HAPs occur naturally, and are generated by man-made sources such as mobile sources and industrial sources (factories, refineries, power plants, etc.).

Although fossil fuel-fired power plants emit HAPs, power plants have not historically been considered among the more significant sources of air toxics nationally, particularly when compared, for example, to chemical plants and petroleum refineries that use and emit highly toxic compounds. Prior to the CAA Amendments of 1990, power plants were not among the types of emissions sources regulated for HAP emissions by the U.S. EPA or by states that had toxics regulations. In Maryland, for example, fuel burning sources are exempt from State toxic air pollutant regulations.

However, the U.S. EPA was required by Congress under the CAA Amendments of 1990 to evaluate HAP emissions from power plants so that Congress could determine whether regulation of HAPs from power plants was warranted. The results of the U.S. EPA's study of HAPs are found in a document entitled Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units Pursuant to Section 112(n)(1)(A) of the Clean Air Act, also referred to as the "Utility HAP Report to Congress." The U.S. EPA has announced that it will develop HAP emissions standards for utility power plants based on this and other studies; recent information suggests that the U.S. EPA may propose the utility HAP standard as early as December 2003.

New Combustion Source Hazardous Air Pollutant (HAP) Regulations

Title III of the CAA Amendments of 1990 mandated a sweeping new program to control hazardous air pollutants (HAPs) from various types of sources. For each source category — such as electric utility power plants, combustion turbines, or petroleum refineries — the U.S. EPA develops source-specific emission standards, called Maximum Achievable Control Technology (MACT) standards, to control HAPs. The U.S. EPA is developing MACT standards for several types of combustion sources, including utility and non-utility boilers and combustion turbines. In September 2003, the U.S. EPA promulgated MACT standards for combustion turbines.

In developing the combustion turbine standard, EPA recognized that although combustion turbines emit a range of pollutants, four HAPs account for essentially all of the mass of HAPs emitted by these units: formaldehyde, toluene, benzene, and acetaldehyde, with formaldehyde being the single largest HAP emitted by combustion turbines (CTs). Therefore, the proposed new MACT sets a stringent formaldehyde emission limit of 91 parts per billion by volume for new CTs.

The U.S. EPA is scheduled to finalize the proposed Boiler MACT standards in January 2004. The proposed Utility MACT standard is expected in December 2003, and scheduled for finalization by December 2004.

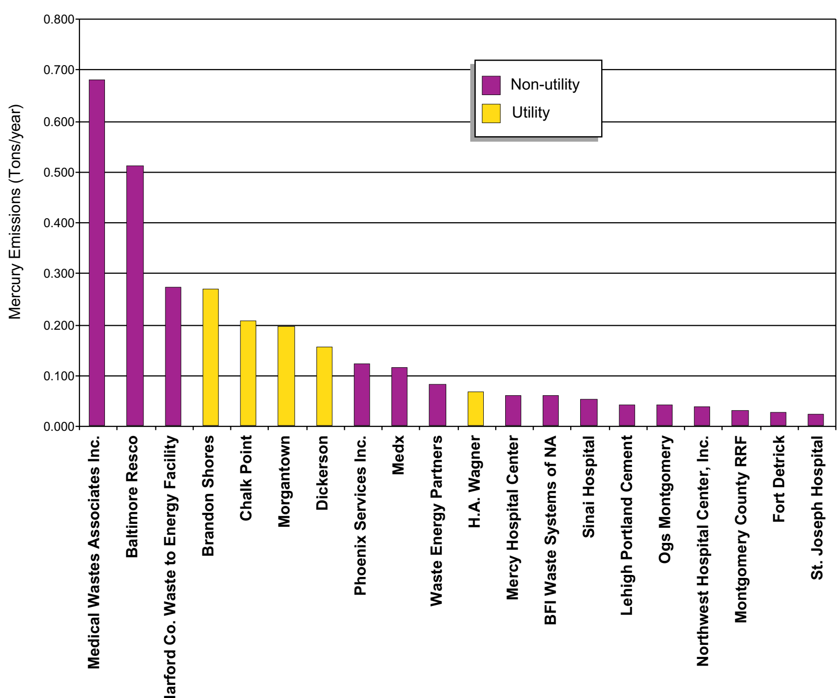
Power Plant HAP Emissions

The types and amounts of HAPs that are released from combustion sources depend primarily on the type of fossil fuel burned (coal, fuel oil, natural gas), the presence and effectiveness of any pollution control devices, and, to a certain degree, the type of generating technology in use (boiler versus combustion turbine versus internal combustion engine, etc.).

Many individual HAPs (organics, inorganics, and trace metals) may be released during the burning of fossil fuels associated with electricity generation. Most of these HAPs are emitted in very small quantities, especially from newer, natural gas-fired power plants. For example, a large (~1,100 megawatt) natural gas-fired combustion turbine facility recently licensed in Maryland — the ODEC Rock Springs project in Cecil County — was projected to emit a maximum of 17 tons per year of all HAPs combined; formaldehyde was the individual HAP with the greatest emission rate of about 8 tons per year. This represents a small fraction (less than 3 percent) of the total 738 tons of pollutants (including NO_x, SO_2, particulates, and HAPs) that the project could potentially emit.

Although the total mass emission of HAPs can be relatively small, especially compared to NO_x, CO, and PM emissions, certain HAPs are highly toxic or carcinogenic, so even small quantities of emissions of these compounds may be significant in terms of public health. In recognition of this, the emission threshold that constitutes a "major" source of HAPs, as defined in the CAA, is much lower (10 tons per year or more of any one HAP, or 25 tons per year or more of all HAPs combined) than the major source thresholds for other pollutants.

Figure 3-4
Top 20 Reported Mercury Emitters in Maryland, 1999



Mercury is the HAP of primary interest to the energy sector at present because power plants, primarily coal-fired power plants, account for 30 to 35 percent of total nationwide mercury emissions annually. Municipal waste combustors and medical waste and hazardous incinerators account for another 20 percent or more each. Because mercury poses significant risks to humans and the environment, there are substantial ongoing regulatory, scientific, and policy debates regarding mercury. Although there are currently no programs that regulate mercury emissions from utility power plants, power plant mercury emissions have been the focus of intense study by the U.S. EPA and will be among the HAPs regulated under the utility HAP standard to be developed by the U.S. EPA.

The U.S. EPA maintains comprehensive information on emissions of mercury and other compounds from power plants and other sources in its National Emissions Inventory (NEI) database. Figure 3-4 shows the top 20 mercury emitters in Maryland reported in the NEI database in 1999 (the most recent year of NEI mercury information); coal-fired power plants represent about 30 percent of the mercury emissions in Maryland.

Although there is considerable interest in mercury emissions from power plants, in the past there has not been a substantial amount of stack testing conducted to quantify mercury emissions. In a cooperative effort to obtain more useful mercury emissions data, PPRP is working with Constellation Power Source Generation to conduct a series of mercury stack testing studies at six coal-fired boilers in Maryland — two units each at Constellation's Brandon Shores, H.A. Wagner, and C.P. Crane power plants. The goal of the program is to gain a better understanding of mercury emissions from various types of coal-fired boilers, providing the basis for better future control of mercury emissions from power plants. The stack testing studies were completed in the summer of 2003, and results are being reviewed and evaluated.

Carbon Dioxide and Other Greenhouse Gases

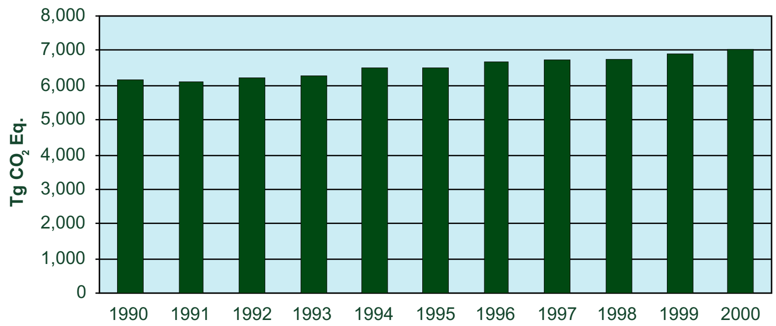
There has been, and continues to be, a substantial amount of evaluation and discussion of the impacts to global climate resulting from emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs). GHGs result from both human activities (burning fossil fuels in cars and at power plants and other industrial sources) and from natural events (volcano eruptions, forest and plant decay, etc.). Climate change generally refers to long-term changes in temperature, precipitation, wind, and other components of the Earth's climate systems.

Among the GHGs associated with power plants under evaluation for impacts to global climate are CO_2, methane (CH_4), nitrous oxide (N_2O), and sulfur hexafluoride (SF_6). Power plants and other sources that combust fossil fuels emit CO_2, CH_4, and N_2O. SF_6 is used within the energy sector as an insulating medium in circuit breakers and in switchyards and substations. Other GHGs being considered in global climate research include both naturally occurring compounds (such as water vapor) and compounds that are primarily man-made (such as classes of refrigerant compounds known as hydrofluorocarbons or HFCs).

Each of these GHG compounds has a different "global warming potential", or GWP, based on the compound's physical and chemical properties. The GWP is a relative measure of the ability of a particular GHG to absorb radiation and thus trap heat in the Earth's atmosphere. The primary GHG by volume emitted by human activities is CO_2. Because the emissions of CO_2 far outweigh all other GHGs in terms of mass (i.e., tons per year), GWPs are presented as relative to CO_2. By definition, CO_2 has a global warming potential of 1; methane, for example, has a global warming potential of 21, meaning that one molecule of methane is 21 times more "efficient" than one molecule of CO_2 at absorbing radiation and influencing global temperatures. SF_6, which is emitted to the atmosphere in very small quantities, is of concern because it has a GWP of 23,900.

The U.S. EPA publishes an annual national GHG emissions inventory (the Inventory of U.S. Greenhouse Emissions and Sinks), prepared under terms of

Figure 3-5
U.S. Anthropogenic Greenhouse Gas Emissions (total all sources), 1990 - 2000 in Teragram CO_2 Equivalent



Note: 1 teragram = 1 billion kg = 1 million metric tons

the 1992 United Nations Framework Convention on Climate Change. According to the Inventory published in April 2002 (covering 1990-2000), the U.S. EPA estimates that energy-related activities in the U.S. are responsible for nearly three-quarters of GWP-weighted GHG emissions annually. Power generating facilities reportedly account for about one-half of the energy sector emissions; combustion from mobile sources accounts for about one-third of the emissions.

The Inventory report indicates that emissions of total GHGs from all sources in the U.S. have increased about 14 percent from 1990 to 2000, from about 6,131 teragrams of CO_2 equivalent (Tg CO_2 Eq) in 1990, to just over 7,001 Tg CO_2 Eq in 2000 (see Figure 3-5). Because the total mass emissions of GHGs are large, the common unit of measure is Tg CO_2 Eq; the same unit can also be expressed as million metric tons carbon equivalent (MMTCE).

CO_2 emissions reported in the U.S. EPA's Acid Rain program database for fossil fuel power plants in Maryland between 1995-2001 are presented in Figure 3-6. CO_2 emissions are directly related to the amount of fuel burned, so Figure 3-6 also provides a good indication of the amount of energy generated at these plants over the period.

Global Warming Potentials

In 2001, the Intergovernmental Panel on Climate Change updated its list of Global Warming Potentials (GWPs) for various greenhouse gases (GHGs). The concept of the GWP was developed to allow better comparisons of the relative contributions of different GHGs to potential global climate change, and to allow policy makers to evaluate the costs and benefits of GHG reduction strategies. GWPs are calculated over a particular time period; the 100-year time horizon is the commonly accepted time period for calculating GWPs.

Greenhouse Gas	GWP*
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydrofluorocarbons	
HFC-23	11,700
HFC-32	2,800
HFC-125	1,300
HFC-134a	3,800
HFC-143a	140
HFC-152a	2,900
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
Fully fluorinated species	
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

*Calculated over a 100-year time horizon

Source: U.S. EPA U.S. Greenhouse Gas Inventory Program, "Greenhouse Gases and Global Warming Potential Values," April 2002.

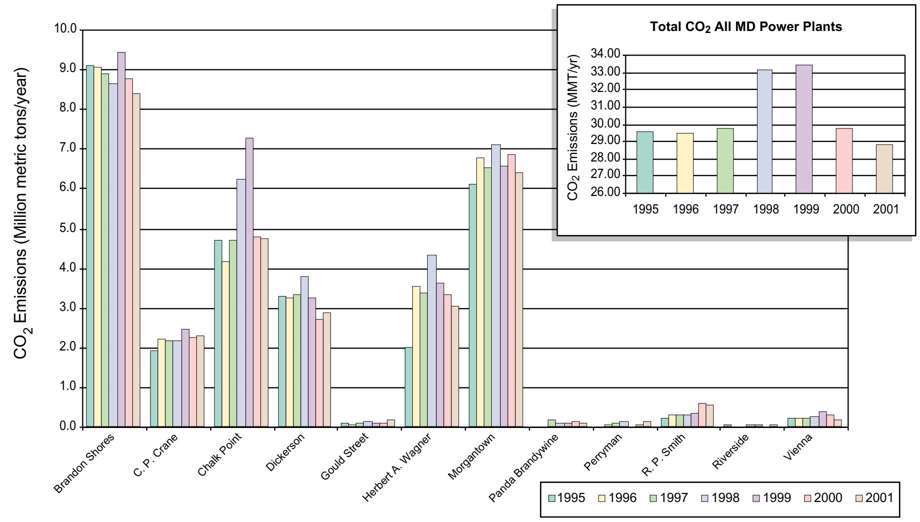
Impacts from Power Plant Emissions

It is relatively easy to determine emission rates from power plant stacks; utilities have been estimating or measuring power plant emissions for decades. However, it is more difficult to determine the impact these emissions have on the environment. In fact, because of the complexities of atmospheric transport and atmospheric chemistry, it is surprisingly difficult to relate emissions from a stack directly to a concentration in the atmosphere, or to an amount of pollutant deposited to the ground.

In this section, four types of impacts to air quality and the environment resulting from emissions of pollutants from power plants are reviewed:

- *Impacts to ozone levels*
- *Impacts from atmospheric deposition*

Figure 3-6
Reported CO_2 Emissions from Maryland Power Plants, 1995 - 2001



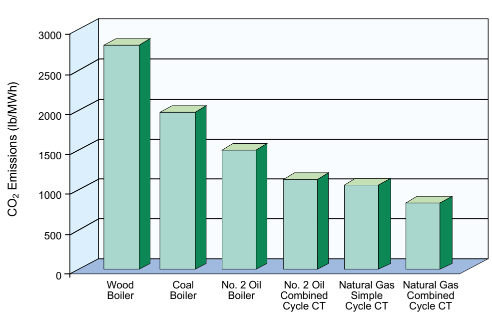
CO_2 Emissions from Different Types of Generating Technologies and Fuels

There are several gases, known as greenhouse gas (GHGs), that influence global climate change. Of the many GHGs, CO_2 is by far the most significant in terms of tons of gas emitted per year. The burning of fossil fuels — coal, oil, and natural gas — for energy generation is the primary source of CO_2 globally.

Actual emissions of CO_2 from combustion sources vary depending on the type of fuel, type of generating technology, efficiency of the generating unit, and other factors. The figure below illustrates "typical" CO_2 emission rates that would be expected from various common generating technologies burning coal, oil, or natural gas.

CO_2 Emissions from Different Technologies and Fuels

Pounds of CO_2 generated for each MWh of electricity generated



How much CO_2 is this?

One megawatt-hour (MWh) is about the amount of electricity that a typical household in the U.S. uses in a month. This means that a coal-fired boiler will produce about 2,000 lbs of CO_2 to generate electricity for a household for a month, while a natural gas-fired combined cycle combustion turbine will produce about 850 lbs of CO_2 to generate the same amount of electricity.

Keep in mind that these are average emission rates for "typical" generating units. Emissions from any specific power plant can vary significantly from these estimates.

- *Impacts to visibility and regional haze*
- *Impacts to global climate*

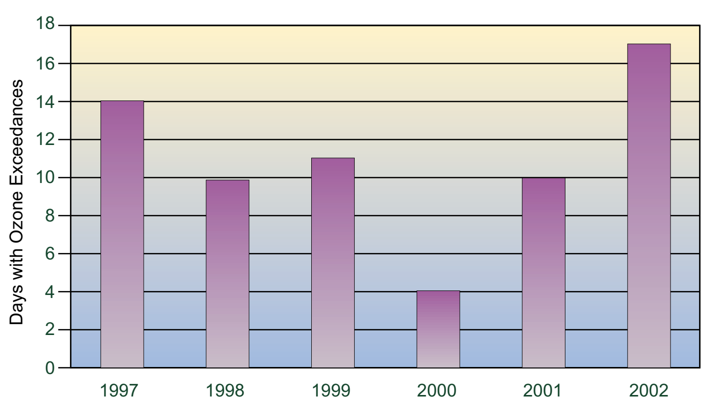
Ozone Pollution

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, an invisible gas, is the major component of photochemical smog. Ozone is not emitted directly into the atmosphere in significant amounts; rather, it forms when the precursor compounds — NO_x from both mobile and stationary combustion sources such as automobiles and power plants, and volatile organic compounds (VOCs) from industrial, chemical and petroleum facilities — react in the presence of sunlight and elevated temperatures. Consequently, ozone levels are highest during the summer months when the hours of daylight are greater and the sun's rays are more direct. In fact, weather plays such an important role in the formation of ozone that the U.S. 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.

The Maryland Department of the Environment monitors ozone at various locations throughout the state to identify areas of concern and to track the State's progress in attaining the ozone standard. The number of days with "exceedances" of the ozone standard in Maryland in recent years is shown in Figure 3-7. Among other things, the figure illustrates how much of an influence weather has on ozone formation. The number of ozone exceedance days in the year 2000 was substantially less than in other recent years. There is no indication that "precursor" NO_x and VOC emissions (the chemicals that contribute to ozone formation) were substantially lower in 2000; rather, the region experienced a relatively cool summer in 2000, so less ozone formed in the atmosphere. The number of "90 degree days" in 2000 was just 11, about one-third of what the region experiences on average in a summer. Fewer days with hot, stagnant weather conditions resulted in fewer days with ozone exceedances. On the other hand, the Baltimore area had relatively hot summers in 2001 and 2002. In 2001, there were 10 days with ozone levels exceeding the standard; four of the 10 days came during one extremely hot, stagnant weather event in August. The summer of 2002, in which Baltimore experienced 17 days with ozone exceedances, was particularly hot and dry.

Figure 3-7
Number of Days with Ozone NAAQS Exceedances in Baltimore, 1997 - 2002



Ozone Transport

Ozone is a regional problem, and transport of ozone and ozone precursors across large sections of the United States makes control and reduction of ozone smog a particularly difficult issue. For example, while much of Maryland actually achieves the ambient ozone standards, the entire state is designated as nonattainment for ozone in recognition of the regional aspect of ozone. In fact, all of the eastern U.S. states from northern Virginia through Maine are designated ozone nonattainment areas, and are collectively referred to as the Northeast Ozone Transport Region.

The evaluation of regional ozone pollution requires the use of highly specialized air quality dispersion models. These models are different from other air dispersion models because they must account for the transport of pollutants over large distances (such as from the Midwest to the East Coast), and must simulate the complex chemical reactions that lead to ozone formation.

The major drawback to most models commonly used to predict ozone concentrations (known as "urban airshed models") is that they require enormous amounts of computer resources. These models are so large and complex that it is impossible to evaluate more than just a few ozone "episodes" (periods of time with high levels of measured ozone concentrations, ranging from a few days to a few weeks) to determine the effect of different pollutant control strategies. In response to this drawback, the Electric Power Research Institute (EPRI) developed a simplified ozone modeling system (SOMS) for estimating ground-level concentrations of ozone. The modeling system requires significantly less computer time than other existing models, and therefore allows users to assess alternative control strategies rapidly, thus helping to evaluate the impact of those strategies on long-term ozone pollution.

Recognizing the usefulness of this type of screening model in the search for solutions to meeting ozone standards, PPRP has been working to expand and refine the model — now referred to as the Semi-empirical Integrated Pollution Model, or "SIPM" — and is beginning to use it as a screening tool to assist the State in identifying ozone reduction strategies.

PPRP's initial evaluations of SIPM have revealed that with its simplified approach to complex atmospheric phenomena, ozone concentrations predicted by the model compare quite well to observed ozone concentrations and to the predictions of more complex computer models. The encouraging results of the SIPM evaluations have prompted PPRP to continue in its effort to establish the model as another tool to help determine the most effective and efficient approaches for Maryland power plants to participate in the ozone attainment effort.

Ozone Regulation

Because ozone pollution is a regional phenomenon, it cannot be addressed effectively on a state-by-state basis. Therefore, in September 1998, building upon analyses conducted by representatives from the U.S. EPA, the Environmental Council of the States, and various industry and environmental groups, the U.S. EPA finalized a rule known as the NO_x SIP Call. The rule requires 22 states (including Maryland) and the District of Columbia to develop regulations (in State Implementation Plans, SIPs) to reduce regional transport of ozone from stationary sources of NO_x. The rule requires NO_x emission reductions from power plants and some other large sources by 70 percent beginning in the ozone season 2004.

The NO_x SIP Call program is an attempt to address the regional nature of ozone, and is designed to alleviate urban ozone levels. Power plants and other large

Ozone

Ozone's effects can be either positive or negative depending on where it resides. Ozone forms in both the Earth's upper atmosphere where it shields the Earth from the Sun's harmful ultraviolet rays, and closer to the ground surface where it can have detrimental effects on public health and the environment. Exposure to elevated levels of ozone can reduce lung function and damage lung tissue in people with impaired respiratory systems as well as in healthy populations.

The "NO_x SIP Call" and Maryland Power Plants

The Clean Air Act requires all states, including Maryland, to develop plans — called State Implementation Plans or SIPs — that outline the emissions and pollution control regulatory programs states will use to achieve and maintain good air quality. Beginning in mid-1995, these plans had to include both VOC and NO_x emissions control and reduction as part of the solution to the ozone smog problem.

In its recent "NO_x SIP Call" program, the U.S. EPA required 22 eastern U.S. states and the District of Columbia to develop new SIP regulations for power plants that require power plants to reduce ozone season (May-October) NO_x emissions to alleviate regional ozone smog pollution. To meet its NO_x SIP Call requirements, Maryland created a NO_x allowance system, modeled after the federal SO_2 allowance system. Under the new program, the State allocated NO_x allowances to each existing large generation facility in Maryland, with each allowance representing one ton of allowable NO_x emissions. Therefore, sources in Maryland must control NO_x emissions to the allocated level or purchase NO_x allowances from sources in the region that have reduced NO_x emissions below the allocated level and have allowances to sell.

NO_x sources will likely be subject to additional NO_x control requirements in the future, as the urban ozone problem persists.

Atmospheric Deposition

The pollutants emitted by power plants and other sources react in the atmosphere and directly affect air quality at ground level, but can also be deposited to ground (and surface waters) and affect the environment indirectly. In fact, atmospheric deposition may be one of the most important non-point sources of nitrogen and trace metals (mercury, lead, zinc, cadmium, arsenic, selenium, etc.) to the Chesapeake Bay. Researchers estimate that approximately 25 percent of the nitrogen load to the Bay comes from atmospheric deposition and subsequent transport. Further, as we have known for decades, SO_2 and NO_x emitted by power plants react in the atmosphere with water, oxygen, and other chemicals to form various acidic compounds which forms acid deposition or "acid rain."

Nitrogen Deposition

Nitrogen is one of the essential nutrients for plant life in estuaries and coastal waters; however, too much nitrogen can cause the depletion of oxygen in a water body, affecting living resources in the water body, and reducing its value as a natural resource and as a source of livelihood and recreation. The Chesapeake Bay is the largest of the 130 estuaries

NO_x Emissions: *Mitigating Impacts of Power Plant NO_x Emissions on Nitrogen Deposition Loading to the Chesapeake Bay Watershed*

Through the processes of wet and dry deposition, both onto the water surface of the Chesapeake Bay and onto land areas within the Bay watershed, a significant quantity of nitrogen can reach the Bay from airborne sources of NO_x. Although nitrogen is one of the essential nutrients for phytoplankton production in estuaries and coastal waters, too much nitrogen, combined with an abundance of other nutrients, can become a problem.

Recognizing the importance of the atmospheric deposition issue, PPRP has begun evaluating the potential impacts of deposition resulting from NO_x emissions from new power plants in the state. Using U.S. EPA's CALPUFF modeling system, PPRP predicts the incremental nitrogen deposition from new power plants, and uses the information to develop mitigation strategies, when appropriate.

For example, Old Dominion Electric Company (ODEC)/Reliant Energy was granted a license to construct and operate a 1,140 megawatt, natural gas-fired combustion turbine power plant in Rock Springs, Cecil County, within the Chesapeake Bay watershed area. PPRP conducted sophisticated deposition modeling to calculate nitrogen loading in the vicinity of the proposed site. The average, model-predicted deposition rate (in kilograms per hectare per year) in the Chesapeake Bay watershed area — approximately 21 million hectares — was used to calculate the total tons deposited in the watershed over a year due to ODEC/Reliant combustion sources.

Deposition impacts do not trigger any regulatory requirements. However, PPRP considered these levels in the context of nutrient loading goals for the Chesapeake Bay as a whole, and recommended that, as a condition to operate the new plant, ODEC/Reliant be required to plant a total of 50 acres of new forest. In response, ODEC/Reliant worked closely with the DNR Division of Forestry and PPRP to implement a successful forest planting plan using on-site and offsite forest planting and reforestation in forest gaps and riparian areas.

in the United States, and the quality of water and living resources in the Bay has been adversely affected by the contribution of nitrogen from manmade sources, including the nitrogen loading that originates from NO_x emitted by power plants.

In recognition of the atmospheric deposition issue, PPRP has begun to evaluate nitrogen deposition impacts as part of its review of new power plants proposed for development within the Bay watershed. PPRP uses sophisticated computer modeling systems to predict the incremental nitrogen deposition resulting from each new power plant. This information is then used to develop a mitigation strategy that the power plant developer can implement as part of the power plant project.

Figure 3-8
Chesapeake Bay Tributary Areas

PPRP has used the same modeling systems to investigate relative contributions of power plants in Maryland and across the eastern U.S. to nitrogen loading throughout the Bay watershed. The results of the nitrogen deposition modeling have been used with a land-to-Bay model developed by the U.S. Geological Survey (USGS), to estimate actual loading to the Bay due to nitrogen deposited throughout the watershed. Tributary teams have been formed for approximately three dozen different areas within the watershed, whose goal is to develop strategies for reducing the Bay nitrogen loading from sources within the tributary areas (these areas are depicted in Figure 3-8). PPRP is providing critically important information to the teams within Maryland and throughout the watershed to assist the teams in quantifying nitrogen loading resulting from air emissions sources, and to develop load reduction strategies that are focused on achieving the most efficient and effective actions.

Mercury Deposition

Mercury is one of several toxic substances found in significant quantities in the human food chain. Atmospheric deposition, resulting from emissions from coal-fired power plants, municipal waste combustors, and medical and hazardous waste incinerators, is recognized as an important source of mercury that enters the food chain. The amount of mercury in the atmosphere is generally thought to have remained constant through pre-industrial ages. However, with

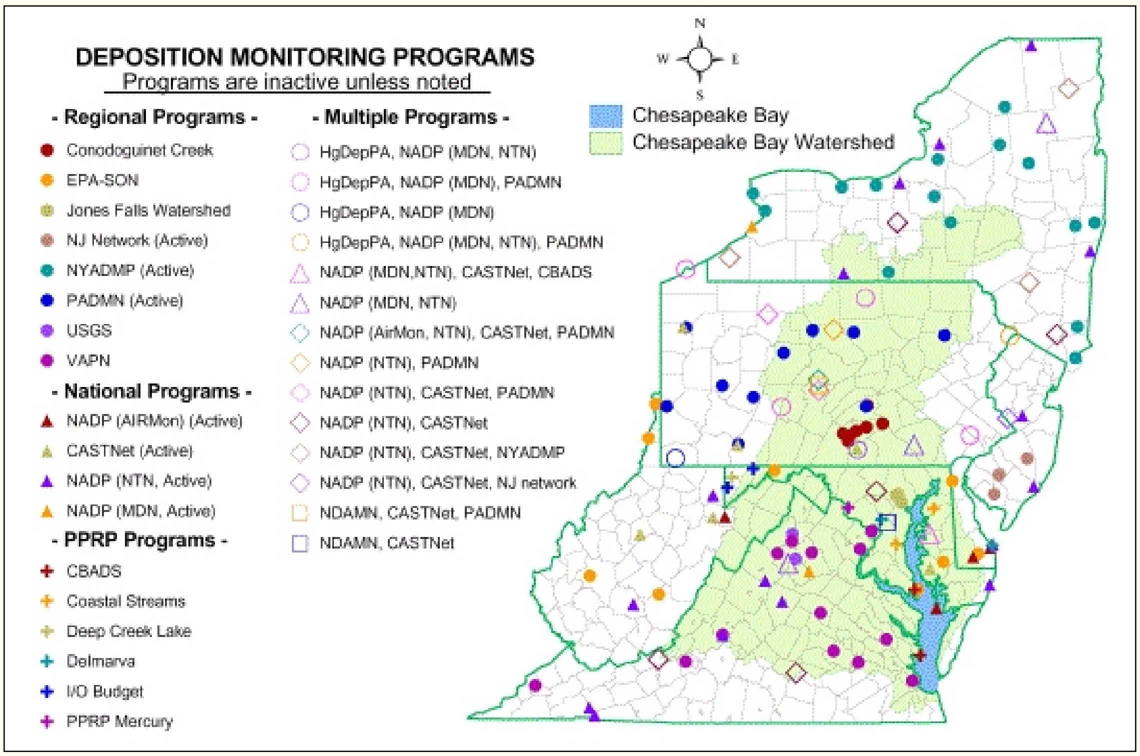
PPRP Atmospheric Deposition Measurement & Analysis Website

Over the past 20 years, numerous atmospheric deposition monitoring programs have been, and continue to be, conducted by various governmental and non-governmental organizations in the region of the Chesapeake Bay watershed. Most of these programs measured deposition of acidic substances; a few others measured deposition of toxic substances. Results of these studies are presented in annual air quality reports, reports to state agencies, masters or doctoral theses, and reports prepared by small organizations. Much of the data are available only to a small group of researchers in the field of air quality monitoring. The information may only be available in hardcopy reports, or electronically on someone's computer, which makes retrieval of important data nearly impossible.

To enable more people to gain access to this type of information, PPRP created the Atmospheric Deposition Measurement and Analysis Information Resource web site (accessible through PPRP's site, www.dnr.state.md/bay/pprp). The site is a repository for atmospheric deposition monitoring program information and data, with the focus on the Chesapeake Bay watershed. PPRP just completed a major update of the web site, making data and information from many previously unavailable studies accessible through the Internet.

Atmospheric deposition monitoring programs summarized on this web site are categorized as one of three types:

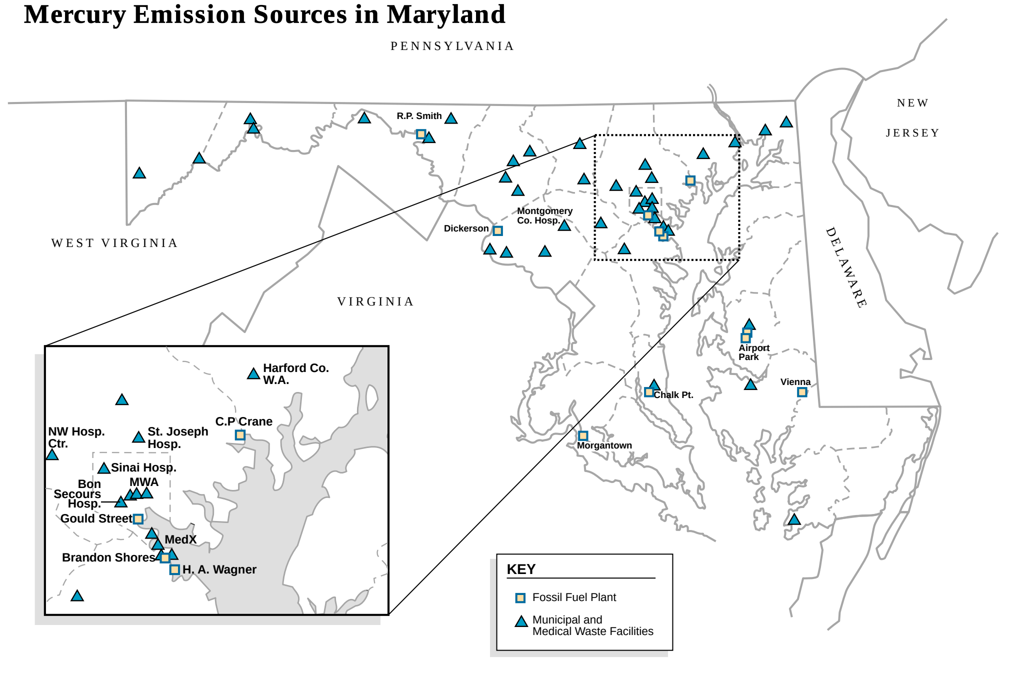
- ***PPRP-sponsored Studies —*** *State sponsored studies in and adjacent to the Chesapeake Bay that have previously been largely unavailable to the general public.*
- ***Regional Studies —*** *studies by environmental organizations, metropolitan councils, and agencies from surrounding states.*
- ***National Monitoring Programs —*** *studies by the U.S. Environmental Protection Agency (U.S. EPA), U.S. National Oceanic and Atmospheric Administration (NOAA), and other federal agencies.*



the advent of the industrial age, the amount of mercury in the environment has increased significantly.

PPRP continues to evaluate the impacts of atmospheric deposition of metals, including mercury, and other compounds to watersheds across Maryland. 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 and regionally.

Figure 3-9
Mercury Emission Sources in Maryland



PPRP has focused particular attention on mercury deposition, and has been on the forefront in developing techniques to evaluate deposition across the Bay watershed. Most recently, PPRP initiated a complex modeling evaluation to identify the sources of mercury within and around Maryland (Figure 3-9), and to estimate the quantity of mercury deposition to the Chesapeake Bay watershed from these sources. Emissions of mercury from the power plants and incinerators were modeled to predict ambient mercury concentrations, and wet and dry mercury deposition rates in Maryland and regionally. Initial work on the project has been devoted to refining the mercury emissions inventory and fine-tuning the model.

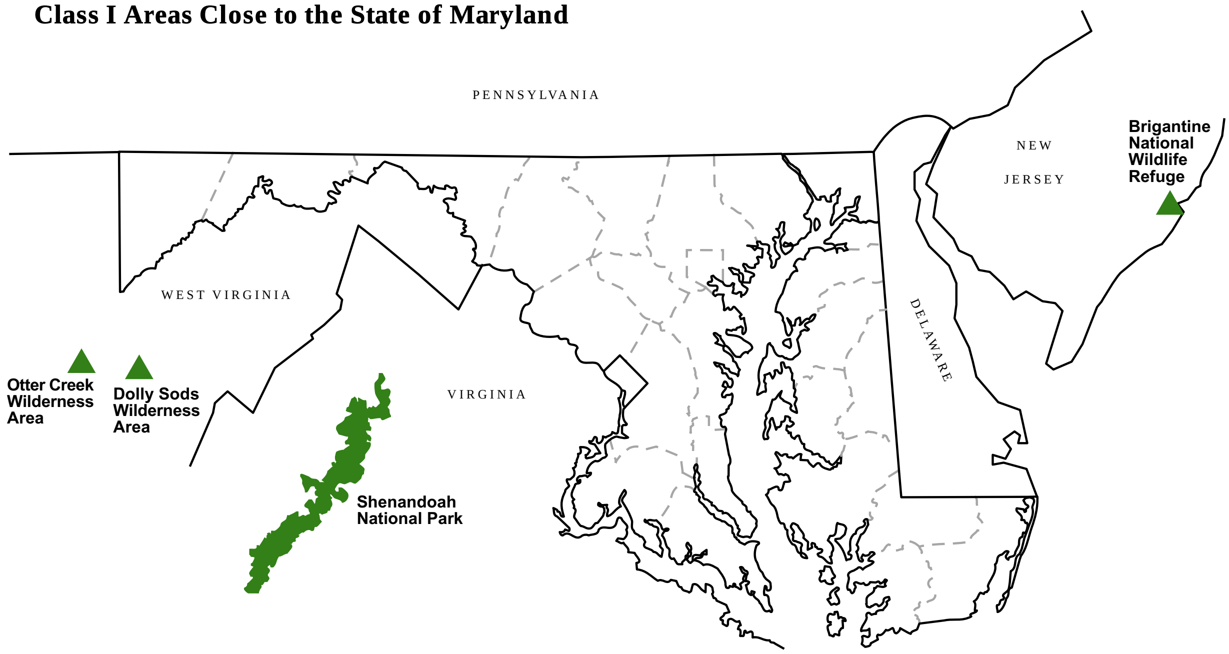
Visibility and Regional Haze

Regional haze is a phenomenon caused when fine particles in the air obscure the clarity and color of what we see. Pollutants that contribute to haze or visibility impairment — fine particulate matter or PM2.5 — can be emitted directly to the atmosphere, or develop in the atmosphere when gases form particles during transport. For example, power plants emit SO_2 and NO_x, which can be transformed into sulfates and nitrates, which are also fine particulates that affect visibility. 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. As with ozone, long-range transport is an important factor in haze formation.

Common sources of fine particulate matter include:

- *Smoke and soot from forest fires,*
- *Wind blown dust,*
- *Fly ash from coal burning,*
- *Diesel particles,*
- *Hydrocarbons associated with vehicles, power plants, and natural vegetation emissions, and*
- *SO_2 and NO_x emitted from fossil fuel combustion.*

Figure 3-10
Class I Areas Close to the State of Maryland



The Clean Air Act established visibility goals for many natural resource areas, including the Shenandoah National Park federal "Class I area." Class I areas are pristine areas, usually national parks or wilderness areas, identified by the U.S. EPA for special protection because of the value of the natural resources they encompass. The CAA visibility goals were developed to prevent any additional decrease in visibility in and around these areas where scenic vistas are important, and to improve visibility in these resource areas.

According to the National Park Service Cooperative Institute for Research in the Atmosphere, the area around Shenandoah National Park, a Class I area in Virginia close to Maryland, is reported to have had visibility in the range of 80 miles or more prior to human introduction of particulates and smog to the atmosphere. Currently, the visibility is estimated by the U.S. EPA to be only 14 to 24 miles.

One of the most difficult air quality issues in siting and licensing new power plants is the issue of visibility in nearby Class I areas. Although there are no Class I areas in Maryland (see Figure 3-10), there are several in nearby states that may be impacted by emissions from power plants in Maryland. Therefore, as part of the licensing of every new large power plant, the State evaluates the potential impacts of the proposed new power plants' emissions to ensure that they are consistent with the CAA visibility goals. In fact, visibility is proving to be one of the most difficult issues in siting and licensing new power plants. In some instances, new plants must accept restrictions on fuel oil burning during parts of the year to minimize adverse impacts to visibility.

PPRP is currently researching the effects of power plant emissions on visibility in Class I areas near Maryland. The focus of the work is on understanding the relative role of power plant emissions on visibility impacts. This work is designed to help the U.S. EPA and other organizations develop plans for controlling emissions to reduce visibility impacts in the most effective and efficient manner possible.

Global Climate

In addition to affecting atmospheric deposition, visibility, and ozone levels, power plants and other fossil fuel combustion sources can affect global climate by emitting large quantities of GHGs. Atmospheric GHGs (water vapor, CO_2, methane, etc.) trap some of the energy from the sun, creating a natural "greenhouse effect." Without this effect, ground level air temperatures would be too low to support life as it is we know it. However, this naturally occurring and beneficial greenhouse effect is enhanced by human-generated emissions of GHGs, including CO_2 from combustion sources. The enhanced greenhouse effect is projected to contribute to changes in global climate patterns, which result in such problems such as increases in global atmospheric temperatures (see Figure 3-11) and changes in precipitation, soil moisture, and sea level.

Potential Impacts from Climate Change

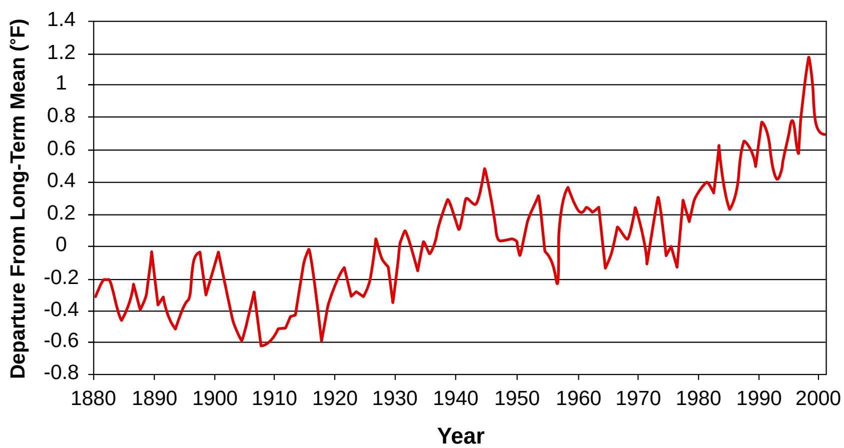
There is debate among scientists, policymakers, and others about the extent of influence on global climate from increasing emissions of GHGs. However, there is general agreement that temperature and other climate factors have been, and will continue to be, affected by enhanced greenhouse effect. Using complex global circulation models and other tools, researchers try to predict the types and magnitudes of climate changes attributable to GHG emissions. Among the many effects that might occur are:

- ***Temperature** — average overall global temperatures may rise, and perhaps more importantly, the frequency and duration of extreme hot days in different areas could increase.*

- ***Precipitation** — there may be increases in the total amount of precipitation, but more importantly, the frequency and distribution of precipitation patterns could change significantly; there could be more frequent heavy intensive rainfall in some areas in different seasons.*

In turn, these changes in temperature and precipitation can affect other climate variables, and can affect them differently in different parts of the world. Among the parameters that might be affected in different parts of the world are magnitude and rate of change of sea level rise, length of the growing season, incidence of

Figure 3-11
Estimated Global Average Temperature, 1880-2000



Source: U.S. National Climatic Data Center, 2001 flooding due to changes in precipitation patterns, and patterns of winter storms.

Although GHGs and climate change are global issues, the U.S. EPA has conducted some investigations into how changes in climate might affect resources in each of the 50 states, based on projections made by the Intergovernmental Panel on Climate Change and from climate modeling conducted at the United Kingdom Hadley Center. For example, according to information from the "State Impacts" section of the U.S. EPA's Global Climate website, the following types of climate changes could theoretically occur in Maryland over the next century:

- *Temperatures in Maryland could increase by about 3˚F in spring and 4˚F in other seasons by the year 2100;*
- *There could be an increase in the frequency and intensity of heat waves in the summertime, which could increase the number of heat-related illnesses and death, particularly in urban areas;*
- *Longer stretches of higher temperatures and strong sunlight could exacerbate ground-level ozone smog problems, again, particularly in urban areas of Maryland and metropolitan Washington, D.C.;*
- *Precipitation could increase by about 20 percent over the year, and the patterns of precipitation could change; and*
- *Sea level rise could lead to flooding of coastal areas, loss of coastal wetlands, erosion of beaches, and changes in salinity profiles and other aspects of the water quality of the Chesapeake Bay. Maryland has more than 3,100 miles of tidally influenced shoreline, which would be subject to impacts of rising sea level. Some models predict a sea level rise of 2 to 3 feet on the Eastern Shore by 2100.*

Given Maryland's diverse coastal environment, impacts of sea level rise will vary from region to region; however, shoreline erosion and coastal flooding pose a potentially significant threat to Maryland. Although sea level rise itself is not the driving force behind erosion, it makes Maryland's coastline more vulnerable to erosion. Also, elevated sea levels could exacerbate coastal flooding associated with tropical storms and hurricanes that impact Maryland's coast.

Beyond direct coastal zone impacts related to rising sea level, changing climate patterns could have dramatic effects on the environment and the economy. For example, changes in climate patterns could affect agriculture, forests, fresh water quantity and quality, ecosystems, biodiversity, fisheries, infrastructure and human health. Research is needed to determine the degree and direction of impact (i.e., positive or negative) to develop appropriate management and policy plans.

Policy and Regulatory Initiatives

There has been significant activity outside the United States in the recent past to develop GHG regulatory and policy initiatives. To date, the U.S. EPA has not moved to regulate GHG emissions on the federal level. Although CO_2 is not addressed in the Bush Administration's Clear Skies Initiative, other multi-pollutant legislation under debate considers regulating CO_2 from power plants.

Most state agencies have not yet begun to regulate GHG emissions directly, although there is increased activity in different states and regions to address GHGs. For example, the state of Maine passed a GHG emissions reduction law in May 2003 that sets specific timelines for GHG reductions, and that requires the state to develop a long-term climate action plan. In July 2003, ten states in the Northeast announced a decision to develop regional "cap and trade" programs for CO_2 emissions from power plants. Maryland is currently not among the participating states in that initiative. Many states are beginning to wrestle with difficult questions regarding how to prepare and certify GHG emissions inventories, the first step to developing workable cap and trade programs, and whether and how to implement climate action plans.

Control of Power Plant Emissions

Emissions from power plants have been, and continue to be, the focus of intense air pollution control programs and initiatives both locally and nationally. Fortunately, efforts to control power plant emissions to address one particular type of impact often coincidentally reduce other kinds of impacts as well. For example, mandated reductions in SO_2 and NO_x emissions from power plants under the CAA Acid Rain program also result in reductions in NO_x that may help alleviate ozone (since NO_x is a precursor compound for ozone formation). Further, those same reductions in SO_2 and NO_x also reduce the formation and deposition of fine particulate matter in the form of sulfates and nitrates, and thus assist in improving visibility and regional haze, and in reducing nitrogen deposition to the Bay. On the other hand, some control programs in place to alleviate ozone smog require that power plants reduce NO_x emissions only during the ozone season (May-September). These seasonal control programs may improve urban smog, but may not adequately address deposition or visibility issues.

Two pollutants in particular — NO_x and mercury — have received significant attention in recent years, are targeted for additional control requirements in the future. These pollutants are discussed briefly here.

Power Plant NO_x Control

There are a number of programs — from U.S. EPA's Acid Rain program, to state- and regional-level ozone reduction requirements, to visibility and regional haze initiatives — that have continued to require power plants to decrease NO_x emissions. One of the most stringent and complex programs requiring NO_x control for new power plants is the permitting program known as Nonattainment Area New Source Review (NA-NSR). In Maryland, because of widespread ozone smog issues, the NA-NSR program covers emissions of the two pollutants that are the primary precursors to ozone-volatile organic compounds and NO_x. Most large new fossil fuel-fired power plants in Maryland are categorized as "major" sources of NO_x under the NA-NSR regulations.

When NO_x emissions from a proposed new power plant are large enough to be considered "major" and thus trigger NA-NSR, the owner of the power plant is required to employ the most stringent level of pollution control, known as Lowest Achievable Emission Rate (LAER). LAER represents the lowest emission rate that any similar type of power plant anywhere in the world has or has

NO_x Control Technologies

There are several regulatory drivers (Acid Rain Program, NO_x SIP Call, Regional Haze, etc.) that require existing power plants and other large sources to retrofit boilers and combustion technology to reduce NO_x emissions. NO_x control can take the form of combustion controls or add-on controls. Common types of NO_x control technologies in use in Maryland and nationally (in order from least to most effective at reducing NO_x), include:

- ***Selective Non-Catalytic Reduction*** *(SNCR) is a control by which NO_x emissions in the flue gas are converted into elemental nitrogen and water by injecting a nitrogen-based chemical reagent (most commonly urea or ammonia). SNCR can generally reduce NO_x emissions by 35 to 50% without significantly affecting unit performance.*
- ***Gas Reburning*** *involves firing natural gas above the main coal combustion zone in a boiler. NO_x drifting upward from the lower region of the furnace is stripped of oxygen as the reburn fuel is combusted, leaving only molecular nitrogen. Implementation of gas reburning systems can reduce NO_x by up to about 30-60%.*
- ***Selective Catalytic Reduction*** *(SCR) uses principles similar to SNCR; however, SCR reduces NO_x to nitrogen and water using ammonia in the presence of a catalyst, and is therefore more efficient than SNCR systems. SCR is one of the most effective NO_x control technologies available, and can reduce NO_x emissions by 90% or more. The use of a urea-to-ammonia conversion process is being used at several power plants, thereby eliminating the need to store large quantities of ammonia on the plant site.*

been permitted to emit. This means that LAER is a "technology-forcing" program - each time there is an advance in the technology for controlling NO_x, the next power plant must apply that control technology, or better, to achieve the lowest emission rates possible.

In addition to applying LAER level of pollution control, new major sources subject to NA-NSR must actually show a net reduction in NO_x emissions as part of a new project. These net reductions are achieved by new plants through purchases of NO_x "offsets." An offset represents one ton of pollutant avoided when an existing NO_x source reduces NO_x emissions beyond what is required by regulations, and "banks" that pollutant reduction. New power plants subject to NA-NSR must purchase offsets at some ratio greater than 1 to 1, to achieve the net reduction in NO_x. The actual ratio depends on the level of ozone pollution is in the vicinity of the new power plant. For example, in the Baltimore metropolitan area, where ozone pollution is classified as severe, new sources subject to NA-NSR must obtain offsets at a ratio of 1.3 to 1.

Proposed new electric generating facility projects in Maryland are reviewed and licensed through the Public Service Commission's Certificate of Public Convenience and Necessity (CPCN) process. The CPCN licensing process includes air quality permitting and pollution control evaluations. All new power plants projects are evaluated to determine potential emissions and appropriate levels of required pollution control. Table 3-2 is a summary of the NO_x limits set for several power plant cases that have been completed recently or are undergoing CPCN review in Maryland.

As intended by the NA-NSR program, NO_x emission rates for proposed new power plants continue to decrease. Where a NO_x emission rate of 42 parts per million (ppm) was considered LAER for a combustion turbine just a few years ago, a similar new state-of-the-art facility would be expected to limit NO_x emissions to 5 ppm or less, representing a reduction in NO_x emissions of hundreds of tons per year.

In 2001, PPRP initiated a study to review the current state of NO_x control technologies in use at existing Maryland power plants. For the evaluation, PPRP consulted with the power plants in the state and created a plant-by-plant database of NO_x emissions control information. The database, scheduled for completion in 2003, includes:

- ***Current NO_x control technologies:*** *A review of NO_x control technologies that are commercially available for fossil power plants;*
- ***Status of NO_x control at Maryland power plants:*** *Detailed descriptions of the NO_x controls and systems installed at existing Maryland power plants, including information on reductions in emissions resulting from those controls; and*
- ***Review plans for future control of NO_x emissions:*** *Information on future plans for reducing NO_x emissions at Maryland power plants, including plans for retrofitting or upgrading controls or operating techniques.*

Table 3-2 NO_x Limits in Recent New Power Plant Projects in Maryland

Power Plant	Location	Size (megawatts)	Generating Technology	NO_x Limit*	NO_x Control Technology
Simple Cycle Combustion Turbine Projects					
Licensed:					
ODEC-Rock Springs	Cecil County	1,140 MW	Six natural gas, simple cycle combustion turbines	9 ppmvd on natural gas; 42 ppmvd on fuel oil	Advanced dry low NO_x combustors
Proposed:					
Mirant-Chalk Point	Prince George's County	340 MW	Four natural gas / No. 2 fuel oil simple cycle combustion turbines	9 ppmvd	Dry low NO_x technology
Combined Cycle Combustion Turbine Projects					
Licensed:					
Free State-Kelson Ridge	Charles County	1,650 MW	Six natural gas, combined cycle combustion turbines	2.5 ppmvd	Dry low-NO_x combustors with selective catalytic reduction (SCR)
Proposed:					
Mirant-Dickerson	Montgomery County	406 MW**	Two natural gas, combined cycle combustion turbines	3.5 and 4.5 ppmvd	Dry low-NO_x combustors with SCR

* ppmvd = parts per million by volume on a dry basis

** The proposed Dickerson project includes two existing simple cycle CTs to be converted to combined cycle, and two new CTs; the NO_x limit is lower for the newer, inherently lower-emitting CTs

Power Plant Mercury Control

Mercury — its emissions, control, fate, and effects — is one of the most pressing environmental issues facing power plants, particularly coal-fired power plants, in the U.S. and internationally. The recent Bush Administration Clear Skies Initiative and other multi-pollutant legislation that Congress may address in 2003 focus on mercury.

Mercury, and many other metals, are present in trace amounts in coal. When burned in boilers to generate electricity, trace metals are released from the coal into the air. Most metals are released in the form of particulates, and can therefore be easily controlled by traditional particulate control technologies such as fabric filters (also known as "baghouses"). Unlike other metals, mercury has unique physical and chemical properties that allow it to be present in flue gas as both a vapor and in particulate form, which makes mercury control much more difficult.

EPA is scheduled to propose standards requiring utility sources to control mercury and other hazardous air pollutants by January 2004, so power plants in Maryland and across the country are beginning to evaluate potential mercury control technologies suitable for retrofitting on existing boilers. Mercury can be controlled through process modifications and add-on control technologies. Examples of some control technologies potentially available for retrofit on boilers are described below.

- ***Coal cleaning*** *can be used to remove impurities in the coal, thereby reducing concentrations of many trace elements including mercury. Some coal cleaning methods use mechanical devices, such as pulsating water or air currents to remove impurities, and "dense media washing" to separate impurities from coal.*
- ***Activated carbon injection control technology*** *has been used to remove mercury from municipal waste combustor exhaust streams; however, the technology must be*

refined to be effective with utility boiler flue gas streams because of the differences in the amount and composition of the flue gas. Utilities produce small concentrations of mercury in a large volume of flue gas, thus requiring large amounts of activated carbon to provide adequate mercury control. Studies are being conducted to identify methods to improve mercury removal in utility gas streams.

- ***Wet flue gas desulfurization*** *(FGD) scrubber systems are currently in use at some large power plants to remove SO_2 emissions, but they also remove mercury. Similar to activated carbon injection, the efficiency of wet FGD systems to remove mercury varies with the type of coal in use.*

Several new control technologies are being investigated for mercury removal, including:

- *Using a regenerable sorbent to recover liquid elemental mercury from the flue gas. In this process, mercury is removed from the flue gas and converted to liquid elemental mercury, which can then be removed and disposed of properly;*
- *Developing an integrated flue gas treatment system based on heat exchanger technology, which recovers waste heat while removing SO_2, and trace elements, including mercury, from coal combustion flue gas; and*
- *Combining limestone injection with dry scrubbing to achieve high efficiency SO_2 particulate and trace element emissions control.*

Control of Pollutants Contributing to Regional Haze

The U.S. EPA recently established federal regional haze regulations (in 40 CFR Part 51, Subpart P) that affect all states. The goal of the regulation is to control fine particulate matter to remedy existing impairment of visibility in federal Class I pristine areas such as Shenandoah National Park, and establish procedures for new sources to ensure future visibility goals are met.

One important aspect of the regional haze regulation is the requirement for states to develop Best Available Retrofit Technology (BART) regulatory control programs to reduce fine particulate matter emissions. To implement BART, each State must first develop a list of all BART-eligible sources within the state. Once eligible sources are identified, the State must make a case-by-case determination of what constitutes BART for each source. In making this determination, the States review available control technologies, determine the cost of different control strategies, evaluate energy and other (non-air quality) environmental impacts of different control strategies, review pollution control equipment currently used at the source, and consider the useful life of the source. Finally, the State must look collectively at the controls to be implemented by BART-eligible sources, and determine the degree of regional visibility improvement that would be achieved as a result of implementing the new controls.

Once BART plans are developed, sources must implement BART as quickly as practicable, but no later than five years after approval of the implementation plan. BART programs will target older (pre-1977) power plants that are relatively large sources of visibility-impairing pollutants such as PM, NO_x, and SO_2. In Maryland, older coal-fired power plant units at Chalk Point, Morgantown, Dickerson, C.P. Crane, and H.A. Wagner, as well as the oil-fired Vienna power plant, will likely be subject to BART.

Control and Mitigation of Power Plant CO_2 Emissions

There are few proven post-combustion pollution technologies or systems available to control CO_2 emissions directly. However, as discussed previously, GHG emissions, and CO_2 in particular, are directly related to the amount of fuel burned in (or electricity generated by) fossil-fuel fired combustion units. Using other energy resources besides fossil fuels — such as wind, solar, nuclear, and hydroelectric — is one method for reducing CO_2 emissions. Other mitigation options include reducing CO_2 emissions through improved energy efficiency (reducing the amount of fuel burned), or "sequestering" and then disposing of or reusing the CO_2 elsewhere.

Carbon sequestration is the term used to describe the long-term storage of carbon in the terrestrial biosphere, underground, or in the oceans to mitigate the buildup of CO_2 in the atmosphere. Sequestration occurs naturally, such as when trees and other plants take up CO_2 in the atmosphere. Depending on how the plant materials are managed, the carbon may then be stored in a variety of inert and harmless forms.

Researchers at the Department of Energy and elsewhere are investigating ways to enhance natural sequestration processes, and also to identify and consider new techniques to sequester and manage carbon. Among the carbon management techniques being investigated are sequestering carbon in underground geologic repositories and injecting CO_2 into the oceans at great depths (greater than 1,000 meters).

There is considerable interest in Maryland in evaluating the potential for maintaining and enhancing natural processes (through agriculture, forestry, and land use management) to capture and sequester some portion of the state's CO_2 emissions. In this context, PPRP has been studying which carbon sequestration methods would be most effective for mitigation of power plant emissions.

Biological Sequestration to Mitigate Carbon Emissions

The upper limit for carbon sequestration in an area is set by the rate at which plants incorporate atmospheric carbon into biomass (carbon fixation), which is largely determined by land use. The fixed carbon can be sequestered in biomass and soil carbon reservoirs, or returned to the atmosphere through the decay of dead plant material. Maryland's carbon fixation rate, or Net Primary Productivity (NPP), is dominated by just a few land use types:

- *Forests (combined deciduous, evergreen, and mixed forest classes) account for almost 48% of the annual carbon fixation;*
- *Wetlands (woody and herbaceous), over 15%;*
- *Agriculture (pasture/hay and row crops) accounts for another 25%; and*
- *Other land use types, less than 12%.*

Forests, wetlands, and agricultural areas, therefore, offer the best opportunities for carbon sequestration. At the present time, models indicate that natural biological sequestration is concentrated in forested areas in Western and Southern Maryland, and in the large wetlands of the Eastern Shore. It is estimated that these areas (combined) permanently sequester 10.6 million metric tons (MMT) of CO_2 each year, or about 20% of the NPP.

There are three categories of management options that are available to managers who are interested in increasing carbon sequestration rates:

- ***Protecting and preserving areas that already have high current sequestration rates or large soil carbon storage reservoirs.*** *This would apply to wetlands, which are assumed to be storing carbon at a maximum rate already, and to some forest areas that have deep, carbon-rich soils;*
- ***Improving net sequestration by changing management practices.*** *This option can apply to both forest and agricultural land management. Frequent timber harvesting and reforestation can maximize growth and carbon fixation. Sequestration is achieved by using the harvested trees for long-lived wood products. Another version of this method is to replace existing trees with genetically improved varieties or species with higher sequestration rates. For example, a switch from hardwood to softwood can increase the sequestration rate by almost 40 percent. There are also hardwood species such as red maple or yellow poplar that have higher growth rates (and therefore, sequestration rates) than many other tree species. While such substitutions may increase sequestration, it is important to be aware that undesirable changes in the ecosystem may result. Agricultural management practices that increase soil carbon storage, such as no-till farming and using winter cover crops, can also improve carbon sequestration rates; and*
- ***Changing the use of a parcel of land to a type that has a higher sequestration efficiency.*** *This applies primarily to agricultural areas that currently underutilized or degraded. Restoration of drained wetlands could also be highly effective if done properly. Another option is to convert areas with degraded soils to managed woodlands and forests, with the hope of not only sequestering carbon through long-lived wood products, but also through improved soil carbon storage.*

These practices, if implemented throughout the state, have the potential to improve Maryland's carbon sequestration rate by as much as 70%. In many locations, pursuing opportunities to enhance carbon sequestration by these methods will also have other environmental benefits. Reforestation of degraded lands or restoration of wetlands, for example, can control soil erosion, improve water quality, and add habitat value. Where these activities augment or buffer existing environmental preserves, they can reduce habitat fragmentation and allow greater biodiversity.

Much groundwork consistent with these strategies has already been completed by Maryland's Green Infrastructure program. Many of the existing high sequestration areas have been incorporated into the program or identified for future preservation. Areas have also been identified that would expand and protect these key areas and / or create ecological links between them. These expansion areas may be good candidates for carbon sequestration management or land use conversion. At a statewide level, maps of the Green Infrastructure areas provide a first pass screening of areas where carbon sequestration programs might be useful and productive.

At a more local level, much additional work is required to build an effective carbon sequestration program. It is necessary to develop a methodology for targeting local areas for preservation, management, or conservation. To evaluate cost and effectiveness, an enhanced modeling tool could be developed. Finally, protocols to measure, monitor, and verify carbon sequestration projects must be developed. PPRP is continuing to develop its carbon sequestration research in these directions.

Water Impacts

Aquatic resources can be significantly affected by the generation of electricity. The withdrawal of water for cooling and other uses at steam generating power plants, and the operation of hydroelectric facilities, alter the natural conditions of surface and ground water resources. Such changes may impact aquatic life as well as other users of the water. The following sections discuss the volume of water used in Maryland for power plant operation, the potential resource impacts resulting from that use, and methods for minimizing any adverse impacts.

SECTION HIGHLIGHTS

The withdrawal of water for cooling and other uses at steam electric facilities represents the majority of surface water usage in Maryland. The U.S. EPA is developing regulations to minimize the ecological impacts of large surface water withdrawals. PPRP is evaluating the potential impacts associated with such water use by Maryland's generating facilities.

Cooling Water Withdrawal and Consumption

Most electricity is produced in Maryland by four broad types of generating technologies: steam-driven turbines, combustion turbines, combined cycle facilities (a hybrid 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. This cooling water is generally supplied from surface water, while the other water needs of the power plant (typically much smaller in quantity) are met by on-site ground water wells or municipal water systems. (See discussion of ground water impacts on page 49.)

Table 3-3 lists all steam generating power plants in Maryland (excluding self-generators) and quantifies their water withdrawals and consumption. Most steam plants in Maryland use once-through cooling, in which cooling water is continuously drawn from a water source, used, 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 varies from 0 to 2.5 percent of the discharge volume, with an average of about 0.6 percent during the summer and 0.5 percent during the winter. Based on ICPRB's data, an estimated 30 mgd of water is lost to evaporation as a result of thermal discharges from Maryland power plants. 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.

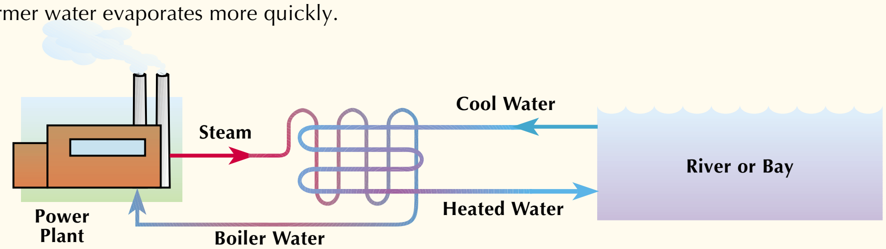
Several steam power plants in Maryland — AES Warrior Run, Brandon Shores, Panda Brandywine, and Vienna — use closed-cycle cooling (cooling towers) instead of once-through cooling. (Chalk Point uses both once-through and closed-cycle cooling.) Closed-cycle systems recycle cooling water and require the use of less than one-tenth of the water needed for once-through cooling; however, 50 to 75 percent of the water evaporates from the tower and, therefore, does not return to the source. The steam generating facilities that use cooling towers are responsible for a total consumptive loss of about 19 mgd, about 3 mgd of which represents freshwater losses arising from AES Warrior Run and Panda Brandywine. These evaporative losses associated with cooling towers are in the same range as freshwater losses caused by heated discharges from once-through cooling systems.

Cooling water withdrawals at steam electric facilities represent the majority of surface water usage in Maryland. Combined water withdrawal for all steam generating power plants in Maryland is 7.8 billion gallons per day (see Table 3-3). All other non-power plant users in the state have a combined appropriation of 3.4 billion gallons per day. By comparison, the Potomac River has an average discharge of roughly 7 billion gallons per day, and the Susquehanna River discharge averages about 23 billion gallons per day, although actual daily flows fluctuate greatly over the year.

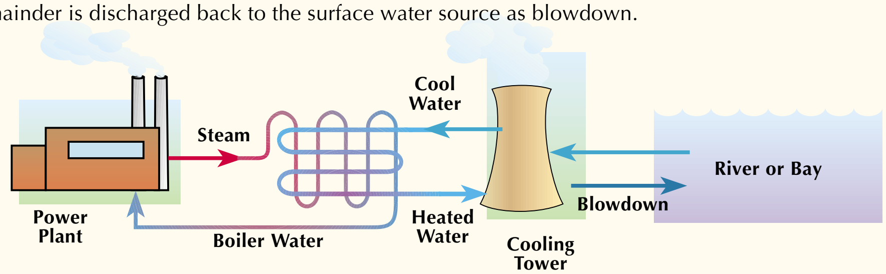
Nuclear power plants fall within the steam generating category; however, they use nuclear reactions instead of fossil fuel combustion to create the thermal energy. Nuclear facilities generate more waste heat than fossil fuel-fired plants of the same capacity, and require 10 to 30 percent more cooling water to produce the same energy, according to data from the U.S. Nuclear Regulatory Commission. Maryland has one nuclear power plant operating on the western shore of the Chesapeake Bay, Calvert Cliffs, which withdraws an average of 3 billion gallons per day from the Bay. This is the largest single appropriation of water in the State of Maryland, 12 times more than the municipal supply for the Baltimore City metropolitan area of 250 million gallons per day.

Once-Through vs. Closed-Cycle Cooling

In **once-through cooling**, water is drawn continuously from a bay or river to cool the power plant's condensers (that portion of the plant where steam is condensed to water and recycled to the boiler). Power plants with once-through cooling withdraw very large amounts of water, then return water to the bay or river at elevated temperatures. About 0.5 percent of the water is consumed because the warmer water evaporates more quickly.



In **closed-cycle cooling**, a much smaller amount of water is withdrawn, compared to once-through cooling, and the water is recirculated several times within a cooling tower. But closed-cycle cooling systems consume more water resources than once-through systems by evaporating the water. As much as half of the water withdrawn for cooling tower use is consumed by evaporation. The remainder is discharged back to the surface water source as blowdown.



The primary types of closed-cycle cooling towers include the natural draft design — large hyperbolic structures like those at the Chalk Point Power Plant (see photo at left) — and smaller mechanical draft systems like the cooling towers at Panda Brandywine (right).

Table 3-3 Surface Water Appropriations and Use at Maryland Power Plants with Steam Cycles

Power Plant	Surface Water Appropriation (average, mgd)	2001 Actual Surface Withdrawal (average, mgd)	Estimated Consumption (mgd)[1]	Water Source
Once-through Cooling				
BRESCO	62.2	22	0.12	Patapsco River
Calvert Cliffs	3500	3200	17.4	Chesapeake Bay
Chalk Point[2]	720	570	2.3 (once-through portion) 10 (evaporative loss from cooling towers)	Patuxent River
C.P. Crane	475	345	2.4	Seneca Creek
Dickerson	400	359	1.5	Potomac R. (non-tidal)
Gould Street	75	24	0.05	Patapsco River
Morgantown	1500	1226	2.6	Potomac River
Riverside	40	3	0.03	Patapsco River
R.P. Smith	70	43	0.5	Potomac R. (non-tidal)
H.A. Wagner	940	736	4.2	Patapsco River
Closed-cycle Cooling				
AES Warrior Run	3.0	1.9	1.75	City of Cumberland
Brandon Shores	35	12	6	Patapsco River
Panda Brandywine	3.0	1.5	1.0	Mattawoman WWTP
Vienna	2.4	0.35	0.23	Nanticoke River
TOTAL	**7,826**	**6,544**	**50.2**	

[1] 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 720 mgd appropriation covers all four steam units.

Low-Flow Issues

In the nontidal portion of the Potomac River, new consumptive users of water (such as power plants with large cooling water needs) must comply with Maryland's Consumptive Use Regulations for the Potomac River Basin (COMAR 26.17.07). 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 support aquatic life and to provide municipal water supply to the Washington, D.C., metropolitan area. (Ecological and biological effects of water usage are addressed later in this chapter.)

The Consumptive Use Regulations require that users consuming 1 mgd of water from the Potomac River must maintain low flow augmentation storage to offset their consumption. Alternatively, users can comply with the rules by reducing consumptive use to less than 1 mgd during low-flow periods. 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. 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 CPCN licensing process incorporates the water appropriations permit for new power plants in Maryland. Therefore, PPRP works closely with MDE Water Resources Administration when reviewing any proposed new power

Dry Cooling

Dry cooling towers have been utilized in areas of the country - and around the world - where water is in critically short supply. In Maryland, dry cooling is part of the design for the proposed Kelson Ridge power plant in Charles County (licensed in 2002) and for Dynegy's proposed facility in Frederick County (for which an application has not yet been formally filed).

In dry cooling, large quantities of air are drawn by fans through the tower where sensible (non-evaporative) heat transfer occurs between the steam cycle condenser and the ambient air by direct contact. This arrangement is analogous to a car radiator. Dry cooling does not consume water, it generates no visible plume, and there is no water discharge.

Large fans are needed to move the substantial volume of air that must be drawn across the condensers. This typically results in a larger tower footprint (about twice as large) compared to wet towers designed for similar sized power plants. Noise propagation from powerful tower fans must be evaluated on a case-by-case basis; noise mitigation structures can be employed if necessary.

Fan power requirements (i.e., the amount of power generated by the plant that must be consumed to run the tower fans) reduce overall power output, just as with mechanical draft wet cooling towers. Furthermore, because dry towers rely only on the sensible transfer of heat to the atmosphere, less net power is available on hot days. This is a disadvantage for meeting summertime peak electricity demands and can result in output reductions up to 10 percent.

plant to ensure that the facility design complies with consumptive use regulations.

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 the U.S. EPA's newly promulgated regulations under the Clean Water Act Section 316(b), which target ecological effects of cooling water withdrawals (see section on Impacts to Water Quality and Aquatic Biota, page 52). 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 million gallons per day of treated effluent from the Mattawoman WWTP. A recently proposed plant, Free State-Kelson Ridge, also incorporated WWTP effluent reuse in its facility plans. 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.

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, this option has been proposed at the Kelson Ridge and Dynegy sites. As appropriations for cooling water become more restricted, dry cooling becomes more attractive.

Recently proposed power plants in the freshwater portion of the Potomac River watershed have incorporated on-site water storage as a contingency against low flow restrictions. A 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. PPRP has addressed this issue in recent licensing cases by recommending that developers incorporate significant on-site water storage to ensure that generating capacity remains available to Maryland customers under most drought conditions.

Ponded mine water is another potential source of water that has been identified, particularly for any future generating facility in Western Maryland. Abandoned underground coal mines in the Appalachian region contain billions of gallons of water, much of which is acidic because of the geologic nature of the coal beds that supported the mines. Pumping that water to the surface and treating it to prevent cooling system corrosion could provide a cost-effective and environmentally preferable alternative to tapping the upper reaches of the Potomac River. Use of mine water would prevent any aquatic impacts associated with a direct withdrawal of cooling water, and it would reduce the amount of acidic water that drains into the Potomac and its tributaries from abandoned underground mines.

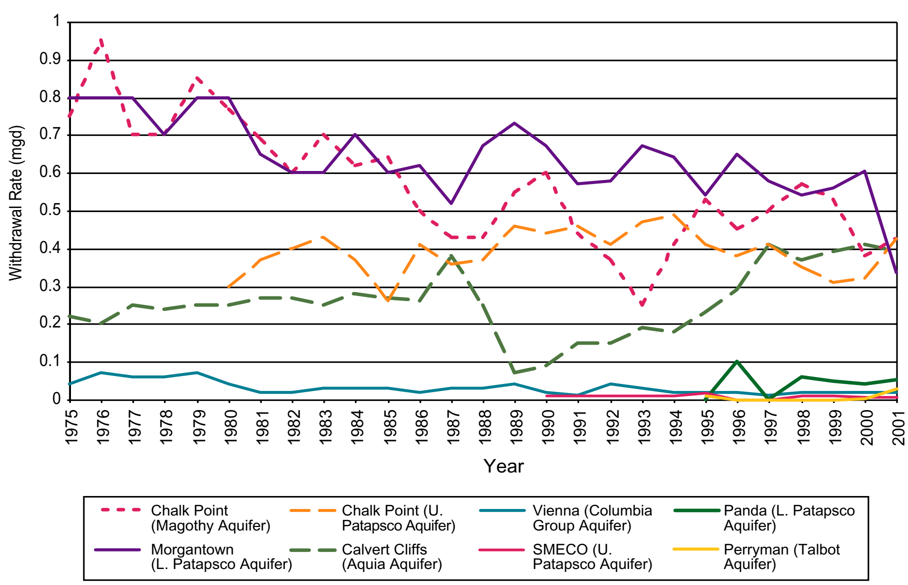
PPRP recognizes the increasingly sensitive issue of water appropriation for power plant use, and supports research and development in the areas of alternative cooling methods and environmentally beneficial water use. New power plant proposals in Maryland will continue to be subject to strict CPCN conditions regarding water use, given the increasing water demands across the state.

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. 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 is 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

Figure 3-12
Average Daily Ground Water Withdrawal Rates at Maryland Power Plants



coastal plain aquifers for plant operations. These plants include: Constellation's Calvert Cliffs Nuclear Power Plant (CCNPP) 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 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, is now operating and has been authorized to withdraw 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. Figure 3-12 shows the ground water withdrawal rates of each of the seven power plants from 1975 to 2001, expressed as daily averages; the rates are also listed in Table 3-4. The power plants typically withdraw amounts of water well below their appropriation permit limits. The average withdrawal for all seven power plants in 2001 was 1.8 mgd compared to a combined daily appropriations limit of 2.8 mgd.

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

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 below for an illustrated example).

Upper Patapsco Aquifer at Chalk Point

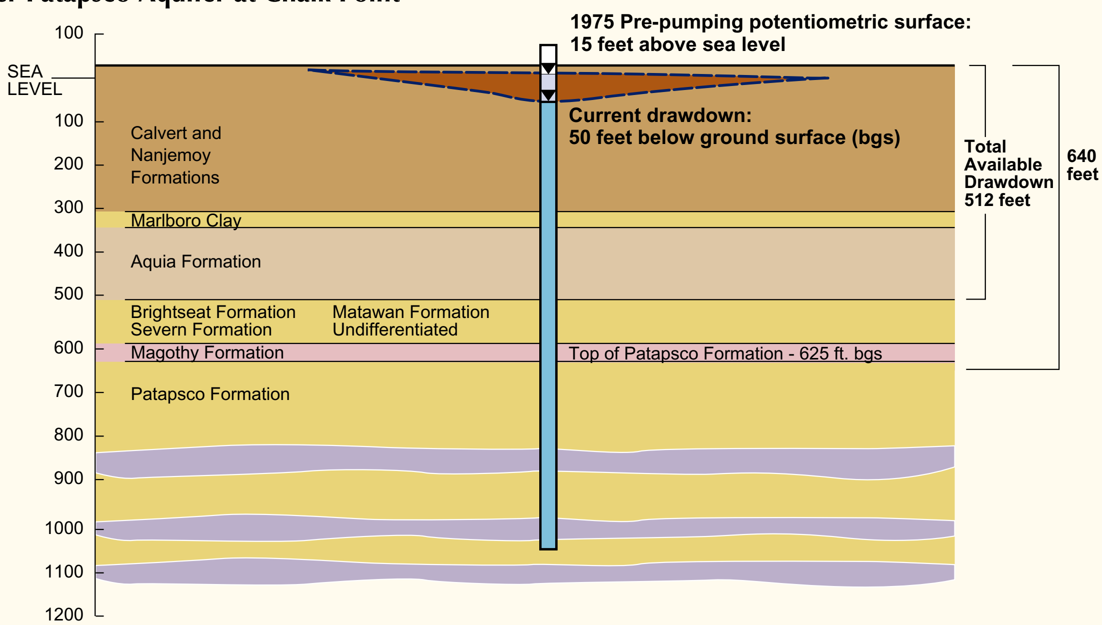


Table 3-4 Average Daily Ground Water Withdrawal Rates at Maryland Power Plants (in mgd)

	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

* Panda was granted a higher appropriation during construction of its pipeline for conveying treated effluent.
Source: U.S. Geological Survey

of ground water. MDE's Water Management Administration, 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.

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 historic pre-pumping level in the 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 60 feet over the period 1982 to 2001, 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 10 feet since 1997 and approximately 100 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 2001 by about 40 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 2001 has been approximately 30 feet, and a total of about 60 feet since pumping at Chalk Point began in 1964. The elevation of the potentiometric head in the Magothy Formation in 1962 prior to pumping was 28 feet above mean sea level; thus the available drawdown is 80 percent of 600 feet plus 28 feet or 500 feet. Consequently, the total drawdown of 60 feet is small compared to the total available drawdown estimated to be about 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 17 feet at Chalk Point between 1990 and 2001. Recent measurements indicate drawdown of nearly 50 feet between 1975 and 1999 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 30 feet between 1990 and 2001. Since 1997, water levels in the vicinity of the Morgantown power plant have remained constant.*

Impacts to Water Quality and Aquatic Biota

Other than a small segment in western Maryland that is in the Youghiogheny River watershed (Ohio-Mississippi drainage) and small estuarine water bodies of Atlantic Shore (the Chincoteague watershed), the bulk of Maryland's drainage system is to 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 geographical area and encompass a broad range of aquatic habitat types, including marine, estuarine, and freshwater streams and lakes.

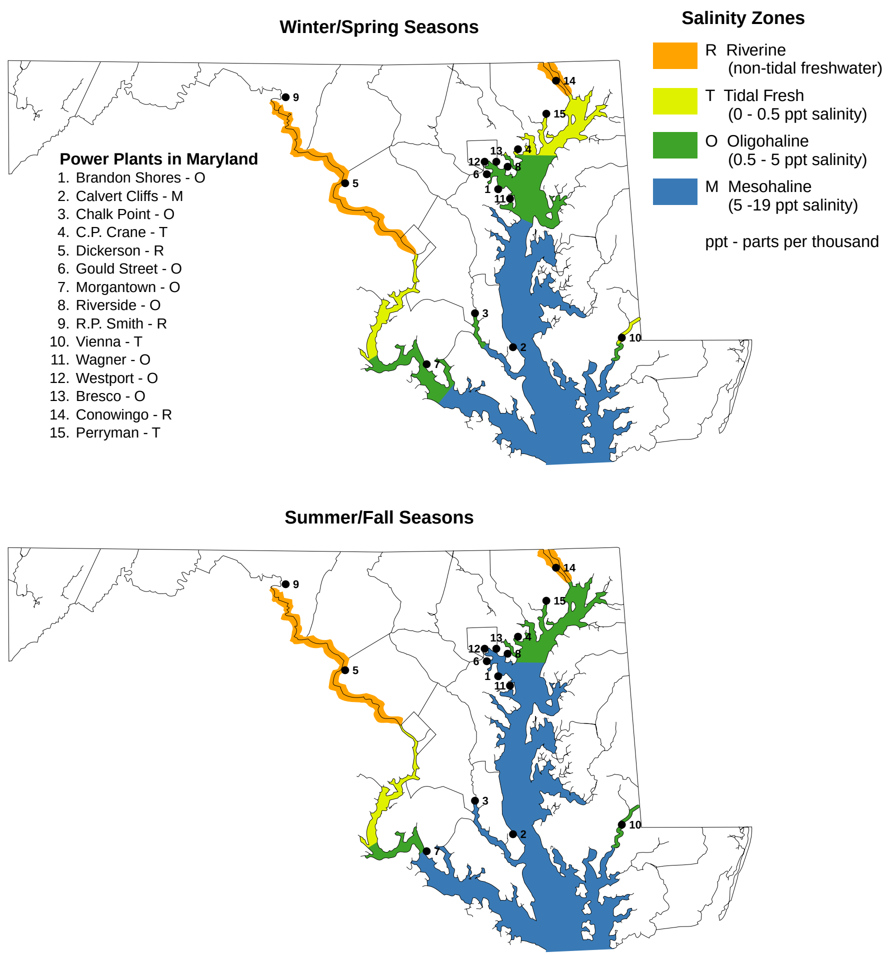
All steam electric power plants in Maryland are located in the Chesapeake Bay watershed (see Figure 3-13). As can be seen, the power plants occupy various physiographic and habitat types, including upland, riverine, and estuarine.

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

Water usage and the resulting environmental impacts have been monitored by various agencies and organizations, and 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 blended 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 depends on 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. Although all facilities are required to ensure that impacts are kept to a minimum, the Maryland Department of the Environment (MDE) issues NPDES permits, in accordance with the Clean Water Act, and uses aquatic impact assessment data to ensure 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 gamefish hatcheries, from which fish are released to the natural ecosystem under the direction of Maryland DNR. Other enhancements include establishment of funds to remove obstructions to anadromous fish migration caused by low-head dams that are no longer used. The types of impacts identified by PPRP and the steps that have been

Figure 3-13
Salinity Zones of the Maryland Chesapeake Bay



New EPA Regulations for Power Plant Cooling Water Withdrawals

As a result of a lawsuit by environmental groups, EPA is currently developing new regulations under the Clean Water Act Section 316(b). These new regulations may be of great significance to power plant owners and electricity consumers in Maryland. Section 316(b) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. There are 12 existing power generating facilities in Maryland that have permits allowing for cooling water withdrawals and thus would potentially be covered by the new rule. During the development of the new 316(b) rules, Maryland has provided and will continue to provide comment on these and other issues that are of particular importance to the State's resources:

- *the manner in which cumulative impacts should be evaluated,*
- *how ecosystem-level impacts should be accounted for,*
- *whether restoration measures should be considered only as a supplement to technology or operational measures or as compensation for adverse impacts of the cooling water system, and*
- *the manner in which economic costs and benefits of intake modifications should be assessed.*

Once EPA's rules are finalized (expected in early 2004), PPRP will assist MDE in revising the State's regulations applicable to cooling water intakes so that they are consistent with the new federal regulations.

taken to minimize and mitigate these impacts are discussed in greater detail below. Once the U.S. EPA finalizes its Section 316(b) regulations (see sidebar), the impacts associated with cooling water withdrawals in the state may need to be re-evaluated for regulatory compliance.

Direct Withdrawal Impacts: Entrainment, Impingement, and Entrapment of Organisms

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

- ***entrainment** — drawing in of plankton and larval or juvenile fish through plant cooling systems;*
- ***impingement** — trapping of 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, including magnitude of and consequences to the State's aquatic resources, 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 impacts, taken together, have no significant consequence to Maryland's aquatic resources.

Although entrainment losses for aquatic organisms have been measured, they do not reveal consistent depletions of populations. However, because impacts occur, mitigation is implemented by various power plants, such as modifying power plant operating procedures and constructing on-site hatchery facilities for fish stocking operations. Other measures include providing funding to remove blockages to migratory fish, developing improved intake technologies and other modifications to reduce entrainment or impingement impacts.

PPRP has conducted follow-up investigations of several intake technologies, several of which showed a benefit; therefore, the design of facility intake structures must incorporate some or all of the following characteristics:

- ***Installing physical barriers —*** *Screens or nets are most successful and economical for reducing both entrainment and impingement; wedge-wire screens keep entrainment low and almost eliminate impingement.*
- ***Collecting and releasing organisms after impingement —*** *Partially effective at reducing impingement losses; some of the collected organisms, particularly those in early life stages and juveniles, are sensitive to handling and abrasion, and if they are returned to the receiving water body near the intake structure, they may be susceptible to re-impingement. Considering this, the Morgantown power plant redesigned its system to return fish to the side of the intake structure flowing away from the plant (depending on the direction of the tide). Similarly, the fish return system installed at the Wagner power plant places impinged fish into a channel leading away from the intake screens.*
- ***Modifying intake screen wash cycles —*** *Intake screens are rotated at various intervals which does not alter the rate of impingement but does reduce the time organisms are exposed to scavengers and anoxic conditions.*
- ***Discontinuing the use of auxiliary tempering pumps —*** *Auxiliary pumps are used to withdraw surface water to mix with the plant's discharge water to lower the temperature of the discharge water (Pepco's Chalk Point plant was the only Maryland station which used this approach). The auxiliary pumping causes additional entrainment and impingement of aquatic organisms. Studies showed that, without this mixing, the water discharge temperature difference did not significantly increase downstream mortalities).*

Because there have been no major modifications in the intake systems of power plant facilities since PPRP conducted its detailed entrainment and impingement studies in the 1970s and 1980s, no additional studies have been performed. Depending on the outcome of the Section 316(b) rules for new and existing facilities, additional entrainment and impingement studies and measures could be required.

Cooling Water Discharge Impacts

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

Thermal Changes

Biological impacts from heated effluents depend upon the magnitude and duration of the temperature difference. Small organisms that pass through a plant's cooling system experience the greatest temperature stress, both in magnitude and duration. Organisms in the receiving waters are more likely than entrained organisms to experience smaller increases in temperature and shorter duration of exposure due to the dispersion of the thermal plume and the 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 the aquatic biota occupying the different habitat types within Maryland waters differ dramatically, study results are presented here according to the habitats within which the plants are located. 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 very localized and are not considered significant. No cumulative adverse impacts to the habitats nor to the Chesapeake Bay ecosystem have been identified; 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 discharge into tidal fresh and oligohaline waters: Vienna and C.P. Crane. The PPRP studies showed that the thermal plume at Vienna was small and 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 did not affect nearfield dissolved oxygen.

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

***Nontidal Freshwater Habitat* —** Only R.P. Smith and Dickerson are located on nontidal riverine habitat in Maryland. Impacts of the thermal discharges of the Dickerson and R.P. Smith plants on the Potomac River ecosystem were 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 did have an adverse impact on benthic communities in the immediate area of the discharges, the effects were localized, such that the affected percentage of the total river bottom within the portion of the river on which the two plants are located is very small. To assess whether these localized impacts on benthic communities may be affecting fish populations within the river, the NPDES 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 to the benthic communities that had been documented in the long-term benthic study.

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 also 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 posed a potential risk to the health of individuals who might consume the contaminated oysters. While no immediate health threat existed, PPRP recommended that the power plants replace the copper condenser tubes with titanium tubes at power plants 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 permits for all power plant discharges include maximum discharge levels for copper (as well as other metals) that are protective of human health and the environment.

Chlorine — This substance is used by power plants to control bio-fouling of condenser tubes in cooling water systems. In that it is an effective means of controlling biological organisms within the cooling system, it can cause mortality to aquatic biota. Presently, the NPDES permits for all power plants in Maryland require that no detectable levels of chlorine be discharged into the state's waters (i.e., concentrations must be below the detection limit of 0.1 mg/l). Compliance with this permit requirement has been achieved through use of alternative control technologies and through de-chlorination of cooling water before it is discharged into the receiving water body. As with copper discharges, chlorinated discharge impacts are now considered resolved and no further action is needed.

Stream Flow Volume Reductions

In response to multiple power plant proposals potentially impacting the Potomac River, PPRP developed worst-case scenarios where proposed new plants were added to the set of plants currently withdrawing water from the non-tidal region of the Potomac River. These scenarios assessed the effects that the multiple withdrawals would have on the river stage (i.e., depth of water at a particular location) and habitat in the Potomac River. PPRP considered the potential cumulative effects of the Dickerson expansion in western Montgomery County, plus up to two new facilities withdrawing Potomac River water, based on the level of interest that power plant developers have shown in that area of Maryland.

The three potential facilities were estimated to withdraw an additional 30 mgd from the river, of which 24 mgd would be consumed. The volume loss was estimated based on the maximum consumptive use from three additional closed-cycle power plants and the potential impact evaluated for a point in the river where the river stage is monitored.

Changes in river stage due to increased water loss are based on the stage-discharge relationships established by the U.S. Geological Survey (USGS) for

Table 3-5 Change in River Stage from Three Hypothetical Additional Power Plants Upstream of Point of Rocks

	Gaging Station					
	Point of Rocks (USGS 01638500) Rating Table No. 24			Little Falls Dam (USGS 01646500) Rating Table No. 8		
Parameter	Before Withdrawal	After Withdrawal	Reduction	Before Withdrawal	After Withdrawal	Reduction
Flow, cfs	842	805	37	458	421	37
Stage, feet	0.49	0.47	0.024	2.40	2.38	0.02
Stage, in.	5.88	5.59	0.29	28.80	28.58	0.22

the gaging stations at Point of Rocks (upper end of the affected reach) and at Little Falls Dam (lower end of the non-tidal Potomac River). Table 3-5 above shows the change in stage that would result from a 24 mgd (37 cfs) decrease in flow at each of these gaging stations. These changes were calculated for the lower end of the rating curve where the decrease in flow would be the greatest percentage drop in flow, as would occur during a drought condition.

The results show that even under a drought scenario, the change in river stage would be less than one-third inch at Point of Rocks and less than one-quarter of an inch at Little Falls. Under higher flow conditions, the change in stage would be less than during these worst-case, low-flow conditions. This is a conservative analysis because it assumes withdrawals are not curtailed during low flow conditions. In reality, the combined withdrawals of the three hypothetical plants would be only 3 mgd during low flow events (1 mgd for each facility), due to regulatory constraints.

Reduction in habitat resulting from additional water consumption from the Potomac River would be expected to be greatest in the Great Falls reach of the

Potomac River at Great Falls, October 2001, with river flow at 670 mgd (1,030 cubic feet per second)

Potomac River Flow-by Evaluation

A 1981 Maryland DNR study served as the basis for a multi-agency agreement that established a Potomac River minimum flow-by requirement at Little Falls of 100 million gallons per day (mgd) and a recommendation of 300 mgd at Great Falls. While these low flow criteria have been in place for more than 20 years, the severe drought conditions that occurred in the Potomac River watershed in 1999 raised concerns about the adequacy of these flow-by requirements for protecting the river ecosystem and its resources. At issue was the technical basis for the designation of those flow targets in 1981 and the methods used to develop them.

Maryland DNR agreed to evaluate whether the current requirement adequately protects natural resources. PPRP serves as lead agency for this effort, based on its previous experience with stream flow issues at Deep Creek, Jennings Randolph reservoir, and Conowingo Dam, and its evaluation of potential power plants with new water intakes on the Potomac River in Frederick and Montgomery counties.

PPRP produced a report that provides background information describing the history of current low flow requirements, a review of the studies conducted to support those requirements, and a habitat assessment conducted during low flow conditions in 2002. In April 2003, a workshop was convened with a panel of nationally recognized experts to review the habitat assessment issues and to develop recommendations for consideration by decision makers. The summary report and workshop recommendations can be viewed on the PPRP web site, www.dnr.state.md.us/bay/pprp.

river, due to the large water supply withdrawals which already occur in that area. The only available flow-related habitat information from that area was collected by Maryland DNR in the late 1970s. In that study, several transects were measured for depth and velocity at several flows and model simulations were made to estimate habitat area at various flow levels. The best habitat in the Great Falls to Little Falls reach was determined to be in the Carderock area. Therefore, in the recent evaluation of potential new plants withdrawing from the Potomac, PPRP used estimated habitat from the Carderock area to calculate the change in habitat in this entire reach, as an environmentally conservative estimate, assuming a river length of 10 miles to represent this reach. The results of the calculations indicate that even at very low (drought) flow, the wetted area would be reduced by only 0.8 percent of the total. This is a very conservative estimate since it assumes ideal habitat occurs for the entire length of the reach and flow reduction measures would not be imposed during drought conditions.

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. Maryland's hydroelectric plants are listed in Table 3-6; see locations in Figure 3-14. All of Maryland's hydroelectric facilities have been in existence for many years, and all have been subject to detailed environmental review as a result of procedures required for licensing by the Federal Energy Regulatory Commission and for obtaining water use permits from the State of Maryland.

Table 3-6 Hydroelectric Projects in Maryland

Project Name	Project Capacity (kw)	River / Location	FERC Project No.	Owner	FERC License Type	FERC License Issued	FERC License Expires	Year Operational
Brighton	400	Patuxent River / Clarksville, Montgomery Co.	3633	Alternative Energy Associated Limited Partnership	Minor License	1984	2024	1986
Conowingo	550,000	Susquehanna / Conowingo, Harford Co.	405	Susquehanna Electric	Major license	1980	2014	1926
Deep Creek	18,000	Deep Creek / Oakland, Garrett Co.		Reliant Energy	None[a]	—	—	1925
Gilpin Falls	396	Northeast Creek / Pleasant Hill, Cecil Co.	3705	American Hydropower Company	License exemption	1982	—	1984
Gores Mill	10	Little Falls / Baltimore Co.	—	C. Lintz	None	—	—	1950s
Parker Pond	40	Beaver Dam Creek / Wicomico County	—	W.H. Hinman	None	—	—	1950s
Potomac Dam 4	1,900	Potomac River / Shepherdstown, WV	2516	Allegheny Energy Supply	Major License	1965	2003[b]	1909
Potomac Dam 5	1,210	Potomac River / Clear Spring, Washington Co.	2517	Allegheny Energy Supply	Major License	1976	2003[b]	1919
Wilson Mill	23	Deer Creek / Darlington, Harford County	UL97-1	A. Phadani	None	—	—	1983
Jennings Randolph (permit requested)	2,570	North Branch Potomac R. / Bloomington, Garrett Co., MD	11650	Universal Electric Power Corp.	Preliminary permit requested Dec 1998	—	—	—

Notes:
[a] Deep Creek Hydroelectric Project is administered under a Maryland water appropriations permit from MDE.
[b] FERC is expected to issue a renewed license for Potomac Dams 4 and 5 before the end of 2003; all permitting issues have been resolved.

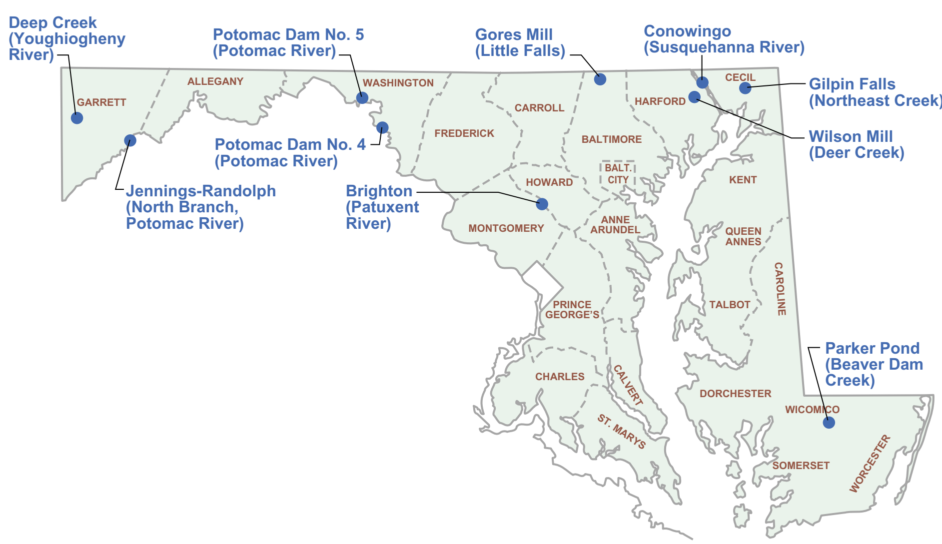
Hydroelectric facilities may present special environmental concerns that are not present at the steam electric power plants. Development and operation of hydroelectric facilities can cause three main types of impacts:

- ***Alterations of water quality* —** *Impoundments created for hydroelectric dams significantly alter river flow from free-flowing streams to deep water flow. This alteration results in 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 discharge from the dam. To mitigate these impacts, a procedure known as turbine venting was implemented at Conowingo Dam on the Susquehanna River, which allows air to be entrained into the water passing through the turbines to increase the oxygen content of the water. Similarly, an aeration weir was constructed in the Deep Creek Station tailrace to increase oxygen in the water from the dam discharge.*

- ***Fluctuation in water level and flow* —** *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 of the dams. Small-scale projects may also divert some stream flow away from the natural streambed. Fluctuations in water level and flow may reduce fish abundances and the abundance of food important to fish growth and survival. Several studies were implemented at Conowingo Dam to determine if a continuous flow is needed and what the correct level of minimum flow is that protects and enhances aquatic biota; these studies were initiated in the early 1990s and completed in 1998.*

- ***Direct adverse affects on fish populations* —** *Dams prevent the natural up-stream and downstream movement of both resident and anadromous fish species. Entrainment of fish attempting to move downstream past the dam may result in mortality in the turbines. Factors that affect fish mortality include the type of turbine, the proportion of flow diverted through the turbine, and the size of the fish. Restoration activities at Conowingo, such as fish lifts, have shown to be effective in enhancing fish populations and reducing fish mortality on the Susquehanna River.*

Figure 3-14
Location of Hydroelectric Facilities in Maryland



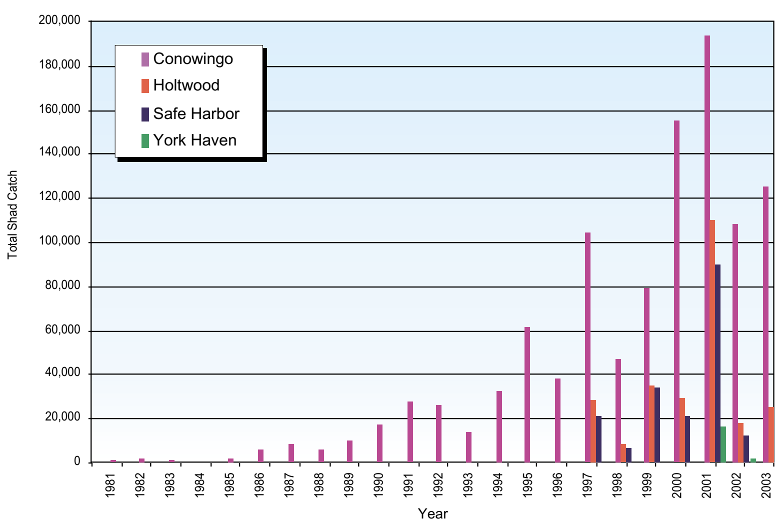
Historically, the Susquehanna River supported large spawning runs of anadromous species such as American shad, river herring, and striped bass. However, the massive anadromous fish runs that generated migrations extending as far upstream as Cooperstown, New York, were eliminated with the construction of four major hydroelectric facilities on the lower Susquehanna in the early 1900s (Maryland's Conowingo Dam, and the 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 the restoration of migratory fish passage at all four dams.

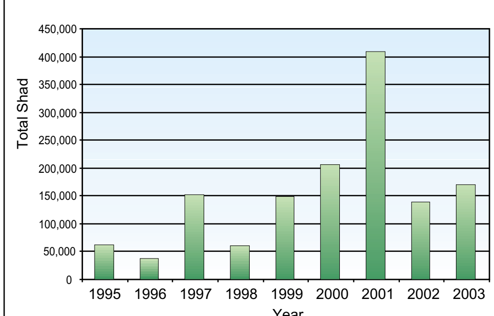
By the year 2000, all four hydroelectric projects had installed fish passage facilities. With the operation of York Haven's fish passage that year, the entire Susquehanna River is now open to migratory fish for the first time since the dams were constructed, creating the potential for shad and other species to move as far upstream as New York State, well over 400 miles of new habitat.

Growth of the Susquehanna River shad stock in response to the restoration efforts and fish passage construction has been dramatic, peaking in the year 2001, which saw nearly 200,000 American shad passed over Conowingo Dam, the largest number ever (see Figure 3-15). 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, particularly at the Holtwood and York Haven projects.

Figure 3-15
Number of American Shad Passed at Susquehanna River Dams



Total American Shad Passed at All the Dams Since 1995



SECTION HIGHLIGHTS

Maryland contains a variety of natural habitats that can be significantly affected by the construction and operation of generation and transmission facilities. Several regulations are in place to afford protection of habitats and species throughout the state. PPRP continues to work with the state and with generating facilities to develop methods to minimize habitat impacts.

Terrestrial Impacts

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.*

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 make up 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). Flora and fauna typical of common Maryland habitats are presented in Table 3-7.

The State of Maryland has enacted the following regulations that afford protection of habitats and species in terrestrial and wetland environments:

Waterway Construction — COMAR 26.17.01 applies to activities in State waterways.

Water Quality and Water Pollution Control — COMAR 26.08.01 through COMAR 26.08.04 applies to discharges to surface water and maintenance of surface water quality.

Erosion and Sediment Control — COMAR 26.17.01 applies to the preparation, submittal, review, approval, and enforcement of erosion and sediment control plans.

Nontidal Wetlands — COMAR 26.23 applies to activities conducted in nontidal wetlands.

Tidal Wetlands — COMAR 26.24 applies to activities conducted in tidal wetlands.

Forest Conservation — COMAR 08.19.01 through COMAR 08.19.06 apply to the development of local forest conservation programs, and the preparation of forest conservation plans.

Threatened and Endangered Species — COMAR 08.03.08 and COMAR 08.02.12 apply to protections for State-listed threatened and endangered flora and fauna.

PPRP's role in the CPCN process is to facilitate compliance with these regulations and natural resource objectives, even when the CPCN supercedes 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. The other laws specifically address the loss of valuable habitats, including wetlands, forests, and species habitats.

Table 3-7 Typical Flora and Fauna of Common Habitat Types in Maryland

Habitat Type	Flora	Fauna
Tidal (salt) Marsh	cordgrasses salt hay black rush glasswort cattail (narrow-leaved) high tide bush	fiddler crab blue crab killifish great blue heron willet osprey
Freshwater Marsh	common reed jewelweed cattail (broad-leaved) woolgrass sedges swamp rose mallow lizard's tail buttonbush	muskrat marsh rice rat star-nosed mole beaver prothonotary warbler water snake leopard frog pickerel frog
Wetland Deciduous Forest	red maple green ash sweetbay greenbrier spicebush highbush blueberry false nettle cinnamon fern	white-tailed deer gray squirrel raccoon woodcock wild turkey wood duck Acadian flycatcher slimy salamander
Coastal Forest	American holly greenbrier red maple sweetgum willow oak scrub oak cottonwood sweet pepperbush pinxter flower	white-tailed deer gray squirrel opossum raccoon mockingbird yellow-breasted chat bald eagle red shouldered hawk American toad
Upland Deciduous Forest	red maple white ash oaks hickories tulip tree American beech black cherry southern arrowwood poison ivy	white-tailed deer gray fox woodchuck white-footed mouse ovenbird pileated woodpecker box turtle red-backed salamander Fowler's toad
Mixed Deciduous Forest	Virginia, pitch, and loblolly pine oaks American beech hickories sugar and striped maple black huckleberry hackberry black birch quaking aspen	white-tailed deer fox squirrel gray squirrel black bear striped skunk raccoon gray fox golden-crowned kinglet Carolina chickadee
Oldfield	Joe-pye-weed Canada goldenrod broomsedge yarrow wild carrot broomsedge evening primrose blackberries raspberries	red fox white-tailed deer groundhog white-footed mouse meadow vole white-eyed vireo prairie warbler garter snake black racer snake

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. Assessing potential wetlands impacts and developing appropriate mitigations are an essential part of the CPCN process.

Similar to the wetland concerns, losses of Maryland's forest resources prompted the 1991 Forest Conservation Act (FCA). With the exception of 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 across the State. Prior to issuance of grading permits or erosion and sediment control plans by county agencies, applicants must provide information on the condition of the existing forest and provide 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. An exemption from FCA requirements for rights-of-way and land for construction of electric generating facilities can be granted if a CPCN is issued by the Public Service Commission. A project may lose its exemption status if the developer of a site or its linear facilities cannot demonstrate that cutting or clearing of forest will be minimized. As a matter of policy, however, PPRP has been successful in having power companies comply with the FCA on proposed projects through CPCN conditions.

Irrespective 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 3-8 lists the number of protected species by taxonomic group that the CPCN process considers when evaluating potential adverse effects and developing protective conditions.

Table 3-8 Total Numbers of Rare, Threatened, and Endangered Species

Animal 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

Facility Construction and Operation

Different types of habitat occur at the 34 existing power facilities in Maryland. Many of these power facilities (e.g., Brandon Shores, BRESCO, H.A. Wagner, Bethlehem Steel) are clustered in the urbanized Baltimore-Washington corridor that is characterized by degraded, human-influenced habitats. Habitats at these facilities generally are limited to their developed site footprints (power facilities, roads, parking lots, etc.), interspersed with small areas of mowed lawn, thin woodlots, and oldfields. Vegetation on these sites is typically dominated by ruderal, invasive species and landscaping varieties. Power facilities in less developed areas of the state (e.g., Dickerson, Calvert Cliffs, Warrior Run), however, often possess ecologically valuable habitats, such as large tracts of deciduous forest and tidal and nontidal wetlands. Despite their locations next to power facilities, these undeveloped parcels often provide valuable habitats for many species of flora and fauna.

In general, Maryland's newest power plants are proportionally much smaller than their predecessors. Most of the new plants are natural gas-fired and use relatively new turbine and cooling technologies (as opposed to coal-fired, oil-fired, and nuclear plants) that provide improved efficiency and require smaller developed sites. For example, at the proposed (but not constructed) Kelson Ridge power plant, the total site is only about 100 acres, licensed for a maximum capacity of 1,650 MW; the new Rock Springs facility site is about the same size, with a maximum generating capacity of 1,125 MW. The "size per MW" of these new generation plants are small compared with older power plants, such as Chalk Point (800 acres for 84 MW) or Perryman (719 acres for 455 MW). Because of this, construction of new plants can result in significantly less direct impacts to terrestrial habitats.

PPRP continues to work with the applicants to minimize habitat impacts at proposed facilities by encouraging small footprints and layouts that avoid valuable habitat areas. As mentioned above, the CPCN licensing process involves coordination with Maryland's environmental agencies and ensures compliance with the laws and regulations protecting the terrestrial environment. Specifically, each CPCN typically includes a set of licensing conditions addressing relevant natural resource issues and regulations.

While power plant construction and operation can adversely affect nontidal and tidal wetlands, power plant construction has caused only minimal direct wetlands impacts, compared with residential and commercial construction, since the implementation of Maryland's wetlands laws. Relatively small losses of wetlands were associated with the Perryman and Panda-Brandywine facilities licensed in the 1990s. Wetlands losses were minimized through the CPCN process, requirements of the Nontidal Wetlands Protection Act, and cooperation from the utilities. To compensate for wetland losses and to meet the State's no net loss goal, mitigation was required for these projects.

The Kelson Ridge, ODEC Rock Springs, and Panda-Brandywine power plant cases are all examples of projects where PPRP was able to work cooperatively with the applicants through the CPCN licensing process to preserve ecologically significant forest, agricultural, and other resources where possible. In the case of ODEC, CPCN conditions required the purchase of 100 acres of agricultural easement to mitigate for farmland lost due to construction. In all three licensing cases, conditions equal to or exceeding the FCA requirements for reforestation were included. For example, CPCN license conditions required ODEC to mitigate for 10 acres of mature forest resources at the Rock Springs power plant site by planting 50 acres of new forest off-site. Identification of off-site locations for planting were coordinated with the DNR Forestry and Watershed groups to benefit the State's ecological assets (e.g., contiguous forest). These 50 acres will also help to offset carbon and nitrogen emissions resulting from operation of the new power plant. The nitrogen sequestration benefits are greatest when the planting is done in riparian areas. Research into the carbon and nitrogen sequestration benefits of these conditions is being conducted by PPRP (see discussion on page 43).

Rare, threatened, and endangered species issues are less commonly encountered in CPCN applications, but PPRP has developed innovative conditions in two cases of proposed (not constructed) power plants. In 1994, PPRP prepared (and obtained approval from the U.S. Fish and Wildlife Service for) an endangered species management plan for the Delmarva fox squirrel plan as a condition to the Dorchester Plant of Delmarva Power. In 2002, the CPCN was conditioned for the Kelson Ridge plant with the requirement for a comprehensive study and "Bog Protective Plan" to address rare, threatened, and endangered species in the adjacent Piney Branch Bog. The condition also required a permanent 100-foot protective buffer from the boundary of the bog be maintained, and that funds be provided to a third party (The Nature Conservancy) for the continuing protection of the bog.

Transmission Line and Pipeline Rights of Way

Electric transmission line and pipeline rights-of-way are located throughout the State of Maryland. Both temporary and permanent changes to terrestrial and wetland environments occur when transmission lines and pipeline corridors are constructed and maintained. With appropriate planning and construction techniques, nontidal wetlands (excluding forested systems) generally recover from construction in as little as two years. A 1994 PPRP study showed that the construction of electric transmission line rights-of-way in Maryland during the preceding four years accounted for only 10 percent of permanent wetlands changes in the state during that period, and did not result in a net loss of nontidal wetlands. Since that time, fewer transmission lines have been constructed and the percentage of wetland changes has been much lower.

Forested communities, in contrast, experience the greatest change in area, since trees are removed and prevented from regrowing in transmission line and pipeline rights-of-way. Once these linear facilities have been installed, the rights-of-way are typically maintained in herbaceous or shrubby vegetation, resulting in a permanent loss of trees. In general, fragmentation of forest habitats adversely affects biodiversity. Populations of forest-interior dwelling species or FIDS (i.e., species that require large tracts of intact forest, such as migratory songbirds) may be reduced and even eliminated by predation or parasitism from edge species that invade the corridor. The loss of these sensitive species reduces biodiversity when they are replaced by regionally common species that flourish in open and disturbed areas.

Whether such corridors adversely affect FIDS or other forest species depends on the width of the corridor and the landscape context. Because transmission line and pipeline rights-of-way are narrow corridors (typically 60 to 200 feet wide), the effects of fragmentation on forest habitat and their resident species are usually small. Nonetheless, PPRP recognizes that adverse impacts from forest fragmentation could result from these linear power facilities and is working with power companies to encourage management practices that reduce edge effects.

Growth of natural woody vegetation on transmission line and natural gas pipeline rights-of-way can present public safety hazards. Trees or branches that grow too close to power lines (danger trees) could fall on the conductors, while deep roots jeopardize the integrity of underground utilities. Utilities manage vegetation through a combination of mechanical and chemical treatments, based on efficiency, local conditions, population centers, and other factors. State regulations permit the use of only U.S. EPA-approved herbicides; these herbicides pose little danger to the terrestrial environment if properly applied. Maryland power companies most commonly use glyphosate herbicides that persist in the environment for less than two months, and are generally non-toxic to wildlife.

Beneficial Right-of-Way Management

Illustration of low-growing vegetation and gradual transition into the adjacent forest that can be maintained at transmission line rights-of-way to benefit wildlife and ecological services.

Power companies also use mechanical cutting of vegetation in transmission line and pipeline rights-of-way. Such management can affect wildlife by altering the original vegetative community (either permanently or temporarily) and by disturbing wildlife behavior, especially during the breeding season. Disturbance effects can be greatly reduced by eliminating mowing when vulnerable species are breeding. While mechanical cutting has the potential for polluting soils and surface waters with petroleum products (e.g., chainsaw bar oil and grease), these temporary impacts are usually negligible or non-existent. Most Maryland power companies use a combination of selective herbicide application and mechanical cutting, rather than just one or the other.

To encourage the implementation of environmentally friendly management in rights-of-way, PPRP has compiled information on innovative practices that reduce fragmentation and other adverse effects on local wildlife and plant communities. Management techniques for grasslands include strip mowing (alternate strips are mowed), creating “feathered” or soft edges to ease transitions between habitat types, rotating mowing schedules, and promoting native grasses. In wetlands, beneficial management practices include maintaining vegetative buffers and native wetland vegetation, creating snags by topping trees and girdling trunks, and providing downed woody habitats by “lop and drop” methods (in which cuttings are left where they fall). In scrub / shrub habitats, the selective removal of tall growing tree species can be used to halt plant succession and promote a lower growing plant community in the right-of-way. Such communities provide a more natural system in which the type and height of vegetation gradually transitions from a low, managed plant community in the right-of-way to a taller, more natural adjacent plant community. It is also possible that such low-growing communities help prevent colonization of rights-of-way by invasive species.

Several of Maryland’s electric utilities currently have maintenance programs to improve wildlife habitats in rights-of-way. Under these programs, stable oldfield (i.e., weedy, shrubby) habitats are established with tree species that do not have the potential for becoming danger trees. This is typically accomplished by spot treating potentially undesirable trees with herbicide every three to five years, in place of annual mowing or broadcast herbicide spraying. Results provided by the utilities indicate that such selective programs have created better, more stable habitats for wildlife, and have saved thousands of dollars in annual maintenance costs.

Some Maryland power companies are using Integrated Vegetation Management (IVM) to better manage vegetation growing within transmission line rights-of-way. IVM approaches use a combination of mechanical and chemical techniques (e.g., mowing, pruning, herbicides, tree-growth regulators) to remove undesirable species and promote low-growing plant communities beneath transmission lines. The introduction of desirable species into the right-of-way through “right tree / right place” planning projects or wildlife habitat enhancement projects is often factored into the design of an IVM program. The incorporation of GIS and GPS technologies into IVM programs is also being pursued so that managers can customize IVM programs at finer scales and help field crews implement site-specific measures to meet the management objectives for individual management units.

In one case, Delmarva Power (now Conectiv Power Delivery) began efforts in the 1980s to establish a desirable vegetation community beneath their transmission lines. Their IVM program relies upon selective herbicide application to control only undesirable species, thereby encouraging a stable, low-growing plant community. The company estimates a system-wide savings of $2.3 million dollars between 1988 and 1996 by moving to an IVM program versus a mowing maintenance schedule; in 1996, the company’s vegetation management expenses were less than in 1980, despite inflation.

PPRP has also been collaborating with Maryland power companies to improve utility tree trimming and maintenance programs within utility rights-of-way through the Maryland Electric Reliability Tree Trimming (MERTT) Council. The MERTT Council is the successor to a PSC-mandated series of meetings between utility companies and the DNR as a result of major storm-related power outages in 1999. The quarterly MERTT Council meetings provide a forum for discussion and continued dialogue on tree trimming issues along utility rights-of-way.

Most recently, PPRP completed a research effort that identified locations where transmission line rights-of-way sever wildlife corridors that are of statewide conservation importance (i.e., are identified in Maryland’s Green Infrastructure). PPRP is currently working with power companies and others to implement management practices designed to promote vegetation at these locations that reduces fragmentation effects and enhances the ecological value of the Green Infrastructure. PPRP is also working with power companies to identify rare, threatened, and endangered species habitats that exist on their rights-of-way, to foster better environmental stewardship. In some cases, these rights-of-way provide important refuges for rare grassland species.

Sociological and Land Use Issues

Cultural and Archaeological Resources

Section Highlights

Power plants can impact the cultural and archaeological resources of an area in many ways. Once a power plant is operational, it can add incompatible sights, sounds and other nuisances to an existing environment. PPRP addresses such issues as light pollution, noise data, visibility, and traffic impacts when conducting the environmental review of a proposed power plant.

Power plants can affect cultural and archaeological resources during construction through site preparation and excavation. The most likely types of impacts to these resources from power plants, however, is the effect on the cultural or historical setting by adding incompatible sights, sounds, or other nuisances to existing environments once they are operational. Recent and ongoing environmental reviews of proposed generating facilities, including Rock Springs, the Frederick County Energy Facility, Mirant Dickerson expansion and two wind energy projects in Western Maryland, have evaluated direct, preemptive effects on specific structures and prehistoric sites, some previously undocumented, and indirect effects on National Register properties, national parks, historic districts, Recognized Heritage Areas, Maryland Scenic Byways, and many other cultural resources.

Under Maryland State law (Article 83B, 5-617 & 5-618 of the Annotated Code of Maryland), the Public Service Commission must consult the Maryland Historical Trust (MHT) on the impacts a Certificate of Public Convenience and Necessity (CPCN) would have on historic properties. Additionally, federal agencies regulating or funding power generation facilities must consult with the MHT on the effects of their actions on historic properties pursuant to Section 106 of the National Historic Preservation Act. Archaeological investigations must conform to MHT's Standards and Guidelines for Archeological Investigations in Maryland. As a result, all CPCN applications for power plants contain comprehensive evaluations based on background research and fieldwork that forms the basis for estimating construction and operating impacts on historical and archeological resources.

Recent licensing cases offer examples. Targeted for a greenfield site in southern Frederick County, the Frederick County Energy Facility was proposed to be located in an area with a well-documented pre-history, and possible links to the underground railroad. Although all documented cultural sites were outside the area of potential effect, the applicant was required to conduct a Phase I archeological survey of the areas likely to be disturbed by construction and operation of the proposed facility. The survey identified both prehistoric and historic archeological sites, but found that only two historic sites were of sufficient integrity to merit further investigation, one of which could be avoided. Additional investigation of the remaining site showed that it had been compromised by crop cultivation and would not be eligible for the Maryland Register of

Historic Properties. PPRP also evaluated the potential visual effects of the proposed facility on historic standing structures. The investigation found that the tops of the stacks associated with the proposed facility would be visible from many of the inventoried historical standing structures and historical districts in the area, but that terrain relief and vegetation would obscure most views of other structures.

In Rock Springs, a Phase I archeological survey discovered three new prehistoric sites and confirmed the existence of another. The three new sites did not contain artifacts in a sufficient density to warrant additional research, and since the other site would not be disturbed, more detailed surveys were not required. However, the developer was required to establish an archeological protection zone around the site to protect it during construction. The developer was also required to develop a detailed visual impact plan to mitigate adverse visual effects on two nearby historic properties.

Wind energy facilities affect cultural and historical resources differently than combustion generation facilities. Because a wind farm is comprised of a linear array of turbines spaced over several miles, more archeologically sensitive lands are potentially within the project area. However, the footprints of wind turbines are small and there is some flexibility in their location, meaning that sensitive areas can usually be avoided. But the linear placement of wind turbines along ridgelines, combined with their height, can result in widespread visual effects upon nearby historic resources.

For the proposed Allegheny Heights wind energy facility along Backbone Mountain in Garrett County, an archeological investigation identified three areas of archeological concern, which archeologists determined could be avoided through the appropriate placement of wind turbines. Avoidance of these sites subsequently was included as a condition to the licensing of this facility. PPRP analysis of visual impacts of the proposed wind turbines suggested a large number of historical properties were within the visual footprint of the facility. Resolution of visual impacts on nearby historical properties was therefore made contingent upon follow-up studies by the project developer. Combining areas within a two mile radius around each turbine into an area of potential effect, the project is conditioned on detailed inventories of properties that may be adversely impacted, formal determinations of eligibility for the Maryland Register of Historic Properties for affected properties, and implementation of a plan for mitigating or minimizing the effects on properties adversely affected by the project.

Nuisance Items

Light

Light pollution is the inadvertent illumination of nearby areas and is a common consequence of development. It is of concern to PPRP because the most recently licensed power plants in Maryland have been located in rural areas. In these cases, the addition of lighting to a dark background could carry greater significance for surrounding property owners. However, lighting is a necessary adjunct to safety. In power plants, lighting is used to illuminate areas that would otherwise be hazardous to workers. In addition, strobe lights on tall structures, such as stacks and wind turbines, are required for aviation safety. Minimum lighting standards for satisfying other regulatory requirements can therefore make some degree of light trespass unavoidable.

Control of light pollution has started to become a matter of public policy in Maryland not necessarily because of power plant development, but because of increasing residential and commercial sprawl. House Joint Resolution 14 sponsored a task force to study lighting efficiency and light pollution in Maryland. The report was published in March 2002 and issued a number of guidelines for achieving efficient/cost effective lighting.

- *Choose luminaires that distribute light only where it is needed, minimizing light pollution and unnecessary energy consumption.*
- *Choose appropriate lamp source color.*
- *Choose lamp types to maximize visibility per lumen output, as well as maximizing lumen output per input watt of energy.*
- *Choose lamps with longer life ratings.*
- *Choose appropriate efficient ballasts.*
- *Design to appropriate lighting levels based on Illuminating Engineering Society of North America (IESNA) recommendations and to avoid over lighting.*
- *Lay out lights to avoid spillover onto adjacent property, and choose appropriate pole heights.*

The report also recommended that State Departments and Agencies and the University System of Maryland analyze their outdoor lighting systems and practices and develop a plan for bringing all state-owned or state-maintained outdoor lighting into compliance with applicable outdoor lighting standards. These plans are intended to bring existing lighting systems and fixtures into compliance within the next six years, when economically feasible. Additionally, all new lighting systems and fixtures should comply with applicable outdoor lighting standards.

Few Maryland jurisdictions address lighting standards through zoning ordinances, although many require an outdoor lighting plan in the site plan review process. Some counties, such as Garrett, impose certain lighting conditions on a case-by-case basis. Public awareness of outdoor lighting issues, however, is increasing and Maryland counties are beginning to recognize light pollution as a planning issue. Frederick County's draft-zoning ordinance, for example, contains strict, measurable standards for outdoor lighting. Outdoor lighting issues have also been raised by the public, the Director of Planning, and County Commissioners during St. Mary's County comprehensive code update.

Although there is no statewide regulatory framework, PPRP recently began addressing light pollution in its environmental reviews of proposed generation facilities. Light trespass was recognized as an environmental issue in the environmental review of proposed facilities in western Montgomery and southern Frederick counties. Additionally, in visual impact mitigation conditions associated with the proposed expansion of Mirant's Dickerson facility, and in licensing conditions applied to the Allegheny Heights and Savage Mountain wind energy projects, conditions addressing light pollution have been included.

Visual

Power plants are large industrial facilities with a number of prominent structures. Although often associated with tall stacks and large cooling towers, recently licensed gas-fired generation facilities in Maryland are less imposing, with the tallest structures (stacks) being less than 200 feet in height. Other prominent structures associated with combustion turbine and combined cycle facilities are turbine buildings, air filters, and fuel storage tanks, all of which are usually less than 100 feet high. Wind generation technologies have a completely different visual profile, comprising many tall towers distributed in a linear array over several miles. Visual effects can be accentuated by stack plumes from conventional generating facilities, and lighting on tall structures, such as stacks and wind turbines, which can extend visual impact beyond daylight hours.

Visual impacts depend upon a number of factors, including the visual setting and cultural context in which the facility is located, the number of receptors whose views are affected, facility placement within the chosen site, and the existence of other or similar industrial facilities. Typically, power plants developed on “greenfield” sites have a greater visual impact on the surrounding landscape than those developed where generating facilities already exist. Power plants located in urban or suburban areas are often less intrusive on surrounding land uses than power plants located in rural areas, even though urban or suburban facilities have a greater number of receptors.

Recent CPCN applications have involved both greenfield sites and expansions of existing generating facilities, and both suburban and rural locations. As a result, PPRP has addressed a wide range of issues related to impacts on visual quality. For example, facilities proposed for Montgomery and Cecil counties are located in areas where agricultural preservation is emphasized, and many cultural and recreational resources are nearby. Even so, other types of development are slowly transforming the visual landscape and views are compromised from some perspectives. In the proposed Dickerson expansion, facilities are located within a large land parcel, which reduces or obscures views from many perspectives.

The Rock Springs facility in Cecil County is situated on a smaller land parcel and, without mitigation, was predicted to compromise views of adjacent landowners and travelers on a nearby highway. Specific conditions were placed on the Rock Springs CPCN that require the establishment of vegetation or other types of buffers.

Visual impact can have a bearing on developers’ siting decisions. Duke Energy relocated its proposed Frederick County power plant to a lower elevation portion of the proposed site than was originally planned, at least in part because the topography would reduce the plant’s visibility.

Visual quality issues associated with recently licensed wind energy facilities in Western Maryland are substantially different than those associated with gas- and oil-fired facilities. Instead of a relatively compact power block and stack, wind facilities, comprising rotating blades on a series of towers arrayed linearly over a number of miles, are proposed for construction along two prominent ridgelines in Allegany and Garrett Counties. As tower heights, including turbine blades, approach 400 feet, visual avoidance of at least some structures from much of the surrounding area is unlikely. PPRP developed visibility maps to both quantify the visual impact and identify sensitive locations (historic properties) where mitigation might be necessary to reduce the visibility of facility structures. Issuance of a CPCN in both cases was conditioned on the developers conducting additional assessments on identified properties to assess visual effects and to develop plans for minimizing effects on properties adversely affected by the project.

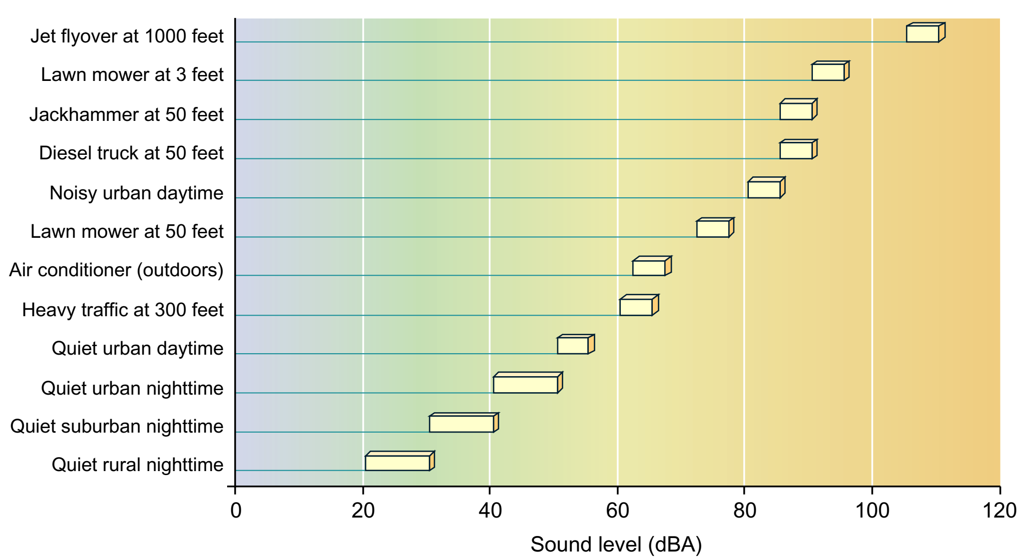
Noise

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; one decibel is approximately the smallest change in sound intensity that can be detected by the human ear. A tenfold increase in the intensity of sound is expressed by an additional 10 units on the decibel scale, and is perceived subjectively as a doubling of the loudness. A 100-fold increase in sound intensity equates to an additional 20 units on the decibel scale, and sounds like a quadrupling of loudness. Ranges of typical A-weighted sound levels for various common sounds are shown in Figure 3-16.

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

Figure 3-16
Typical Range of Common Sounds



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 3-9.

Table 3-9 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 A.M. and 10 P.M.; night refers to the hours between 10 P.M. and 7 A.M.

The State regulations provide certain exemptions for specified noise sources and noise generating activities. For example, the regulations also 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.

Structures such as berms and walls may be constructed solely to provide noise control, and have been used in transportation applications for many years. Vegetative buffers may be used in conjunction with these structures for additional noise abatement. Sound waves decrease in strength as they travel, and each doubling of distance from a noise source results in a decrease of 6 dBA in the measured sound level.

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.

In the recently licensed Rock Springs power plant, noise levels were of particular concern because the predominantly rural setting has a low background noise level. Following negotiations with State agencies, local residents, and elected officials, the developer, ODEC, agreed to incorporate additional noise reduction features at the facility. These noise control measures include upgraded silencers for the exhaust stacks, improved muffling for the combustion air inlet and turbine vent fans, and improvements in the turbine enclosure design. The Rock Springs plant will have to meet a noise limit of 55 dBA at the nearest residential property boundary at all times, which is significantly quieter than the current State regulatory standard of 65 dBA for residential areas during daytime hours.

Traffic

Traffic impacts from power plants are highly localized conditions that are mitigated in a number of ways. Most traffic impacts occur during construction of the facility, and relate to the number of commuting laborers and equipment/ materials delivery vehicles. Local roads and intersections in the area of the facility can become congested during morning and afternoon peak periods. Deliveries of goods and services during construction tend to be distributed throughout the day and have little effect on local roadways, except when major components are delivered. In the latter case, travelers may experience delays, but such events are infrequent. State and county highway authorities typically issue permits for the road transport of major components.

In recent years, traffic impacts from the operation of new generating facilities in Maryland have been inconsequential. New facilities have required few workers to operate them. In addition, most are designed to burn natural gas, which is transported via pipeline. Some facilities require periodic truck deliveries of fuel oil or ammonia, but at frequencies (one to several per week) that have little, if any, impact on local traffic.

Mitigation for traffic impacts can take many forms and usually involves cooperation and coordination with local or state highway departments. In some cases, roadway improvements, such as turning lanes and roadside tree trimming, have been required to reduce congestion at targeted intersections and improve visibility to oncoming traffic. Other conditions to CPCN approval include establishing traffic control monitors, traffic flow management at intersections or roadway segments, special telephone numbers for citizen complaints, changing cycle lengths at signalized intersections, and staggering construction worker shift schedules.

Unless traffic congestion forecasts are definitive, CPCNs for power plants in Maryland are usually conditioned by a monitoring requirement, followed by administrative steps, then infrastructure improvements if congestion is prolonged and severe. Traffic monitoring and management are preferred because vehicular congestion is usually temporary and occurs when construction activities are most intense, usually for six months or less.

PPRP also coordinates its environmental review with state and county highway departments when new access roads are required or right-of-way permitting is needed. Conditions to CPCN approval consider safety by specifying that new intersections meet minimum sight distances for oncoming traffic. Conditions also take into consideration the effects of permitted loads on local traffic. Wind energy facilities are an interesting example in that the most significant traffic impacts are associated with transportation of major components. These components, on trailers up to 90 feet in length, can briefly delay traffic through road closure, particularly at intersections when turning movements are required, on ascents to ridgelines where they are assembled, and when trucks are being maneuvered at construction staging areas.

Economic Development

Power plants generally help local economies. During construction, millions of dollars are injected into the Maryland economy in the form of construction wages and sales of goods and services by Maryland businesses. Power plant operation adds permanent jobs, goods and services expenditures for operation and maintenance, and sizeable contributions to the state and local tax base.

Employment and income impacts are magnified by ripple effects through the economy. These “multipliers” are numerical coefficients that relate a change in demand or employment from a given investment to a consequent change in total income or total employment. Thus, construction and operation of a power plant creates more employment and income than simply the number of construction workers and operating staff and the wages they are paid.

The Department of Business and Economic Development (M-DBED) publishes economic multipliers for Maryland industries. Multipliers used in recent PPRP environmental reviews are shown in Table 3-10.

Table 3-10 Multipliers for Construction and Electric Utilities in Maryland

Multipliers	Employment	Income	Output
Construction	2.138	1.922	1.716
Electric Utilities	1.379	1.415	2.073

The construction employment multiplier indicates that more than two additional jobs are created in Maryland for every job created in the construction industry. Similarly, the income multiplier for electric utilities indicates that $1.41 more additional income is created from the addition of $1.00 of payroll income in the electric utilities industry.

Through the multiplier, construction activity that adds hundreds of jobs and millions of dollars of earnings to local economies contributes hundreds of additional jobs and millions of additional earnings to local economies. However, as construction jobs are of a limited duration, the beneficial economic effects from construction are also temporary. Indirect employment and income effects from the operation of power plants are permanent, but have a smaller impact on local economies because most new and proposed facilities in Maryland operate with few employees.

Land Use

Conventional generating facilities require proximity to a reliable fuel source and cooling water. Additionally, all power plants connect to the electric transmission grid. Proximity requirements such as these have resulted in the permitting of several new generating facilities in rural greenfield sites, arousing concern in host communities. Such concern is in response to perceptions about urban sprawl and its causes, with the argument that power plant development contributes to urban sprawl by encouraging industrialization of the rural landscape. However, there is little direct evidence to support either the contention that power plants encourage industrialization of the rural landscape or that industrialization encourages urban sprawl. Another concern is that power plants have an adverse effect on nearby property values, although there is little in the literature to support or refute the contention. However, empirical evidence from studies of facilities considered more noxious than conventional power plants have failed to demonstrate any consistent causal relationship between proximity and property values.

In the evaluation of the proposed Rock Springs generation facility, it was concluded that the facility was unlikely to influence development because there is no economic advantage to industries collocating with electric generating facilities. Sprawl preceded Duke Energy's proposed Frederick Energy Facility into southern Frederick County. The review of the proposed facility did not support the contention that it would encourage additional sprawl, suggesting instead that the large land buffer around the plant would probably stimulate the creation of a greenbelt and additional perpetual environmental easements around Point of Rocks. In Montgomery County, strict land use controls in the Agricultural Reserve have impeded sprawl despite the existence and subsequent expansion (Station H) of the Dickerson generating facility.

Wind energy technologies are particularly suited to rural areas in the Allegheny Mountains of western Maryland. Yet there has been a lower level of public concern about the siting of wind energy facilities in the context of Smart Growth and urban sprawl. This may be due to the small footprints of individual towers, the ability of the turbines to coexist with adjacent land uses and, probably, public perceptions of wind facilities as "green" energy sources. The fact that neither project required state infrastructure funding was recognized by PPRP in the evaluation of land use impacts in environmental reviews of the two facilities. Located as they are along remote ridgelines on difficult terrain, recently licensed wind energy facilities are improbable engines for urban sprawl.

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 3-17 illustrates, natural radiation sources account for more than 80 percent of the average radiation dose to humans. Of the approximately 18 percent of the radiation dose arising from man-made sources, only 1 percent is attributed to commercial nuclear power production.

SECTION HIGHLIGHTS

PPRP conducts monitoring programs to assess the radiological effects on the environment attributed to Calvert Cliffs Nuclear Power Plant and Peach Bottom Atomic Power Station. The concentrations of radioactive elements released into the environment from these two plants are very small compared to naturally occurring background radioactivity.

Figure 3-17
Estimated Effective Radiation Dose from Natural and Manmade Sources

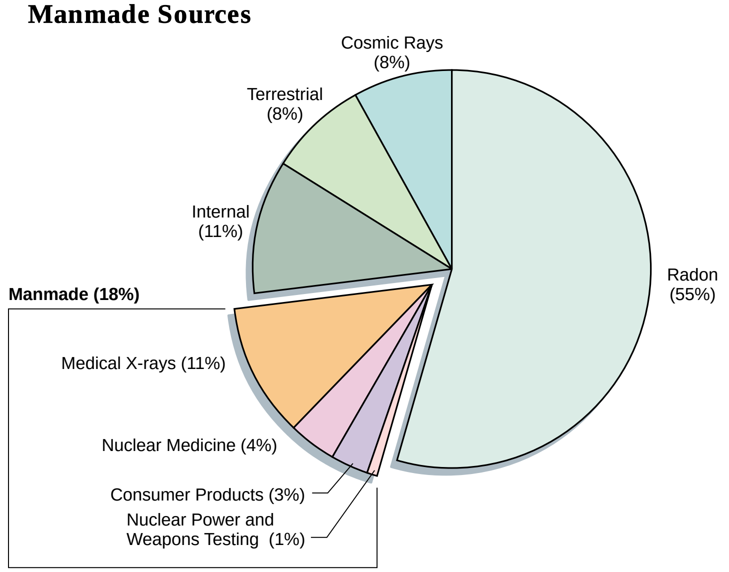


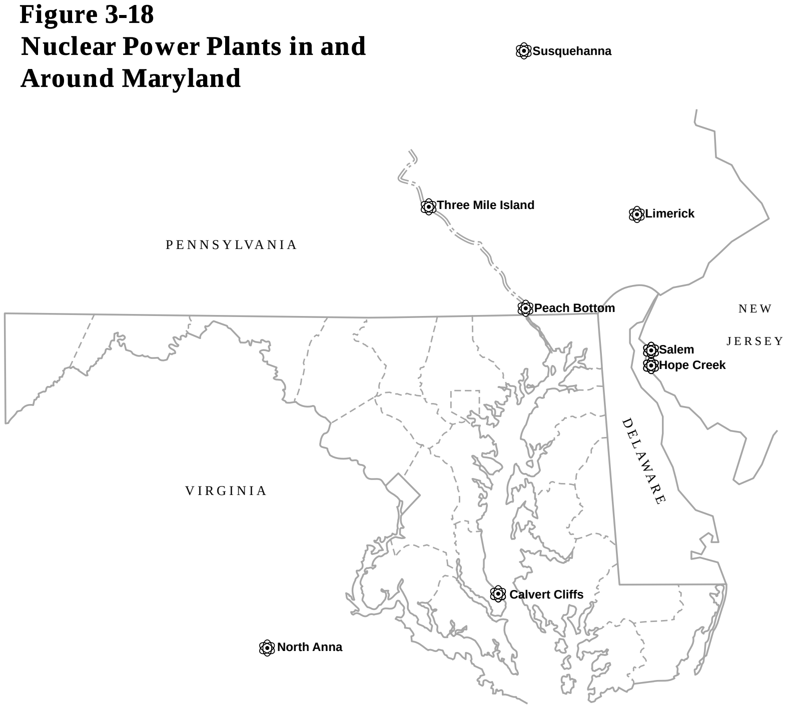
Figure 3-18 shows the locations of nuclear power plants in and near Maryland. Calvert Cliffs Nuclear Power Plant, in Calvert County, is the only nuclear power station in the state. The next closest plant, Peach Bottom Atomic Power Station, is on the Susquehanna River just north of the Pennsylvania / Maryland border. These two facilities both 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 860 MW. The units began service in May 1975 and April 1977.

Calvert Cliffs routinely releases low-level gaseous, particulate, and liquid radioactive effluents into the atmosphere and the Chesapeake Bay. The level of radioactivity of these effluents at any given time depends on many factors, such as plant operating conditions and conditions of the nuclear fuel. Since Calvert Cliffs has been in operation, releases of radioactivity to the environment have been well within the regulatory limits.

Figure 3-18
Nuclear Power Plants in and Around Maryland



Radioactive noble gases, primarily 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 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 from environmental monitoring (for the years 2000 and 2001) indicate that releases of radioactivity to the atmosphere by the Calvert Cliffs plant were not detectable in air, precipitation, or vegetation.

In the plant's aqueous releases to the Chesapeake Bay, the environmentally significant radionuclides are primarily forms of radioactive iron, cobalt, niobium, chromium, and zinc. These radionuclides are notable because Bay biota, such as oysters, accumulate them readily. They also can be trapped in sediments at the bottom of the Bay. Through the food chain, these radionuclides in sediments may ultimately contribute a radiation dose to human populations. However, the quantities of environmentally significant radionuclides released from Calvert Cliffs and subsequently detected in shellfish and Bay sediments were quite small (approximately 1 percent of all radioactivity detected in sediments, which includes historic nuclear weapons testing fallout and naturally occurring radionuclides).

Bay oysters are ideal indicators of environmental radionuclide concentrations because they do not move and they readily ingest and concentrate metals. Oysters are commercially harvested near Calvert Cliffs, and they have the greatest potential for contributing to a human radiation dose through seafood consumption. PPRP routinely monitors the uptake of radionuclides in test oysters placed on platforms on the Bay floor in the vicinity of the Calvert Cliffs discharge. The oysters are collected at scheduled time intervals and analyzed for radionuclide content in their tissues. Radiosilver continues to be the principal plant-related radionuclide accumulated by oysters; it has consistently been detected in test oysters as well as oysters on natural beds.

As part of the surveillance 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 materials potentially available. Results indicate that radiation doses attributable to operations at Calvert Cliffs are well below federally mandated limits.

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. Cobalt-60 was the plant-related radionuclide detected almost exclusively in Bay sediments during the 2000-2001 reporting period.

A comparison of radionuclide concentrations in environmental samples collected in 2000 and 2001 with levels detected since 1978 shows the following:

- *The levels of plant-related radionuclides detected during 2000 and 2001 are slightly less than the range of concentrations detected over the previous decade.*
- *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 is very small compared with background radioactivity from natural sources and weapons test fallout.*
- *Atmospheric and aqueous releases and radiation doses to humans are well within regulatory limits.*
- *Environmental, biological, and human health effects of releases of radioactivity from Calvert Cliffs are insignificant.*

Peach Bottom Atomic Power Station

Peach Bottom Atomic Power Station 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 currently licensed capacity of approximately 1,150 MW, and have been in service since 1974. Exelon Nuclear, the company that operates Peach Bottom, was granted a 20-year operating license extension by the NRC on May 7, 2003.

Like Calvert Cliffs, Peach Bottom routinely releases low-level gaseous, particulate, and liquid radioactive effluents into the atmosphere and the Susquehanna River. Since the plant has been in operation, all liquid and atmospheric releases of radioactivity have been well within regulatory limits.

Information from monitoring programs shows that in recent years radionuclides of xenon and krypton accounted for nearly all of the radioactivity released to the atmosphere by the plant. These particular radionuclides are chemically inert and, therefore, are of little environmental concern. Based on environmental monitoring from 2000 and 2001, no radioactivity attributable to atmospheric releases by Peach Bottom was detected in air samples collected from the plant site and distant locations.

Of the radionuclides released by Peach Bottom to the Susquehanna River in 2000 and 2001, 99 percent was tritium (a radioactive form of hydrogen), which is not bioaccumulated and is of limited environmental concern. Very small quantities of radioactive cobalt, zinc, and manganese accounted for most of the remaining radioactive material released in liquid effluent. These particular radionuclides are environmentally significant because they can be readily accumulated by aquatic life such as mussels and finfish.

Finfish collected from the Conowingo Reservoir area contained both plant-related and fallout-related radionuclides. Peach Bottom plant-related radioactivity was also detected in sediments collected down-river of the plant, at slightly lower levels than in previous years. Concentrations of radiocobalt and radiocesium were highest in the Conowingo Reservoir area, as they have been in previous years. 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.

Estimates of radiation doses to individuals consuming fish were calculated using the maximum plant-related radionuclide concentrations, similar to the studies at Calvert Cliffs; 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. The annual total body doses associated with the consumption of finfish and drinking water are well below federal limits.

Comparing PPRP's radiological monitoring of Peach Bottom-related radioactivity of aquatic life and sediments collected from 2000 and 2001 with monitoring results since 1978 shows the following:

- *The low 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 significant accumulation of radioactive material within the Conowingo Reservoir.*
- *Atmospheric and aqueous releases and radiation doses to humans are well within regulatory limits.*
- *Environmental, biological, and human health effects of releases of radioactivity from Peach Bottom are insignificant.*

Peach Bottom License Renewal

On May 7, 2003, the Nuclear Regulatory Commission (NRC) approved a 20 year extension of the operating licenses for both reactors at the Peach Bottom Atomic Power Station. The original 40-year license for Peach Bottom Unit 2 was to expire in 2013 and Unit 3 in 2014. Peach Bottom Unit 1, an early gas-cooled prototype reactor was decommissioned in 1974. Peach Bottom's license renewal program began in 1999 and required four years of extensive engineering, safety and environmental impact analysis. As with the renewal of the license for the first nuclear plant to do so — Calvert Cliffs in 1991 — PPRP represented Maryland agencies in administrative and legal proceedings before the NRC. Interacting with the applicant, Exelon Generation and the regulator, PPRP provided comments, detailed information on our studies and research and participated in public and regulatory forums throughout this 4 year license renewal process.

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

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. All are transported by truck to a licensed radioactive waste disposal facility located in Barnwell, South Carolina. At the facility, the waste is sealed inside containers, then placed into large concrete vaults located in earthen trenches. When the trenches are full, the burial site is capped with high density polyethylene, sand, clay, and topsoil. Water, groundwater, vegetation, and soil sampling at the site provide monitoring of the waste as it decays to less intense levels.

Irradiated Fuel

Spent nuclear fuel from both Calvert Cliffs and Peach Bottom are presently stored onsite within spent fuel pools for the recently discharged fuel or, in the case of older, "decayed" 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 U.S. Nuclear Regulatory Commission (NRC) for twenty years. ISFSI design and construction must conform to strict NRC specifications 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 2010; however, legal challenges will more than likely delay that schedule. The Yucca Mountain, Nevada, repository is currently the sole site under consideration as the central long-term storage facility.

SECTION HIGHLIGHTS

Coal combustion "by-products" result from the combustion process at coal-fired generating stations. The two primary types of coal combustion products produced by Maryland's coal burning power stations are fly ash and bottom ash. Studies have shown that these materials are usable products and PPRP is supporting exploration of uses of such products in a variety of beneficial applications.

Coal Combustion Products

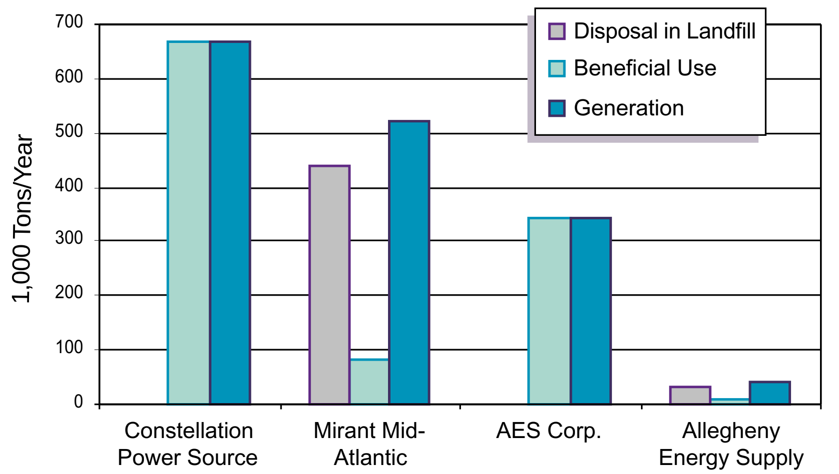
Coal-fired generating stations in Maryland produce a substantial amount of material, including those components of coal that are not consumed during combustion. A wealth of projects and applications over the past 20 years have demonstrated that many of the "by-products" from coal-fired plants are actually usable products. This section describes the major uses of these products and their generation and use in Maryland.

Generation/Disposal

Coal combustion products (CCPs) are produced during the combustion process necessary for the production of electrical energy at modern coal-burning power stations. In 2001, coal-fired power plants in Maryland generated an estimated 1.3 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 solid material fine enough and light enough to rise out of the furnace with emissions gases. Fly ash is composed of very fine, and generally spherical and glassy particles. 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 chemical nature of CCPs depends upon the nature of the coal burned and the burning process. Power plants in Maryland burn bituminous coal from the eastern United States, which produces predominantly Class F fly ash. Class F fly ash is distinguished from Class C fly ash by having less than 10 percent free lime (CaO) by weight. The ash is typically composed of more than 85 percent silicon, aluminum, and iron oxides by weight. The ash also contains carbon, calcium, magnesium, and potassium oxides; it may also contain trace metals such as titanium, nickel, manganese, cobalt, arsenic, and mercury.

Figure 3-19
Summary of CCP Generation and Disposal in 2001



Fluidized bed combustion (FBC) by-products and flue gas desulfurization (FGD) solids result from relatively new, clean coal technologies, which include the use of sorbents such as limestone during or after combustion. These sorbents reduce air pollution by removing sulfur compounds from power plant emissions; but, the noncombustible sorbents significantly increase the volume of CCPs produced. FBC by-products and FGD sludges resulting from these clean coal technologies contain many of the same chemical components as ordinary coal ash, but they tend to contain much larger proportions of calcium sulfate and sulfite minerals. They may also contain lime (unreacted sorbent), causing the ash to behave like cement when it is mixed with water. The AES-Warrior Run power plant in Cumberland is currently the only Maryland power plant that uses FBC technology. No FGD scrubbers are used today at Maryland's coal-fired plants.

Figure 3-19 highlights the amount of CCPs generated and disposed by Maryland's coal-fired power plants annually. Of the approximately 1.3 million tons of CCPs produced by these plants each year, about 45 percent are placed in disposal sites (see locations in Figure 3-20). Like all landfills, CCP disposal sites have the potential to adversely impact Maryland's terrestrial and aquatic resources if not designed and managed properly. As described below, the remainder of the CCPs are used beneficially in a variety of applications including surface mine reclamation, structural fill, and cement manufacturing.

Beneficial Use

The term "beneficial use", as it applies to CCPs, refers to a use offering equivalent success relative to other alternatives. Increasing the beneficial use of CCPs would reduce the need for landfills to dispose of these materials. Unlike other neighboring states, Maryland does not have a formal beneficial use program for CCPs. MDE's Water Resources Administration approves most beneficial use projects on a case-by-case basis, upon consideration of pollution prevention measures to be implemented.

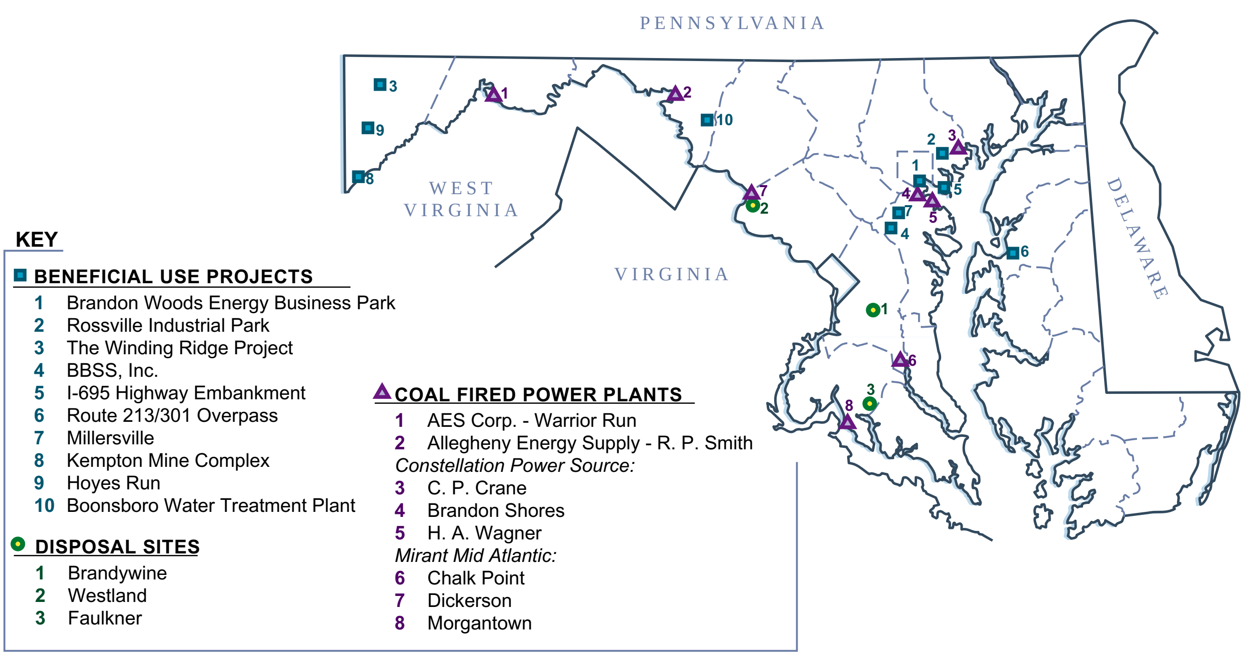
Large volume uses (those which utilize thousands to millions of tons of CCP material) such as structural fill, cement and concrete manufacturing, and mine reclamation are of particular interest for their beneficial use potential. Engineering advantages of fly ash over conventional soil include uniform moisture content, low unit weight, and higher strength. The cost for structural fill can vary because of availability and the transportation distance, and is subject to spot market pricing. Use of CCPs can void the volatility of spot market pricing and provide significant cost savings. For example, structural fill can cost up to $8 to $10 per cubic yard delivered, compared to fly ash at $2 to $3 per cubic yard.

Recent Projects Involving the Use of CCPs

Historically, the beneficial use of CCPs generated in Maryland has been moderate. Over the last 20 years, CCPs have been used as a replacement for raw materials in a variety of applications (see locations in Figure 3-20):

- ***Highway Embankment Structural Fill —*** *Between 1993 and 1998, BGE (now Constellation) supplied 360,000 tons of Class F fly ash for construction of the Interstate 695 and Route 213 highway embankments;*
- ***Regrading Structural Fill —*** *Since 1982, BGE has supplied nearly 5 million tons of CCPs for structural fill to support commercial construction of the Brandon Woods Energy Business Park and Rossville Industrial Park;*
- ***Concrete Manufacturing —*** *In 1999, BGE and Separation Technologies, Inc. (STI) entered into an agreement to allow STI to process CCPs generated at the Brandon Shores power plant to lower the carbon content and market the CCPs to the concrete industry. The STI facility at Brandon Shores processes about 100,000 tons of CCPs annually, or about 20 percent of the CCPs generated at the Brandon Shores and Wagner power plants. The entire output from the STI process is provided to the concrete industry;*
- ***Flowable Fill —*** *American-Stone Mix purchases approximately 22,000 tons of Class F fly ash from Constellation annually for the manufacture of FLO-ASH™, a flowable cement fill;*

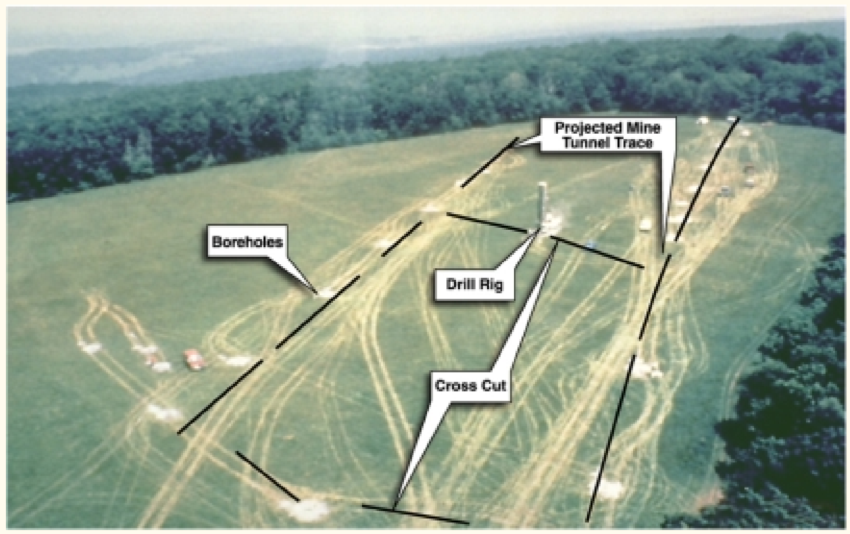
Figure 3-20
Distribution of Beneficial Use CCP Projects in Maryland



- ***Cement Block Manufacturing —*** *In 2001, approximately 80,000 tons of CCPs from Mirant's Chalk Point and Dickerson power plants were sold for reuse in cement block manufacturing;*
- ***Surface Mine Reclamation —*** *AES Corporation reuses all of its nearly 350,000 tons of alkaline CCPs generated annually at the Warrior Run plant near Cumberland for the backfill of surface coal mines at Frostburg and Barton, Maryland. The additive of the alkaline-rich backfill reduces the potential for the formation of acidic water; and*
- ***Aggregate Mine Reclamation —*** *CCPs are currently being used in Anne Arundel County to reclaim a sand and gravel mine. Extraction of the sand and gravel mine creates pits, and structural fill is needed to restore the mine site to pre-mining grades. Constellation has executed a long-term agreement with BBSS, Inc. to provide fly ash from its Brandon Shores and Wagner power plants to assist with reclamation of the surface mine. Since 1995, Constellation has placed approximately 3 million tons of CCPs at the site to reclaim the mining pits.*

Winding Ridge Project

PPRP and the MDE Bureau of Mines initiated the Western Maryland CCP/AMD Initiative in 1995 with the Winding Ridge Demonstration Project. In 1996, 5,600 cubic yards of 100% CCP grout were injected into the Frazee Mine, a small abandoned coal mine in Garrett County, Maryland. Grout core samples retrieved from the mine about one year after injection had compressive strengths above 1,000 pounds per square inch (psi). Grout cores recovered from the mine two years after injection revealed that the grout remains intact in the mine. Based on post-injection monitoring results, the concentration of AMD-related parameters — including iron, aluminum, total acidity and trace elements — are comparable to or below pre-injection conditions, and pH has trended upward. In summary, the Winding Ridge Demonstration Project shows that CCPs can be used beneficially to form a grout that can be injected into an abandoned, underground coal mine to reduce acid formation and control mine subsidence.



Aerial view of the Winding Ridge project location

PPRP CCP Use Demonstration Projects

To reduce the risk of adverse impacts to the environment resulting from CCP disposal sites, PPRP has supported exploration of traditional and new uses of CCPs in a variety of beneficial applications. A growing number of recent projects and applications have helped define the uses of CCPs, reducing their presence in landfills. In 1995, PPRP and MDE Bureau of Mines undertook the Western Maryland CCP / AMD Initiative to develop large volume uses of CCPs to reduce acid mine drainage (AMD) in Maryland's abandoned underground coal mines. The Initiative started with the Winding Ridge Project, which involved the successful injection of CCP grout into a small abandoned coal mine to reduce acid formation (see sidebar). Building on the success of the Winding Ridge Project, PPRP is performing ongoing research and development of the beneficial use of CCPs.

- ***Kempton Mine Complex —*** *PPRP is currently conducting two demonstration projects using CCP grout barriers at the Kempton Mine Complex in Garrett County.*

The Kempton Mine Complex is Maryland's largest source of AMD, currently discharging at an average of 3.5 mgd of low pH water into Laurel Run. The complex consists of nine interconnected mines that involve about 12 square miles of underground mines. The immense scope of the Kempton Complex provides the opportunity for beneficially using millions of CCPs if these demonstration projects are deemed successful.

— ***Manshaft.*** *In July 2003, PPRP initiated a study to evaluate the efficacy of CCP grout material for use as an underground vertical seepage barrier around a vertical shaft, which had been used during operation to transport miners (see Figure 3-21). The barrier should prevent as much as 100,000 gpd of good quality ground water from entering the 420-foot deep shaft and contributing to the production of AMD in the mine pool. A combination of non-toxic dye tracers, water quality data, and water elevation data are being used to determine whether the barrier reduces or eliminates the flow of ground water into the shaft.*

— ***Siege of Acre.*** *At the Siege of Acre site, another part of the Kempton Complex, a horizontal water barrier constructed of CCP grout material is being proposed to cover the acid-producing surface of the mine floor. Implementation of the construction phase of the project depends on obtaining funding from the U.S. Department of Energy. Water quality monitoring will determine if the CCP grout surface reduces or eliminates AMD production.*

- ***Treatment of Geologic Hazards in Karst Formations —*** *Karst refers to the topography that develops over limestone, and is characterized by sinkholes, caverns, and lack of surface streams. PPRP is supporting several projects demonstrating the use of CCP grout (i.e., synthetic rock) to reduce the threat of karst-related hazards in populated or developed areas.*

— ***Hoyes Run Project.*** *Hoyes Run is a small tributary to the Youghiogheny River that runs along the south side of an active quarry. A small reach of the stream loses water during low flow, which has resulted in a declining trout population in the stream. Geophysical surveying located three specific areas of losing stream underlain by bedrock fractures (possibly enhanced by quarry operations) through which surface water leaves Hoyes Run and enters the quarry. PPRP has identified a reach of Hoyes Run as a candidate for injecting a CCP grout to seal the fractures and mitigate the loss of surface water to these subsurface conduits. The result will be a stream where fish populations thrive as they have in earlier years.*

— ***Boonsboro Water Treatment Plant.*** *The town of Boonsboro, Washington County, has brought attention to a man-made channel running adjacent to two wastewater treatment ponds. The channels were cut into karst, leaving it prone to rapid drainage into the underlying limestone. PPRP is demonstrating how a CCP grout can be combined with traditional methods of treating sinkholes to reduce or eliminate the threat of losing surface water (or treatment plant discharge) into the deeper aquifer.*

Figure 3-21
Profile of Kempton Manshaft