Environmental Impacts of Power Generation

Introduction

Most environmental impacts can be classified into those that primarily affect our air, water, or land. For example, emissions of nitrogen oxides (NO_x) from power plant stacks may affect smog levels; discharges of heated water into rivers and the Chesapeake Bay affect fish populations. Beyond environmental impacts, the construction of power plants and transmission lines can also affect valuable historical and archaeological resources.

Some activities at power plants can affect air, water, and land resources simultaneously. Acid rain, for example, arises partially from air pollutants that are released from power plant stacks, transformed in the atmosphere and then fall to the ground affecting lakes, rivers, and forests. Radiological releases from nuclear power plants enter the air, water, and river sediments. Each of these topics, as well as other environmental impacts of concern, are discussed in this chapter.

Air Impacts

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. It has been amended twice, once in 1977 and again in 1990. The Act only regulates air quality over property to which the public has access (i.e., beyond plant fence lines). Air quality on privately owned property, such as power plants, is covered by regulations of the Occupational Safety and Health Administration, which is part of the Department of Labor.

The U.S. EPA has defined **National Ambient Air Quality Standards** (NAAQS), which are maximum ambient air concentrations of six pollutants known as **criteria pollutants**. NAAQS have been established to protect human health (primary standards) and welfare (secondary standards).

Air Quality Forecast Scale

The U.S. EPA has defined National Ambient Air Quality Standards (NAAQS), or upper limit air concentration levels of various pollutants, that it judges to be necessary to protect public health. The Maryland Department of the Environment (MDE), in coordination with the University of Maryland, has devised a system for forecasting air quality, with respect to the ozone NAAQS, called the Air Quality Forecast Scale. The forecast scale is based on the MDE Air Quality Index (AQI). The AQI ranges from 0 to 500, with 100 corresponding to the NAAQS for ozone. The purpose of the forecast is to provide advanced warning of periods of unhealthy levels of ozone.

In making the air quality forecast, pollutant concentrations are assessed at 9 a.m., 1 p.m., and 4 p.m. daily. The one-day forecast, issued to the public in the afternoon for the following day, is reported according to the following color-coded scale:

- Code Green (good air quality) - AQI between 0 and 50;
- Code Yellow (moderate) - AQI between 51 and 88;
- Code Orange (approaching unhealthful) - AQI between 89 and 99; and
- Code Red (unhealthful) - AQI of 100 or greater.

It is not uncommon to have a few summer days in a row with a "Code Red" forecast; however, unhealthful levels of ozone will typically occur in only the afternoon hours of each of these days. When the air quality is forecast to be "Code Red," MDE advises that 1) individuals with heart or respiratory ailments, emphysema, asthma, or chronic bronchitis reduce outdoor activities; 2) children and elderly individuals reduce outdoor activities; and 3) healthy individuals limit strenuous outdoor exercise.

Maryland began issuing daily air quality forecasts in 1994 for the Baltimore metropolitan area. The forecast area now includes the Washington metropolitan area as well. The forecast can be obtained from the MDE Air Quality Hotline (410-631-3247).

Ozone: Good Guy or Bad Guy?

The topic of ozone is frequently in the press, usually with reference to either the "ozone layer" or the "urban ozone problem." These are two completely different issues. In the first case, we are worried about the destruction of ozone; in the second case, we are worried about its formation. What is ozone? And why are we so concerned about it? It is the difference in location and origin that leads to confusion regarding ozone. The same chemical with the same properties is regarded as a "good guy" or a "bad guy" depending on where it is found in the atmosphere and how it is formed.

Ozone is a colorless gas composed entirely of oxygen. It is most recognizable by its odor — the electrical smell noticeable immediately after the passage of a strong thunderstorm is ozone. Ozone occurs naturally in the stratosphere (about 18 to 30 miles above the ground) and in trace amounts at the Earth's surface. The naturally occurring ozone found in the stratosphere is essential for life on earth because it absorbs most of the dangerous ultraviolet radiation coming into the atmosphere. A major reduction in this stratospheric ozone layer could produce a substantial increase in the number of human skin cancers and major changes in the Earth's flora and fauna.

Ozone also results from human activities but, unlike most air pollutants, there are very few human activities that generate ozone directly. Instead, ozone is formed indirectly from other air pollutants. When these "ozone precursors" (such as nitrogen oxides from power plants and cars, and hydrocarbons from cars and petroleum-based chemicals) are heated by sunlight under stagnant weather conditions, large quantities of ozone can be formed near the ground.

The ozone found near the ground that results from human activities is considered an air pollutant because, among other effects, it reduces lung function in humans and causes damage to forests, crops, rubber, and fabrics. It is the presence of this ground-level ozone of human origin that gives rise to the urban ozone problem.

Currently in Maryland, measured ambient levels of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM), and carbon monoxide (CO) are within the standards set by the U.S. EPA. Regions of the state in which the criteria pollutants are within standards are said to be "attaining the NAAQS," and are thus known as **attainment areas**. On the other hand, many areas of Maryland are not meeting the NAAQS for ozone, making ozone one of three air quality issues of particular concern in Maryland. The ozone issue and the other two key issues — visibility and acid rain — are discussed in the following sections.

NO_x Emissions and Urban Ozone

Of the major pollutants for which the U.S. EPA has set NAAQS, the most pervasive problem continues to be ozone, an important component of urban smog. One of the goals of the CAA is to bring areas that are not attaining the NAAQS (**nonattainment areas**) into attainment with the standard. In the past, ozone reduction strategies focused on controlling emissions of certain hydrocarbons, such as volatile organic compounds (VOCs); however, recent studies indicate the need to control both VOC and NO_x emissions to attain the ozone NAAQS.

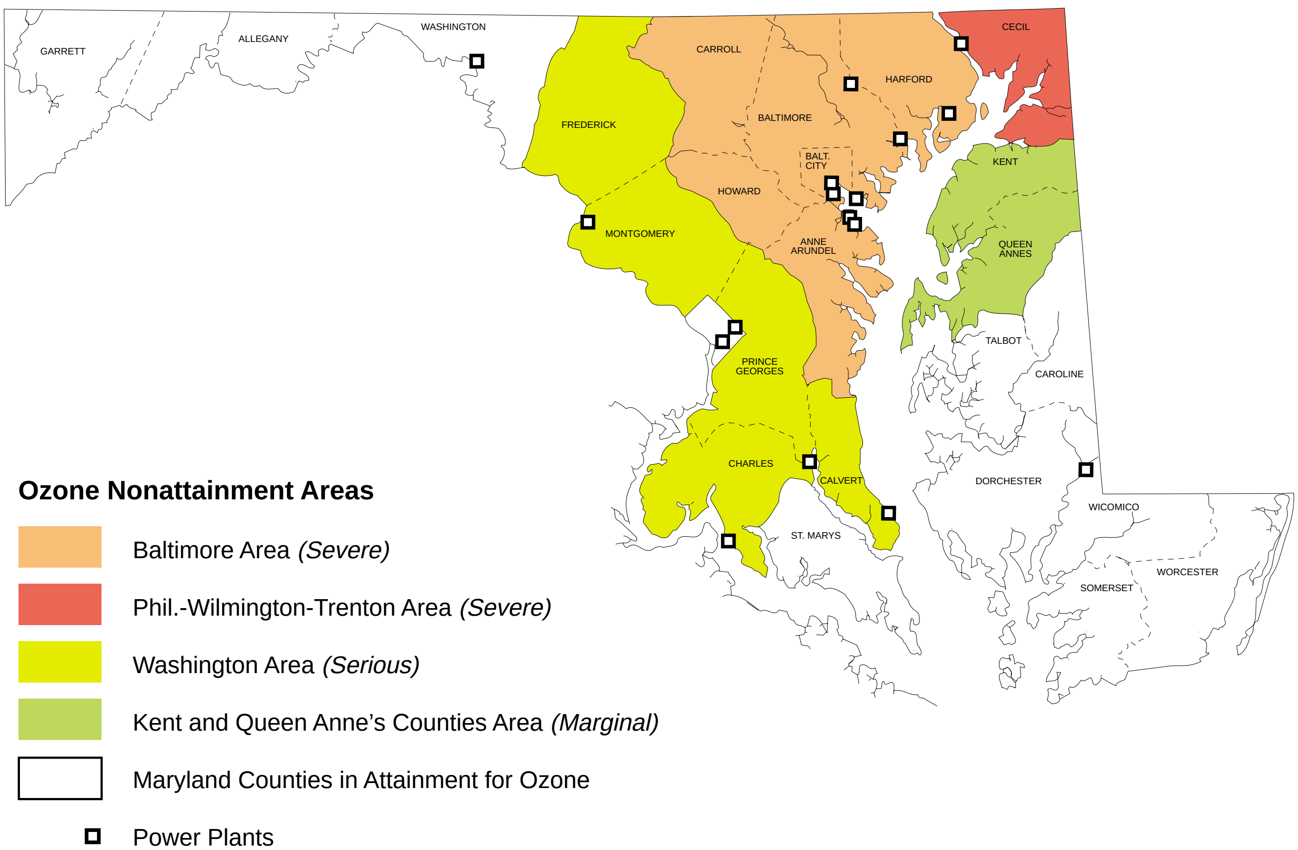
Ozone Levels in Maryland

Maryland's ozone air pollution is a significant concern. The ozone problems in the Baltimore and Washington, D.C. areas rank sixth and tenth worst in the nation, respectively. Under the U.S. EPA's classification system for indicating the magnitude of ozone pollution, the Baltimore area is designated a "severe" ozone nonattainment area, and the Washington, D.C. area is designated a "serious" ozone nonattainment area (Figure 3-1). Violations of the ozone standard continue in Maryland; measurements showed that the NAAQS was exceeded on 10 days in 1994.

Power Plant Emissions Contributions

VOCs emitted by power plants are formed from the incomplete combustion of fossil fuels. As shown in Figure 3-2, mobile sources and area sources are the prime emitters of VOCs. Power plants are responsible for less than 1% of the total VOC emissions. On the other hand, power plants are significant emitters of NO_x. NO_x emissions from power plants are formed by high-temperature chemical reactions during the combustion of fuels. These NO_x emissions consist primarily of NO_2 and nitric oxide (NO); the NO converts to NO_2 in the atmosphere. Power plant emissions account for 35% of the total NO_x emissions in Maryland, by far the largest point source contributor. Mobile sources account for the next largest percentage of the total NO_x emissions (Figure 3-2).

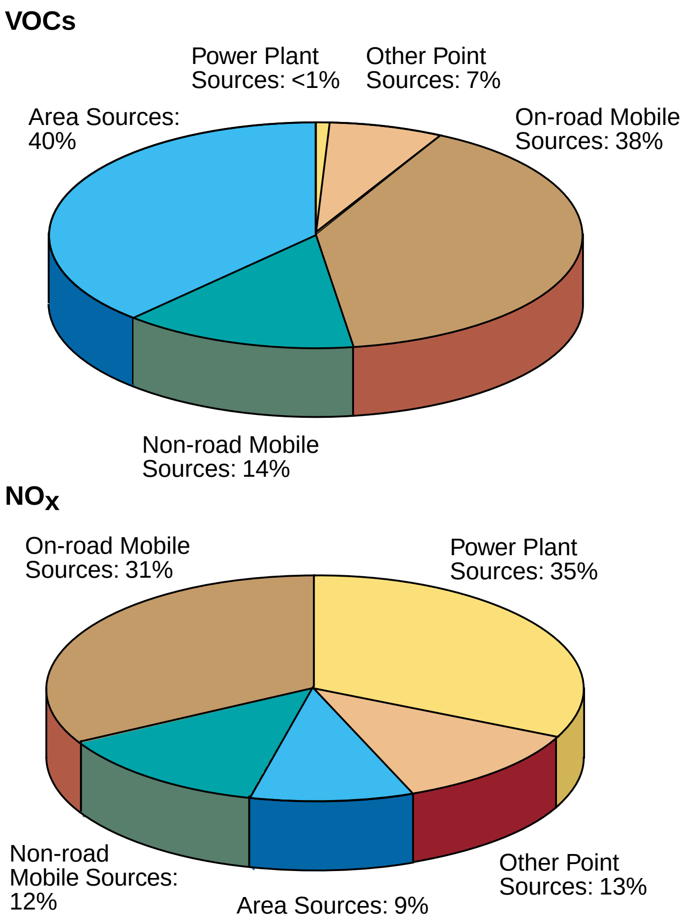
Figure 3-1
Ozone Nonattainment Areas in Maryland



Regulatory Approaches to Reducing NO_x Emissions

The CAA Amendments of 1990 address the ozone problem by requiring reductions in emissions of **ozone precursors** (NO_x and VOCs). The CAA requires all states, including Maryland, to submit plans to the U.S. EPA for meeting the ozone NAAQS. Most importantly for power plants, for the first time, these state plans must include both VOC and NO_x emissions control and reduction as part of the solution to the ozone problem. The state plans must outline specific controls or emission limits, representing **Reasonably Available Control Technology** (RACT), to reduce NO_x and VOC emissions from existing facilities. Proposed new sources whose NO_x and VOC emissions will exceed certain levels are subject to even stricter control requirements, known as **Lowest Achievable Emission Rate** (LAER) technology. Additionally, a proposed new source must include provisions to offset its new NO_x and VOC emissions with reductions from other sources in the area. The offset ratio must be greater than 1 to 1, meaning that there must always be a larger quantity of emissions reduced than the amount of new emissions added. Depending on the severity of the ozone nonattainment area, different offset ratios are imposed. For example, in the Baltimore area, an offset ratio of 1.3 to 1 is required.

Figure 3-2
Sources of VOCs and NO_x in Maryland, 1990



The states must demonstrate to the U.S. EPA that the ozone NAAQS will be attained by the deadlines mandated in the CAA Amendments. These demonstrations of attainment are made through the use of computer modeling that predicts smog levels based on projected future emissions, photochemistry, and meteorology. The U.S. EPA has developed such a computer model for the entire northeast region of the United States, including Maryland. Current studies for this region suggest that additional NO_x and VOC emissions reductions from existing sources are needed throughout the region to attain the ozone standard.

Concurrently, studies using a more detailed model are being conducted by states, including Maryland. The goal of the state studies is to identify specific areas where NO_x and VOC reductions will help achieve the ozone standard. MDE is currently conducting the modeling analysis of the Baltimore-Washington, D.C. area with assistance from the University of Maryland. These results will be critical for designing appropriate control plans for the various source categories, including power plants, and for determining areas where NO_x emissions control would help in attaining the ozone NAAQS. PPRP is following the progress of these studies closely.

Power Plant NO_x Control Options

NO_x is generated during the combustion of fossil fuels in two ways: 1) **thermal NO_x** formation and 2) **fuel NO_x** formation. Thermal NO_x results from the high-temperature reaction of nitrogen and oxygen in the air used for combustion. As the combustion temperature increases, the amount of thermal NO_x that is formed

Offset Requirements

Although offset requirements have been part of the air quality permitting process since 1977, there have been few offset transactions outside of California. With the passage of the 1990 Clean Air Act (CAA) Amendments, however, emissions offset transactions likely will occur more frequently. This is due to the establishment of many more ozone nonattainment areas, the creation of the Northeast Ozone Transport Region (OTR), and the institution of lower offset trigger levels and higher offset ratio requirements.

An additional change with the 1990 Amendments is the allowance of interstate trading within the OTR. Although the details pertaining to interstate offset transactions are not fully developed, a fundamental criterion is that offsets for a particular new source must be obtained from an area that has an equal or higher (i.e., a more severe) nonattainment classification.

Another significant change resulting from the 1990 Amendments is that both volatile organic compound (VOC) and NO_x emissions are regulated as ozone precursor emissions. In the past, only VOC emissions were regulated as ozone precursors. Thus, now new and modified major NO_x sources must also obtain emission offsets.

increases. Fuel NO_x results from the oxidation of nitrogen bound in the fuel during combustion. Increasing amounts of fuel-bound nitrogen will result in higher NO_x emissions.

In 1994, power plants in Maryland emitted approximately 115,000 tons of NO_x into the atmosphere. Nearly 80% of these emissions come from utility boilers, as opposed to combustion turbines and other generating units. Most of the utility boilers in Maryland burn coal as their primary fuel. On the other hand, combustion turbines burn relatively clean fuels, such as natural gas and distillate oil, and operate for shorter periods than boilers. Consequently, the greatest stationary source NO_x reductions will be realized by controlling utility boilers.

There are generally three ways that NO_x emissions from boilers can be reduced:

- *Fuel conversions, which reduce NO_x emissions by burning fuels with lower nitrogen contents – for instance, changing from coal to oil or natural gas, co-firing natural gas with oil, or switching to a lower nitrogen content coal or oil;*

- *Combustion modifications, which reduces the amount of NO_x that is formed during the combustion process, including such techniques as **low-NO_x burners** or **overfire air**; and*

- *Post-combustion control equipment, which reduces NO_x after it has formed by injecting a reagent (e.g., ammonia) into the exhaust gas to convert NO_x into atmospheric nitrogen and water, including such control devices as **selective catalytic reduction** (SCR) and **selective non-catalytic reduction** (SNCR).*

In April 1993, Maryland adopted RACT regulations mandating NO_x reductions from existing fuel-burning equipment. For boilers, utilities have the option of meeting prescribed emissions limits, which are based on the type of fuel burned and the particular boiler design, or of submitting a RACT proposal with an alternative emission limit for review. RACT proposals that have been submitted by the Maryland utilities suggest that combustion modifications, as opposed to any type of post-combustion controls, will meet RACT requirements. The NO_x controls were required to be implemented by May 1995.

For proposed new fuel-burning equipment subject to LAER, routine combustion controls (e.g., standard low-NO_x burners) alone probably will not be sufficient to satisfy the regulatory requirements. For example, Delmarva Power is planning to use SCR in conjunction with low-NO_x burners to meet LAER requirements for NO_x emissions for its proposed Dorchester plant, a 300-MW coal-fired unit. This control scheme will reduce NO_x emissions by more than 70% from uncontrolled levels. Although SCR has been used on coal-fired units in Europe and Japan for a number of years, there are currently only about five coal-fired boilers in the United States that use (or propose to use) SCR.

Tradeoffs of Control Options

Selecting one control strategy over another often involves an environmental tradeoff. In some instances, one pollutant can increase as a result of reducing another. For example, using a common technology called water injection to control NO_x emissions from combustion turbines results in an increase of both CO and unburned hydrocarbon emissions. Similarly, the use of SCR technology results in ammonia emissions. Some control technologies transfer contaminants

Regional NO_x Strategy

On September 27, 1994, air quality officials from Northeastern and mid-Atlantic states voted to develop regulations reducing NO_x emissions by at least 55% from 1990 levels by May 1, 1999. The action is part of an effort to move the Ozone Transport Region (OTR) into attainment of the Federal ozone standard. Nearly all of the reductions will come from utility boilers. The Memorandum of Understanding (MOU) splits the OTR into three regions: the inner, outer, and northern zones. The inner zone extends from Washington, D.C., to southeastern New Hampshire. Major stationary NO_x sources in this zone must either meet a 65% reduction, or comply with a NO_x emission rate of 0.2 lb/MMBtu. The MOU also requires the Ozone Transport Commission to develop a region-wide trading program, an element that many industry representatives feel is vital to achieve the required NO_x reductions. Furthermore, under the MOU, the states must re-evaluate the need for controls prior to implementing the reductions requirements, to assess their effectiveness towards achieving the ultimate MOU goals.

from one environmental medium to another (such as from the air to a solid waste). For example, periodic replacement of the catalyst used in SCR results in generation of a hazardous waste. In the case of low-NO_x burners in boilers, unburned fuel (in the form of carbon) present in the ash is not uncommon; however, high-carbon carryover can reduce the commercial use of the ash. Post-combustion technologies, such as SCR, using ammonia injection for NO_x control have also been found to contaminate ash, possibly hampering its reuse. Tradeoffs also occur in generating efficiency with different pollution control systems. For example, water injection can increase the power output of a combustion turbine, while the use of an SCR system can reduce efficiencies. Aspects of the environmental tradeoffs are considered by the regulators and affected utilities to select the best economic and technically feasible control strategy.

Power Plants and Acid Rain

Power plant emissions contribute to another regional air quality problem — the formation of acid rain. Acid rain is produced by the reaction of precursor compounds, SO_2 and NO_x, with water in the atmosphere to form sulfuric and nitric acids.

The majority of SO_2 emissions, and a significant but smaller percentage of NO_x emissions, arise from the burning of fossil fuels in power plants and other combustion sources. In Maryland, power plant emissions account for 35% of the total NO_x emissions, by far the largest point source contributor (see Figure 3-2). Maryland power plants are responsible for roughly 85% of the total SO_2 emissions.

From 1960 until 1970, nationwide SO_2 emissions increased by approximately 40%. Emissions of NO_x steadily increased by nearly 50% between 1960 and 1980. However, emissions of both precursors have generally declined during the past decade.

Regulatory Approaches to Reducing Acid Rain

Title IV of the CAA Amendments of 1990, the acid rain program, sets forth an innovative program to control acid rain precursor emissions. The program is directed primarily toward coal- and oil-burning utility plants, because of the magnitude of their SO_2 and NO_x emissions.

The acid rain program mandates significant SO_2 and NO_x reductions. Power plants must meet a national emissions cap of 8.9 million tons of SO_2 per year from all electric utilities across the United States, a reduction of 10 million tons per year compared to 1980. These reductions will be achieved in two phases. In Phase I, which begins in 1995, the 110 largest utility plants located in 21 eastern and midwestern states, including six units at three power plants in Maryland, must meet an intermediate SO_2 emissions limitation. In Phase II, beginning in the year 2000, the annual emission limits imposed on the Phase I plants will be tightened, and the number of plants subject to the limits will be greatly expanded.

The acid rain program also calls for a reduction of approximately two million tons per year of NO_x emissions below 1980 levels. Utility coal-fired boilers will be required to meet new emissions standards based on the installation of low-NO_x burner technologies. Because Maryland is part of the Northeast Ozone Transport Region, utility boilers here will have to comply with RACT emission limits for NO_x that may be more restrictive than those under Title IV.

The centerpiece of the acid rain program for SO_2 control is a pollution trading system based on the use of marketable emission **allowances**. An allowance is effectively a permit to emit one ton of SO_2. Existing electric utility units are granted annual allowances based on their historic fuel use and the emission limitations specified in the acid rain program. Beginning in 1995, each utility must ensure that SO_2 emitted from its Phase I units does not exceed the total number of allowances held by those units. Under Phase II, which begins in the year 2000, virtually all units will have to hold allowances to cover their emissions, and utilities must demonstrate compliance on a system-wide basis. New generating units (units starting commercial operation after 15 November 1990) must obtain allowances before beginning operation.

The market-based allowance approach is designed to allow utilities to meet their emission control requirements in the most cost-effective manner possible. As part of its compliance strategy, a utility may install SO_2 emission controls, switch to fuels that contain less sulfur (either lower-sulfur coals or oil or natural gas), or purchase allowances from another utility. Utilities may purchase allowances from distant utilities, even ones that are out of state. For example, an early SO_2 allowance trade involved Wisconsin Power selling 10,000 allowances to the Tennessee Valley Authority. The rationale behind such long-distance trading is that acid rain is a regional problem, caused by emissions over a large area, not by sources concentrated in a particular location. Consequently, the specific location in which the emission reductions actually occur is unimportant, assuming the total regional reductions are achieved.

In addition to individual private sector trades, Title IV mandates that the U.S. EPA establish a special allowance reserve containing allowances to be offered for auction or direct sale. The auction and sales programs are intended to stimulate the market in allowance trading and help establish an early market price for allowances. In the fall of 1992, the U.S. EPA delegated the administration of the auctions and sales to the Chicago Board of Trade, which has held annual auctions since.

Power Plant SO_2 Control Options

Emissions of SO_2 from combustion sources result from the oxidation of sulfur and sulfates contained in the fuel. Unlike NO_x emissions, SO_2 emissions are not affected by conventional boiler modifications. For conventional boilers, the alternatives for limiting the amount of sulfur in the exhaust gas are to: 1) limit the sulfur contained in the fuel, or 2) remove the SO_2 after it has been formed during combustion.

A common way to limit the sulfur contained in the fuel is to simply switch to a fuel that contains less sulfur. Most often this involves changing from a higher to a lower sulfur content coal. Coals with

SO_2 Allowance Trading

On 27 March 1995, the third annual SO_2 allowance auction was conducted by the Chicago Board of Trade. More than 176,000 allowances were sold; prices ranged from \$1 to \$350 each, with a typical price in the \$100 to \$150 range. Allowance Holdings Corporation, Duke Power Company, and Virginia Power were top bidders in terms of number of allowances purchased. The sales from the 1995 auction totaled roughly \$22.8 million, down nearly \$4 million from the 1994 auction. Substantial trades and direct sales also occur throughout the year independent of the annual SO_2 allowance auctions. Like the annual auctions, the U.S. EPA administers these sales through the Chicago Board of Trade. EPA is expecting prices and trading activity to increase as Phase II approaches (1997-1998 time frame).

lower sulfur content may also have other characteristics that differ from the coal currently used. Power plant boilers are designed to burn coal with a specific range of characteristics, so utilities must evaluate potential lower-sulfur coals carefully before switching fuels. In general, fuel switching options involve relatively low capital investment and can be implemented in a short time frame. A potential risk with fuel switching, however, is the uncertainty in the future cost and availability of low-sulfur fuels.

For the second alternative, the SO_2 emissions can be reduced by a **flue gas desulfurization** system, otherwise known as a scrubber. Scrubbers are commercially proven pollution control systems that can remove SO_2 very efficiently. However, potential drawbacks of scrubbers include the high capital and operating costs, some loss of generating efficiency of the power plant, and the production of relatively large amounts of by-product, which may present a costly disposal problem.

Some advanced combustion technologies, such as fluidized bed combustion (FBC), achieve SO_2 removal in the combustion zone as it is being created. FBC technology results in high generating efficiency, but retrofitting requires significant capital expenditure. FBC boilers also create a large amount of solid by-product.

Generally, power plants that have the largest SO_2 reduction requirements may consider the more capital-intensive strategies, such as installing scrubbers. On the other hand, utility units with more modest SO_2 reduction requirements may find that fuel switching is more cost-effective. A third option for a source is simply the purchase of emission allowances from other sources, without any SO_2 emission reduction. Naturally, the costs for control equipment, fuel, and allowances must all be factored into a utility's compliance strategy.

SO_2 Control Plans for the Maryland Utilities

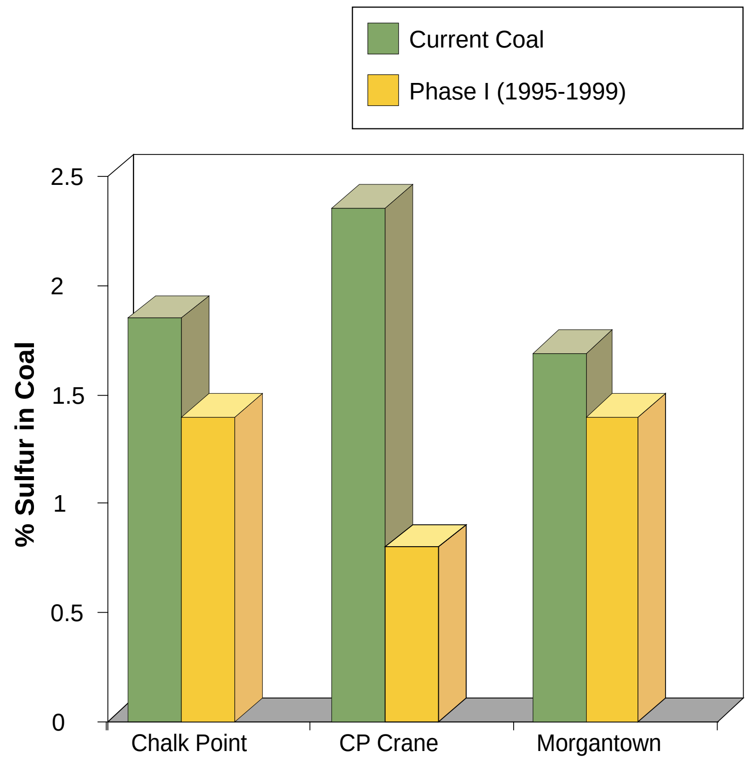
Two electric utilities have generating units in Maryland that are subject to acid rain controls in Phase I: PEPCO's Chalk Point Units 1 and 2 and Morgantown Units 1 and 2; and BGE's C.P. Crane Units 1 and 2. Under Phase II (beginning in 2000), virtually all generating units in Maryland will be affected. Maryland utilities have outlined Phase I acid rain control strategies, but due to uncertainties in fuel prices and allowance prices, compliance strategies for Phase II are not yet finalized. Utilities must file their Phase II compliance plans with the state by early 1996.

Both PEPCO's and BGE's plans for Phase I include substantial SO_2 emission reductions at the Conemaugh plant located in Pennsylvania, a plant in which both utilities (in addition to others) share ownership. The owners of the Conemaugh units have elected to install high-efficiency SO_2 scrubbers on two generating units; this measure will reduce emissions beyond the level required in Phase I, thereby generating excess allowances that can be applied elsewhere or sold. PEPCO and BGE planned to use a portion of these excess allowances and burn lower sulfur fuels (i.e., lower sulfur coals and/or natural gas) to comply with Phase I (see Figure 3-3). During 1994, EPA approved the Maryland utilities' Phase I compliance plans.

To meet Phase II requirements, PEPCO and BGE are evaluating installing scrubbers, using even lower-sulfur coal, burning more natural gas, and purchasing allowances when economical. BGE also may benefit from the possible installation of a scrubber at the Keystone power plant in Pennsylvania, a plant in which BGE has part ownership.

Generally, Maryland utilities have emphasized flexibility in their acid rain compliance plans. To date, no utility has proposed a scrubber for any existing generating units at Maryland power plants to achieve SO_2 reductions. The cost of lower-sulfur coal, which will likely increase due to increased demand, and the market price of allowances will have a large impact on the future compliance actions taken by Maryland utilities. PPRP has had continuing contact with the utilities on the status of their compliance plans, and participated in hearings before the PSC on PEPCO's Phase I proposal. The goal of PPRP's involvement is to ensure that all facets of compliance alternatives are considered.

Figure 3-3
Average Coal Sulfur Content for Phase I Affected Maryland Power Plants



Biological Effects of Acid Deposition

The formation of acid rain, or **acid deposition**, has been evaluated in a number of projects nationally over many years. Years of research have enabled scientists to characterize the types and amount of emissions of acid deposition precursors. However, researchers have found it more difficult to discern how acid deposition actually affects terrestrial and aquatic resources. As a result, Congress created the National Acid Precipitation Assessment Program (NAPAP) in 1980 to conduct scientific and economic analyses of the causes and effects of acid deposition.

In addition to federal research efforts, PPRP has conducted a substantial amount of research on the generation and effects of acid deposition in Maryland. This research program is ongoing, and the state has sponsored a variety of acid deposition studies in recent years. Projects have been designed to evaluate the effects of acid deposition on resources unique to Maryland or to address topics important to understanding acid deposition in Maryland that are not being studied elsewhere. Recent research has focused on three areas:

- *acidification processes and biological effects,*
- *mitigation, and*
- *"critical loads."*

Acidification Processes and Biological Effects

Studies have shown that the deposition of acidified materials can affect terrestrial and aquatic resources. The magnitude and type of impact of the acid deposition, however, depends on a variety of complex factors, including the amount of materials deposited, the relative ability of the water body or soils to buffer the effects of the acidity, the sensitivity of organisms to pH changes, and the types and amount of vegetation. PPRP has examined a number of these processes in recent years because studies have shown that some aquatic resources in Maryland are particularly sensitive to acid deposition. The goal of much of Maryland's acid rain research is to generate information needed for effective management, including mitigation, of the acid deposition problem in Maryland.

The statewide, multi-year Maryland Biological Stream Survey (MBSS) was initiated in the 1990s to assess the status and trends of biological resources. The MBSS collects information on aquatic biota (fish and macroinvertebrates), physical habitat, and water quality to assess the fishability and biological integrity of Maryland streams. The MBSS will yield a comprehensive assessment of the extent to which acidic deposition may be affecting critical biological resources within streams of the state. Other studies have evaluated and developed the **index of biotic integrity** (IBI) approach to characterizing stream health, which takes into account water quality, physical habitat, land use, and watershed area, among other factors. The IBI approach shows promise as a tool for assessing impacts of acid deposition, and interest is growing in using the approach for assessing other types of impacts.

Other research has focused on **episodic acidification**, a short-term peak in acidity caused by an acid rain event or runoff of acidic materials from the ground into a stream or lake. PPRP is currently sponsoring the development of mathematical models for identifying streams in western Maryland at risk of episodic acidification. The objective of the project is to determine if the combinations of models and data can identify the streams most at risk. These streams would then form the pool of candidate streams for acid deposition mitigation in that region of the state.

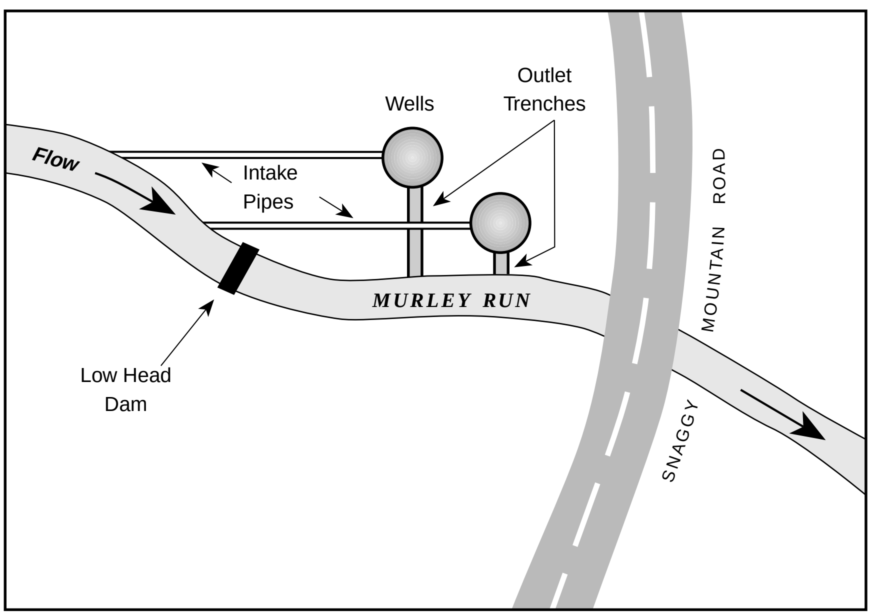
Mitigation

Once it is determined that streams, fish, or other wildlife habitats are sensitive to acid deposition and that impacts have occurred, questions are raised about how the impacts can be mitigated. Maryland has conducted a number of research projects to investigate the effectiveness of various liming applications to mitigate acidification of Maryland surface water bodies. A series of Maryland studies investigated the use of automated stream liming devices to neutralize acidic episodes in several Maryland Coastal Plain streams. In these projects, researchers operated **dosers** in study streams, which automatically release liming materials at preset intervals into the streams. Although the dosers were able to mitigate acidic pulses during storm events, the devices experienced mechanical breakdowns and power failures during long-term use.

In addition to direct stream liming, PPRP has been evaluating a different type of mitigation technique for acidified streams known as **watershed liming**. With this technique, limestone materials are placed over the land area of a watershed and natural precipitation processes wash the limestone into the stream over time, instead of a doser applying the materials directly to the stream. PPRP has conducted a watershed liming pilot project at Alexander Run in Garrett County; however, no long-term change in the water chemistry of Alexander Run has been observed. This suggests that the ground water that provides base flow to the stream is not coming in contact with the limed soils. Hydrologic event monitoring will help determine whether watershed liming can be an effective mitigation method in this system.

Maryland recently launched another demonstration project for two innovative mitigation designs: diversion wells and constructed wetlands. Diversion wells have been successful in Sweden, but have only been implemented at a few sites in the United States. They involve diverting the acidic water from the stream into a cylindrical concrete well with limestone on the bottom; neutralized water is then returned to the stream (Figure 3-4). Constructed wetlands have never been attempted as a mitigation for acid deposition, but they could provide an economical means of raising stream pH, while at the same time contributing wildlife habitat and other benefits to the landscape. If successful, these methods can be added to the repertoire of potential mitigation alternatives for acid streams in Maryland.

Figure 3-4
Use of Limestone Diversion Well for Acid Mitigation in Western Maryland

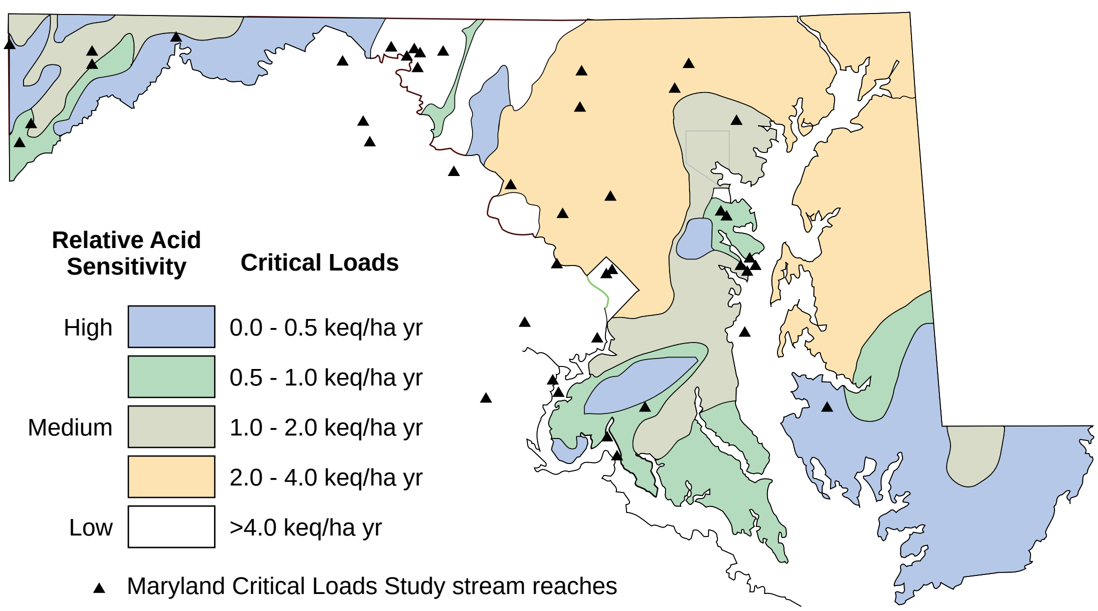


Critical Loads

Maryland has also sponsored studies to determine the **critical loads** of streams. The critical load for a particular location is defined as the level of acidic deposition below which adverse impacts to sensitive biological resources would not be expected. Maryland's research in this area, which began in the late 1980s, is being conducted to determine the critical loads of sulfur and nitrogen that can be accommodated by sensitive Maryland streams without causing further acidification. The work is also used to evaluate the ability of various precursor emission control strategies at power plants to achieve these critical load targets.

The critical load map for Maryland (Figure 3-5) illustrates that the Appalachian Plateau, the Coastal Plain, and portions of the Blue Ridge provinces of Maryland all are highly acid sensitive, as indicated by the low critical load values for acid precursors. Streams in other parts of the state may accommodate deposition rates approximately an order of magnitude higher. The Maryland Critical Loads Study concluded that some streams in Maryland are still acidifying under the present deposition load, as determined by mapping steady-state stream chemistry. By comparing current deposition rates to critical loads calculated for particular watersheds, sensitive locations in Maryland can be identified. The critical load values can be used as a reference point for judging the benefits of lower sulfate and nitrate deposition rates. At those Coastal Plain and Appalachian Plateau sites that have very low critical loads, research indicates that deposition would continue to exceed critical loads even if all Maryland power plant emissions were eliminated.

Figure 3-5
Critical Loads for Streams in Maryland



Power Plants and Regional Haze

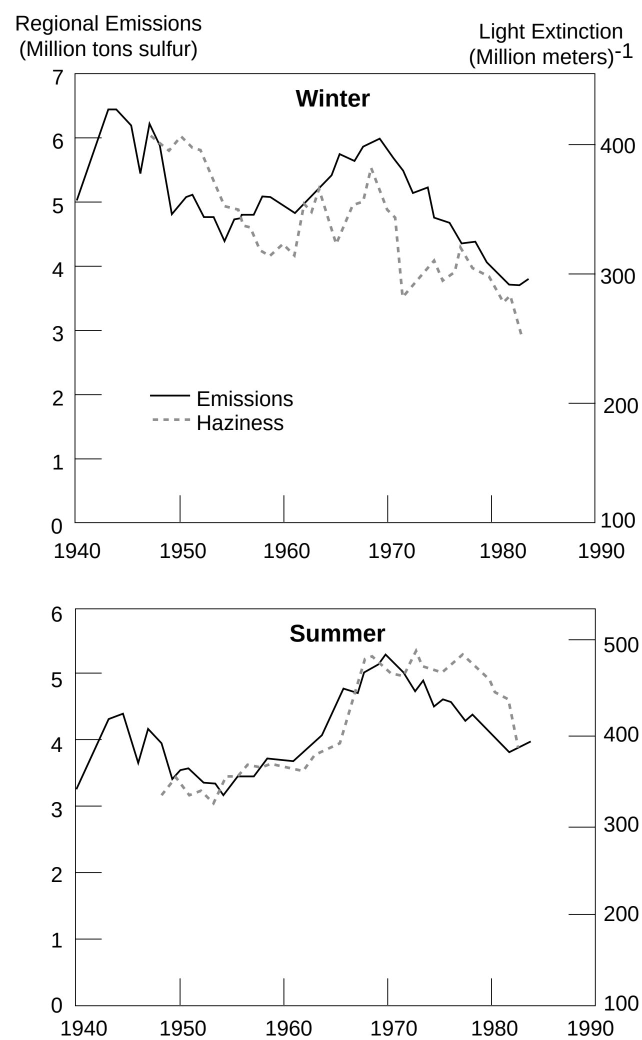
Visibility

Reduced visibility, particularly in the summertime, often results from pollutants building up in stagnant air, leading to a widespread, uniform haze. These air pollution events or episodes may be the most noticeable effects of anthropogenic pollution. Recent studies have shown that 80% of people are aware of poor visual air quality. Much of the concern today regarding visibility deals with the aesthetic value of a scenic vista. If the atmosphere is sufficiently hazy that an object is barely perceptible, then in the eyes of most people the object has essentially no scenic value.

Visibility impairment can be caused by a variety of processes, both natural and of human origin. For example, fog is a naturally occurring form of visibility impairment, while air pollution is a form of visibility degradation resulting from human activities. While anthropogenic sources emit a variety of air pollutants, power plants emit two pollutants in particular that can have a deleterious effect on visibility: SO_2 and NO. SO_2, as it travels through the atmosphere, converts to sulfate particles. These particulates scatter light efficiently, and thereby reduce visibility. The National Park Service (NPS) has stated that sulfates are the most important contributor to visibility degradation in the parks of the eastern United States. NO, as it travels through the atmosphere, converts to NO_2, a precursor to nitric acid. At high concentrations, the presence of NO_2 can be detected by the brownish color of the sky, as visible light is absorbed by NO_2.

Over the past 50 years or so, the northeastern United States has experienced a decline in haziness during the winter months while the amount of summer haziness has generally increased. The haziness increased the most in the 1950s and 1960s, then leveled off and even decreased after the early 1970s. Total sulfur emissions have followed a similar pattern, with sulfur emissions peaking about 1970 and then decreasing in the following years. The correlation between these two parameters is depicted in Figure 3-6.

Figure 3-6
Comparison of Historical Trends for Sulfur Emissions and Haziness (light extinction) for the Northeast U.S.

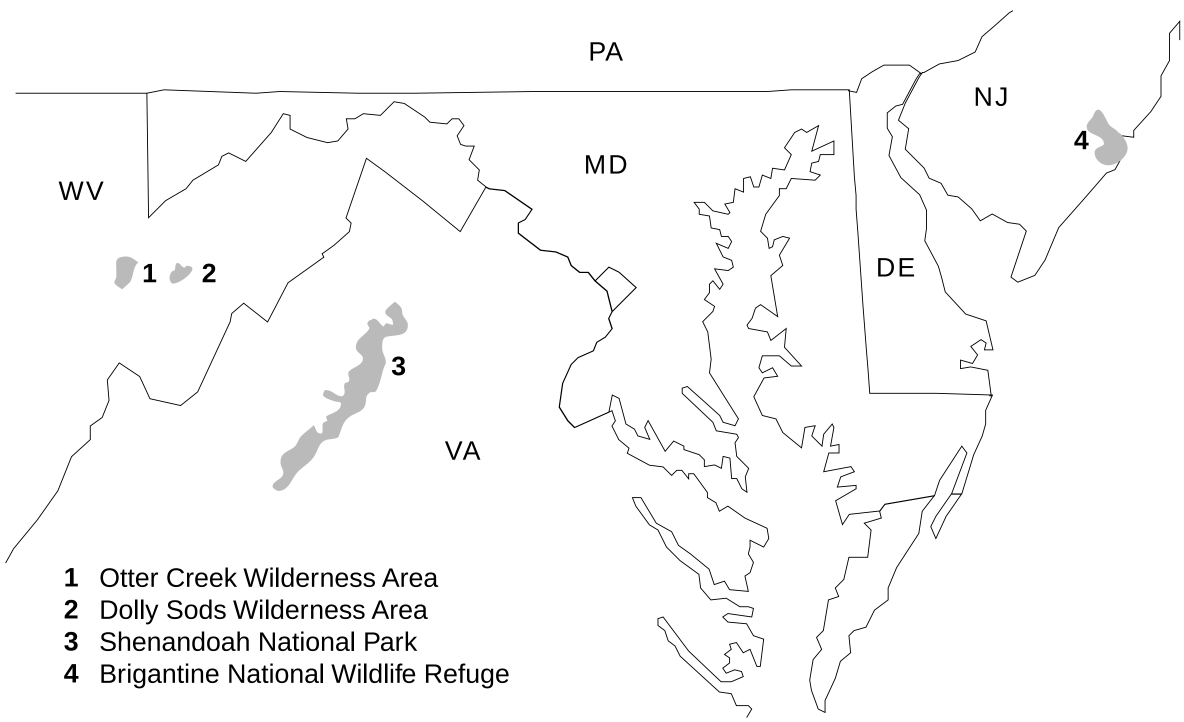


Millions of people visit national parks and wilderness areas throughout the United States each year. Although people visit these places for a variety of reasons, an often-cited reason is for the scenic vistas. As a result, the NPS and the U.S. Forest Service are particularly concerned with regional haze and visibility degradation. In general, visibility at national parks is poorest during the summer when visitation is highest.

Recent Impact Assessments

In 1979, the U.S. EPA promulgated a list of **Class I areas** (national parks with an area greater than 6,000 acres, or national wilderness areas with an area greater than 5,000 acres) across the country where visibility is considered an important value. Congress gave the Federal Land Manager at each national park and wilderness area the responsibility to protect the air quality related values (AQRVs), including visibility, of such lands. In recent years, Federal Land Managers at Class I areas have been requiring air permit applicants to conduct more extensive, detailed analyses of the effects of proposed emissions on AQRVs. The four Class I areas closest to Maryland are indicated in Figure 3-7.

Figure 3-7
Federal Class I Areas in States Surrounding Maryland



Recently, two proposed coal-burning power plants — one in western Maryland and the other on Maryland's Eastern Shore — had to assess their impacts at nearby Class I areas as part of the permitting process.

- *Applied Energy Systems, Inc. (AES) addressed the effects on visibility at Shenandoah National Park in Virginia, and the Dolly Sods and Otter Creek Wildernesses in West Virginia, due to emissions from the proposed Warrior Run cogeneration facility in*

Cumberland. Using state-of-the-art plume optics models and NPS-approved methodologies, AES established that its proposed project would not adversely affect visibility at the three Class I areas.

- *Delmarva Power assessed potential visibility impairment due to emissions from the proposed Dorchester power plant near Vienna at the nearest Class I area, the Brigantine National Wildlife Refuge in New Jersey, using standard U.S. EPA conservative modeling techniques. Delmarva Power's analysis indicated that the proposed plant would have no adverse effects on visibility at Brigantine.*

Water Impacts

Water is a vital resource for power plant operation. The construction and operation of power plants can impact Maryland's surface water and ground water resources, as outlined in the following sections.

Surface Water Impacts

Steam generating power plants use large volumes of water for cooling. In Maryland, the Chesapeake Bay is the major source of this water. The Bay also receives most of the effluents, or wastewater discharge, from power plants in the state. Both withdrawal and discharge of water at power plants can adversely affect surface waters.

Hydroelectric power plants also use vast amounts of water. These plants use impounded water produced by the damming of rivers to generate electricity. Inundation of land, blockage of rivers, and changes in water quality both upstream and downstream may result from construction and operation of these facilities.

This section focuses on the nature and extent of surface water impacts from these two types of power plants found in Maryland.

Water Withdrawal and Consumption

Steam generating power plants need water to cool operating equipment. In a **once-through cooling system**, water is drawn continuously into a power plant from a **source water body** and is used to draw the heat from the power plant condensers. This heated water is then discharged into a **receiving water body** (usually the same as the source). Once-through cooling systems require large volumes of water — a fossil fuel-fired plant with once-through cooling uses about 1.4 million gallons of cooling water per day for each MW of electricity produced. Nuclear power plants, such as the Calvert Cliffs plant, generate more waste heat than fossil fuel plants and therefore must use more water per MW for once-through cooling.

Closed-cycle systems are used at three major Maryland power plants: Brandon Shores, Chalk Point, and Vienna. These systems recycle cooling water and typically require only 2 to 25% of the water needed for once-through cooling systems. However, as much as half of the water withdrawn is **consumed** (used and not returned) due to evaporation. Steam electric plants in Maryland consume nearly 70% of the total freshwater consumed in the state by all sources.

Impacts of Steam Electric Power Plants

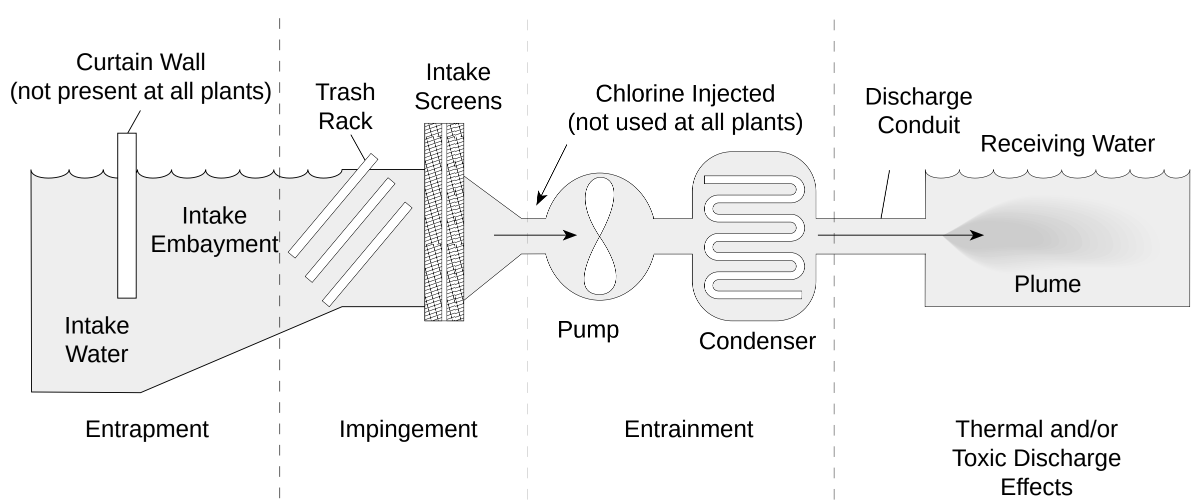
In Maryland, most cooling water is drawn from the Chesapeake Bay or one of its tributaries. Although there is ample water available in the Bay for cooling purposes, adverse environmental effects can result from withdrawing, heating, and discharging such large volumes of water. The ways in which aquatic organisms are impacted by power plant operations include:

- **Entrapment** - *accumulation of fish and crabs (brought in with cooling water) in the intake region;*
- **Impingement** - *trapping of larger organisms on barriers such as intake screens and nets;*
- **Entrainment** - *drawing in of plankton and spring fish through plant cooling systems; and*
- **Discharge Effects** - *adverse impacts of exposure to heated effluents and toxic discharges.*

Figure 3-8 illustrates where these impacts occur.

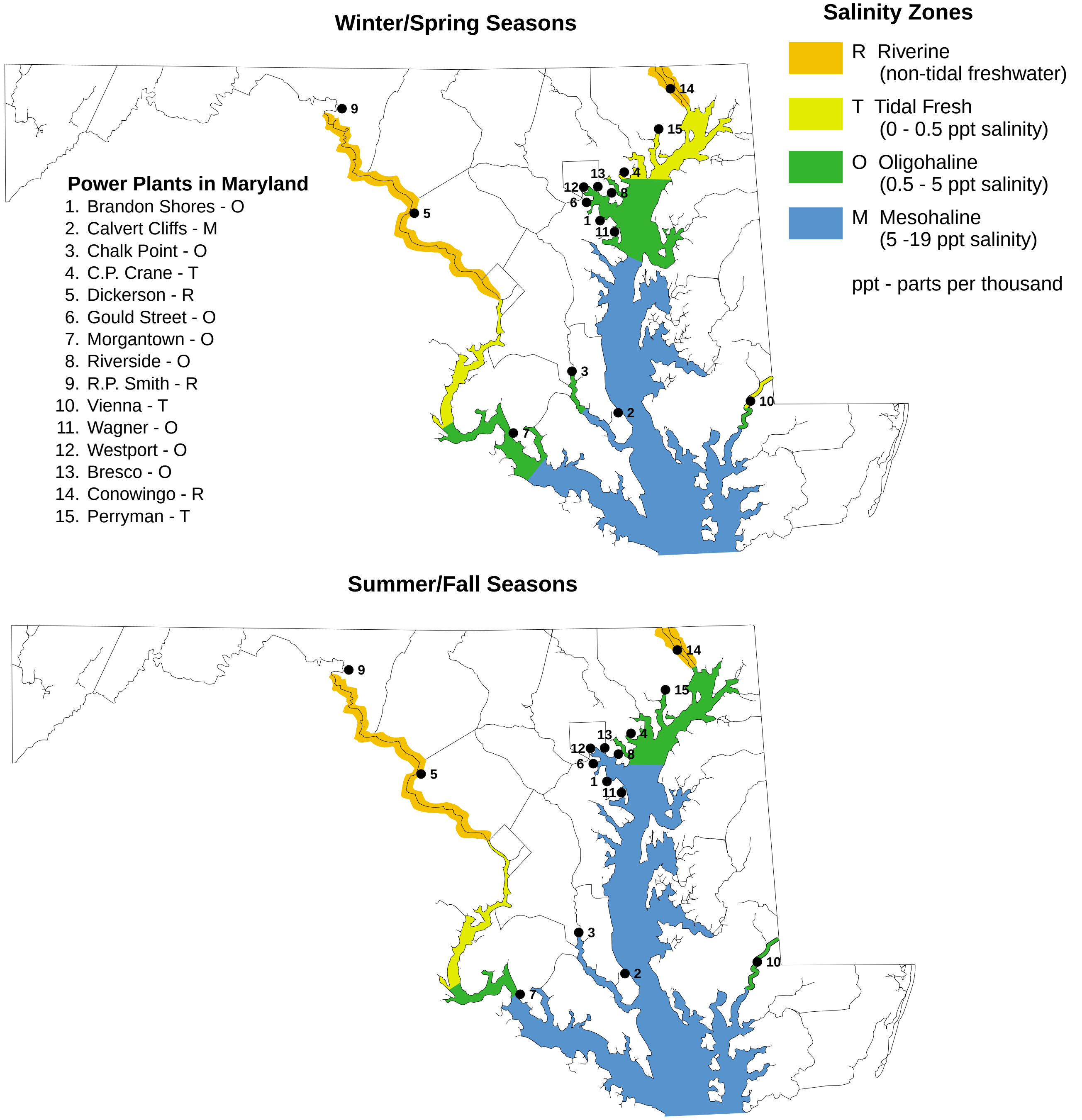
Any new thermal discharges and withdrawals of water for cooling purposes must comply with state water quality regulations. These regulations allow a certain area within the receiving water body in which thermal discharges may mix (a mixing zone).

Figure 3-8
Water Flow Through a Power Plant Using Once-through Cooling



PPRP and Maryland's utilities have evaluated impacts at 12 major power plants in the state over the last two decades, conducting several dozen studies on the nature and extent of entrainment, impingement, and discharge effects. These studies were used to evaluate the relative impacts of power plant operations on the aquatic environment in the state, with special emphasis on the Chesapeake Bay. Some studies were also used as the basis for modifying operating proce-

Figure 3-9
Salinity Zones of the Maryland Chesapeake Bay



dures at the plants to minimize impacts and to provide dollar cost estimates of unavoidable losses in aquatic biota.

Several **habitat types** exist in the Chesapeake Bay, which are defined by salinity zones (Figure 3-9). Each habitat type supports a different mix of biological communities. Each community will react differently to the stresses of entrainment, impingement, and discharge effects; consequently, the impact of power plant operations varies among habitat types. Results of PPRP's many impact studies are summarized below by salinity zone.

Mesohaline Zone (Lower Bay)

Results of studies at all power plants in the **mesohaline** zone, which is a primary shellfish production area, show that there have been no cumulative impacts to aquatic resources to date. Although large entrainment losses of some types of aquatic organisms, known as phytoplankton and zooplankton, have been measured frequently, no consistent depletions in numbers of organisms have been found. This is most likely due to the fact that these small organisms have short generation times (hours to days), and therefore populations recover quickly from entrainment.

The only power plants in this type of habitat that may affect riverwide fish spawning and nursery areas are Chalk Point and Wagner. At Chalk Point, this potential loss is being mitigated with a program to rear and stock fish in the Patuxent River and to remove blockages to migratory fish. At Wagner (located in Baltimore's outer harbor), data from recent field studies indicate that entrainment impacts are much smaller than previously believed and mitigative measures may not be warranted. Power plants in the mesohaline zone impinge large numbers of juvenile fish and crabs; however, fish and crab losses do not cause measurable depletions in these species because of the large size and wide distribution of their populations.

Tidal Fresh - Oligohaline Zones

Studies indicate that entrainment losses from power plants in these zones, which are spawning areas for some fish such as striped bass and white perch, are small and do not affect regional populations. Many organisms in these habitats survive impingement; the major species that are impinged are abundant throughout Maryland's tidal waters. Impingement losses are too small to have a detectable effect on regional fish populations.

Riverine (Non-tidal Freshwater) Zone

Studies in this habitat zone, which is a major spawning area for many types of fish, have shown that, in general, entrainment and impingement impacts are small. There are some discharge effects in this habitat, but they are localized. None of the studies have identified long-term cumulative impacts from these facilities.

Reducing Aquatic Impacts

Numerous **intake technologies** and modifications to operating practices have been developed to reduce entrainment or impingement impacts at steam electric power plants. However, relatively few have the ability to reduce both entrainment and impingement impacts. PPRP has investigated the applicability of several intake technologies to Maryland's power plants and ecosystems.

Intake technologies can be classified into three categories: **physical barriers**, **behavioral barriers**, and **collection**. Physical barriers, such as screens or nets, are the most successful for reducing both entrainment and impingement.

Barrier nets are generally economical to install and maintain, particularly for retrofitting at older plants. Nets reduce impingement effectively in both estuarine and freshwater habitats. Wedge-wire screens are moderately expensive to retrofit into existing power plants or to install into new plants. Their fine wire mesh keeps entrainment low and essentially eliminates impingement. Small spacing makes the screens susceptible to clogging due to biofouling, although air backflushing minimizes this problem. Wedge-wire screens are successfully employed on the Delaware River and are currently being incorporated in the design of the Dorchester power plant in Maryland.

Behavioral barriers, such as air bubble curtains and sound, are designed to cause fish to avoid intake flows. These barriers have been found to be moderately effective in reducing impingement of schooling fish, but are unsuccessful for protecting other types of fish from impingement, or at reducing entrainment and impingement of fish in early life stages.

Collection of organisms after impingement is only 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 returned to the receiving water body near the intake structure, may be susceptible to reimpingement. The Morgantown power plant has redesigned its fish return system to be capable of returning fish to either side of the intake structure depending on the direction of the tide, thus reducing the potential for reimpingement. Similarly, the fish return system installed at BGE's Wagner power plant places impinged fish into a channel leading away from the intake screens.

Modification of plant operations is frequently the most cost-effective approach for reducing many aquatic impacts. Two operating practices that PPRP has evaluated are modifications to **intake screen wash cycles** and the use of **auxiliary tempering pumps**. Intake screens at Maryland power plants are rotated on a frequency of anywhere from once per day to continuously. Increasing the frequency of rotation does not alter the rate of impingement, but it can be beneficial by reducing the amount of time organisms are exposed to scavengers and conditions leading to suffocation.

Auxiliary tempering pumps were used at Chalk Point until the 1980s. This type of system withdraws surface water to mix with the plant's discharge and to decrease the effects of thermal and chemical water discharges. Studies by both PEPCO and PPRP, however, showed that turning off the pumps would reduce entrainment and impingement while not increasing downstream mortalities significantly. PEPCO has now discontinued use of the pumps.

Another method of reducing aquatic impacts of power plants is requiring out-of-kind mitigation. Examples applied within the state of Maryland include production and release of hatchery reared fish, and participation in stream blockage removal programs to provide anadromous fish access to spawning habitats. Both a hatchery and a stream blockage removal program have been instituted to offset losses at PEPCO's Chalk Point facility; similar elements have been included as a license condition to the proposed Dorchester power plant on the Nanticoke River.

Impacts of Hydroelectric Facilities

Nine hydroelectric projects are operating in Maryland. The largest facility in Maryland is the Conowingo Hydroelectric Station, with a capacity of 512 MW. The second largest is Deep Creek Station, with a capacity of 19.2 MW. Seven smaller projects around the state have a combined capacity of 3 MW. The development and operation of hydroelectric facilities can cause three types of impacts — alteration of water quality, fluctuations in water level and flow, and prevention of fish passage.

- Alterations of water quality - *Hydroelectric generation can affect water clarity, dissolved oxygen (DO) concentration, and water temperature both upstream and downstream of the dam.*

- Fluctuations in water level and flow reductions - *Operating hydroelectric facilities in a* ***peaking mode*** *(that is, not continually but in response to peak demand for electricity) produces unnatural, and frequently extreme, water level fluctuations in impoundments and in aquatic habitats downstream of dams. Small-scale hydroelectric projects may also divert some streamflow away from the natural streambed. Fluctuations in water level and flow may reduce the abundance of food important to fish growth and survival.*

- Prevention of fish passage - *Hydroelectric development can prevent the movement of both resident and anadromous fish species past the dam. Entrainment through turbines may kill fish, depending on the type of turbine, the proportion of flow diverted through the turbine, and the size of fish passing downstream.*

In Maryland, there are two general concerns about fish passage through hydroelectric facilities: 1) interruption of the migratory patterns of fish (primarily shad, herrings, and striped bass) that swim upstream to reproduce; and 2) fish mortality in the turbines, which can reduce resident fish populations. Studies to date on fish passage at small facilities in Maryland have only been conducted where resident fish were of concern. These studies indicate that there is some turbine-related mortality of fish. However, the magnitude of this effect varies between sites, suggesting the need for evaluation at each project.

Small-scale hydroelectric projects in Maryland undergo a review process that allows for early involvement by state resource agencies. By this means, PPRP has been able to work with developers to mitigate potential impacts before a hydroelectric plant is constructed. Where potential impacts could not be addressed fully before construction, monitoring programs to measure the degree of impact have been required of the developer or conducted by PPRP.

The state has devoted substantial study to potential impacts of the Conowingo hydroelectric station on the Susquehanna River operated by PECO. Significant stocks of resident and anadromous fish species, such as channel catfish, white perch, striped bass, and river herring, occur downstream of the dam. Historically, the Susquehanna River supported large spawning runs of anadromous species such as American shad. Sport fishermen regularly visit the region, and surveys suggest that the area has been one of the most intensively fished locations in the state.

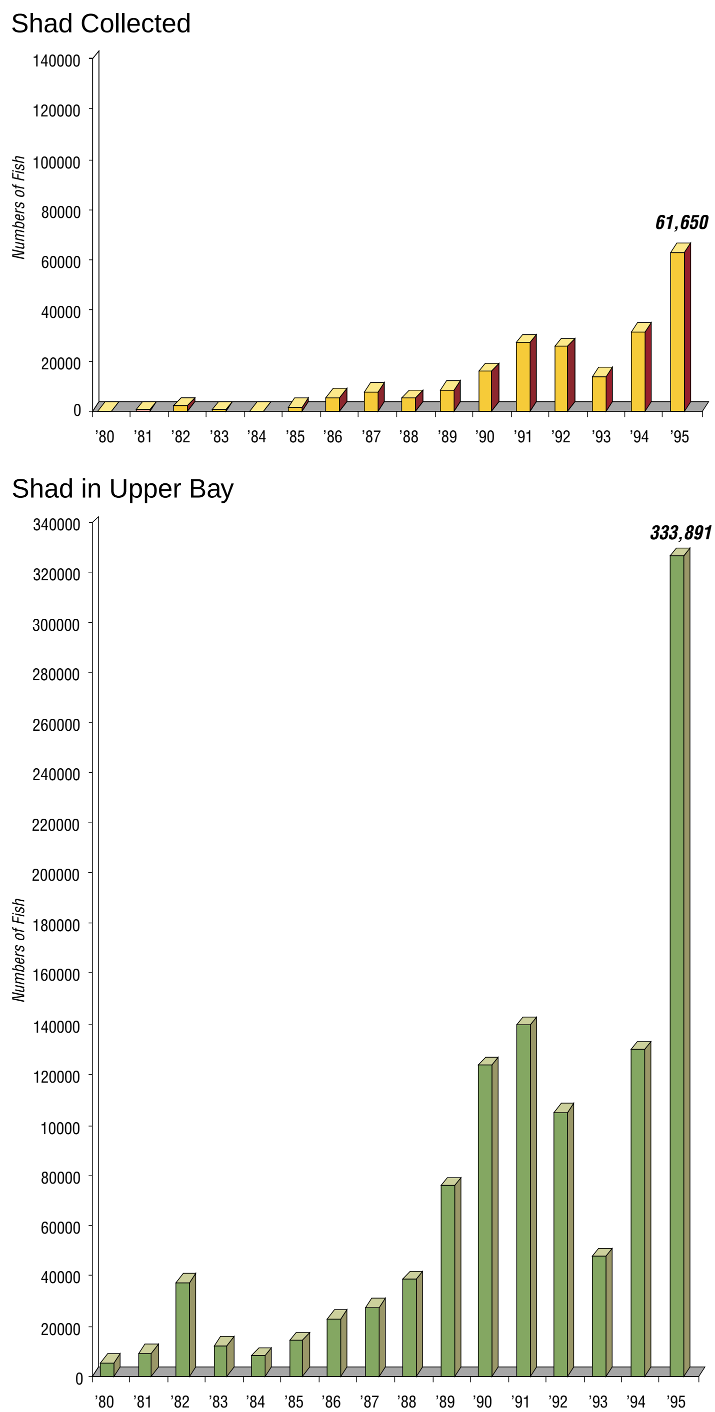
Dam operations at Conowingo control water levels and flows in downstream aquatic habitats, thereby directly affecting the abundance and type of food organisms available for fish. During peak electricity demand periods in the summer, river water upstream of the dam, if released unconditioned, often has low DO concentrations, which can cause poor water quality downstream of the dam. The dam has also prevented anadromous fish from reaching spawning areas upstream. After many years of negotiation, the Federal Energy Regulatory Commission (FERC), the State of Maryland, and PECO reached agreement in 1988 to address these problems in three broad areas:

- Water Quality - *PECO evaluated several methods to improve DO in water released from Conowingo and selected turbine venting as the most effective and feasible. PPRP has conducted studies in cooperation with PECO to evaluate the effectiveness of turbine venting. To date, venting has proven effective in providing water below the dam that meets Maryland's DO standard.*

- Water Flow and Downstream Habitat - *As a result of studies which showed that a minimum flow could improve fish habitat below the dam, PECO agreed to provide minimum flows all year. The amount of flow is seasonal, varying from a high of 10,000 cubic feet per second (cfs) in the spring to 3,500 cfs in the winter. PPRP has also studied the need for providing continuous flows during the winter months (December through February) and found that the risks to biological resources were minimal during those months. Reducing the minimum flows required during the winter is currently under consideration.*

- Anadromous Fish Restoration - *In the 1970s, PECO installed an experimental fish lift at Conowingo in response to concerns about restoring anadromous fish runs upstream of the*

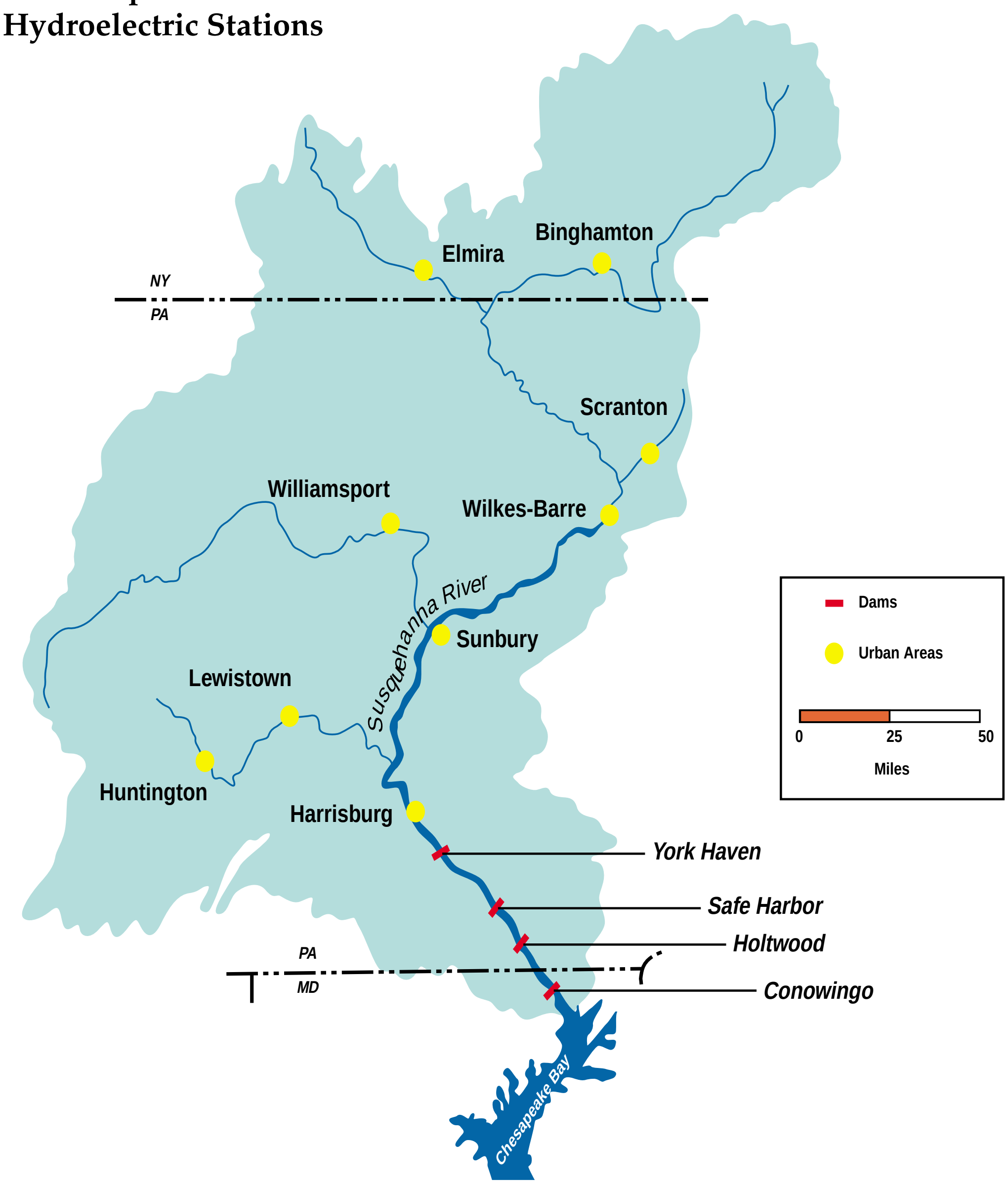
Figure 3-10
Numbers of American Shad



dam. Due to the success of the experimental fish lift, PECO, FERC, and the resource agencies agreed on permanent fish passage at Conowingo. Construction of the new east side fish lift was completed in the spring of 1991, in time for the spring shad run. PECO collected 27,227, 25,721, 13,546, 32,330, and 61,650 American shad in the 1991, 1992, 1993, 1994, and 1995 runs, respectively (Figure 3-10).

The ultimate goal of the resource agencies was to establish fish passage at dams upstream of Conowingo as well — Holtwood, Safe Harbor, and York Haven hydroelectric facilities. A breakthrough in achieving this goal and in enhancing the recovery of the American shad and other migratory species that live in the Chesapeake Bay and the Susquehanna River was reached in October 1992. After many years of negotiations with Maryland DNR, the U.S. Fish and Wildlife

Figure 3-11
The Susquehanna River Watershed and Mainstream Hydroelectric Stations



Service, the Pennsylvania Fish and Boat Commission, and other groups, Safe Harbor Water Power Corporation and Pennsylvania Power and Light (which owns Holtwood) agreed to build fish passage facilities at their two hydroelectric facilities on the Susquehanna River by 1997 (Figure 3-11). Metropolitan Edison (a subsidiary of General Public Utilities), which operates the York Haven Dam further upstream, will also construct a passage facility to be operational by the year 2000.

Deep Creek Hydroelectric Station

The Deep Creek hydroelectric project is a 19.2-MW facility located in Garrett County and owned by Penelec. Discharges from the Deep Creek project enter Maryland's only designated "wild" river, the Youghiogheny, which supports a developing trout fishery, a number of rare or endangered plants and animals, and one of the most challenging kayaking and canoeing runs in the United States.

In 1988, Penelec initiated renewal of the Deep Creek facility's license with FERC. As the coordinating agency for the state, PPRP was involved at the outset of the relicensing and consultation process. PPRP identified issues of concern and conducted necessary environmental studies in close cooperation with Penelec. The relicensing presented an opportunity to develop and implement a plan for controlling the timing and quantity of water released from the project to satisfy two objectives: 1) providing a reliable source of electricity, and 2) enhancing lake and river natural and recreational resources. This required finding balanced solutions to a variety of technically complex problems, because the interests of various users of Deep Creek Lake's resources are often conflicting.

In late 1991, Penelec was released from FERC jurisdiction (effective in 1994) and is now operating with a State surface water appropriations permit. The permit issued to Penelec in 1994 included conditions to ensure an operational regime adequate to maintaining an economically viable hydroelectric operation, while also balancing the following suite of conflicting natural resource and recreational concerns: 1) reservoir operations to make lake-based recreational opportunities more dependable and extend further into autumn, 2) mitigation of a long-standing DO problem in project discharges, 3) maintenance of a continuous minimum flow in the river to increase trout habitat, and 4) timing of generation during summer to maintain coldwater habitat for trout on a year-round basis.

Chalk Point Mitigation

The Patuxent River drainage is of special interest and concern to the State of Maryland because it is the largest river drainage contained entirely within Maryland's borders. In 1991, the State of Maryland and PEPCO reached an agreement specifying that PEPCO would provide some measure of compensation for the loss of forage finfish resulting from entrainment at the Chalk Point station. Specific conditions of this agreement included: 1) funding for production and stocking of striped bass and American shad, and 2) removal of obstructions to migratory fish in the Patuxent River tributaries.

The first objective was already being partially addressed by PEPCO's aquaculture facility at Chalk Point, where PEPCO rears juvenile striped bass and American shad hatched at DNR's Manning hatchery. Since 1985, over 3 million striped bass were produced and 2.8 million of these were released in the

Patuxent River. Since 1990, over 200,000 American shad were produced, all of which were stocked in the Patuxent River.

The obstruction removal program is designed to provide anadromous fish access to upstream habitats. An evaluation of stream obstructions was conducted during the summer of 1991. Twelve sites were selected as priority barriers to fish passage; these sites are all at various stages of preliminary investigation, engineering surveys, conceptual design, detailed design, and construction. Based upon completed conceptual design plans, steep-pass fishways were identified as being needed for three fish passage projects, and purchase of pre-fabricated fishways has been initiated.

Ground Water Impacts

In addition to affecting surface water resources, the siting, operation, and expansion of power plants have the potential to impact the quantity and quality of ground water resources in Maryland. Some power plants use ground water resources to satisfy their need for high-quality water as boiler feedwater or for emissions control. The significant quantity of ground water used by power plants in the state has raised concerns about whether these withdrawals are lowering ground water levels to an unacceptable extent in critical regional **aquifers**. In addition to ground water withdrawal impacts, the storage and handling of large quantities of fuel oil, coal, and coal combustion by-products typical at power plants has the potential to degrade ground water quality.

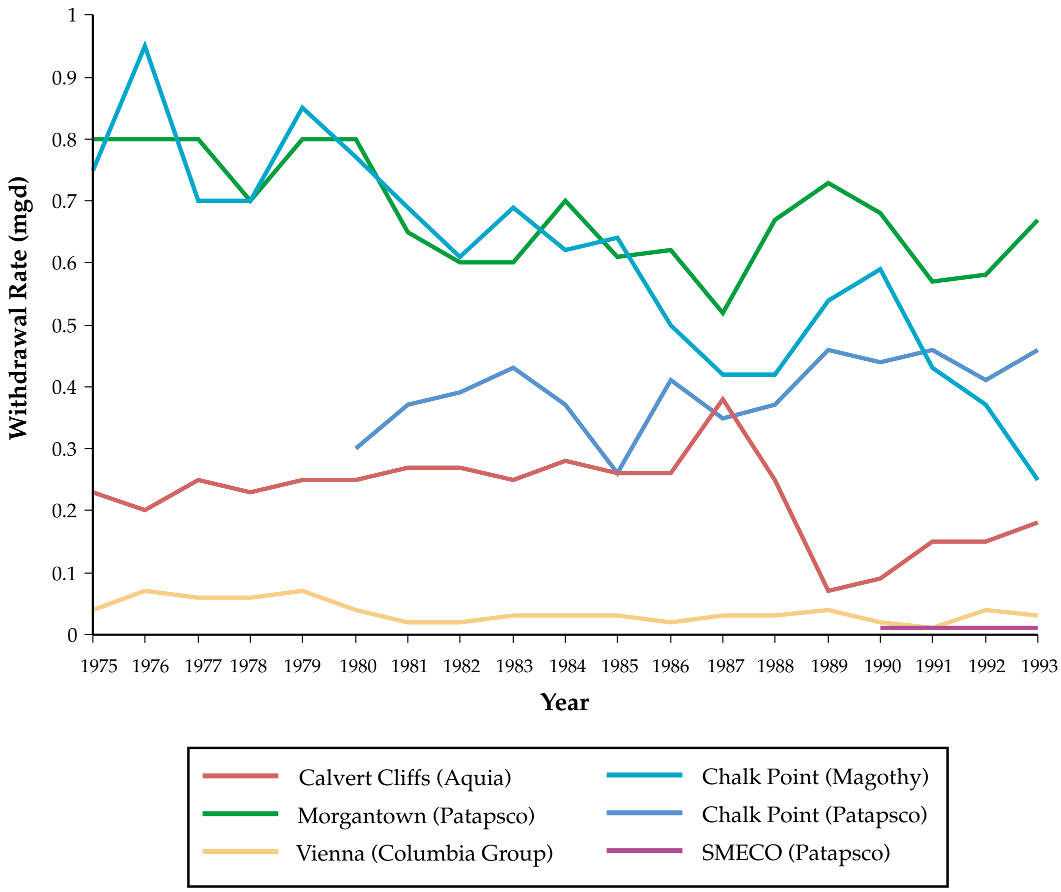
Ground Water Withdrawal Impacts

The impact of withdrawals of ground water by power plants is an issue in southern Maryland and the Eastern Shore, where there is an increasing public awareness of the importance of ground water as a natural and economic resource. Maryland's power plants withdraw ground water from several Coastal Plain aquifers in these two areas. There are large volumes of ground water available in these aquifers, but the aquifers must be protected over the long term to ensure that ground water remains available to current and future users. High-volume ground water withdrawals by power plants, if not managed properly, have the potential to lower the water level in the aquifer and cause intrusion of salt water or water of otherwise poor quality into the aquifer.

Currently, five power plants use ground water for plant operations. These plants include BGE's Calvert Cliffs Nuclear Power Plant, PEPCO's Chalk Point and Morgantown power plants, Delmarva Power's Vienna Power Plant, and SMECO's combustion turbine (located at the Chalk Point plant). All of these power plants are located in the Coastal Plain of Maryland and withdraw ground water from four major Maryland aquifers: the Columbia Group, the Aquia, the Magothy, and the Patapsco.

Figure 3-12 shows the ground water withdrawal rates of each of the five power plants from 1975 to 1993, expressed as daily averages. The average amount of ground water withdrawn in 1992 and 1993 from all five power plants was 1.56 and 1.60 mgd, respectively. By comparison, the combined appropriation limit for daily ground water withdrawals established by the permits for the five plants is 2.66 mgd. The total average daily withdrawals decreased slightly in 1992 and

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



1993 relative to 1990 and 1991. The following trends in withdrawal rates can be observed for each plant:

- BGE's Calvert Cliffs Plant - *The withdrawal rates in 1992 and 1993 were similar to the 1991 rate, which was two-fold higher than in 1989 and 1990 when the plant was shut down. However, the withdrawal rates remained below pre-shutdown levels.*

- PEPCO's Morgantown Plant - *The withdrawal rate from the Patapsco Aquifer was consistent with 1990 and 1991 withdrawal rates.*

- Delmarva Power's Vienna Plant - *Withdrawals from the Columbia Group Aquifer increased about two-fold from 1990 and 1991 levels; however, the higher withdrawals were significantly below the levels in the 1970s.*

- PEPCO's Chalk Point Plant - *The ground water withdrawal from the Magothy Aquifer decreased in 1992 and 1993, continuing a trend of decreasing withdrawals since 1989. There was also a slight decrease in the withdrawal from the Patapsco Aquifer in 1992; however, the withdrawal in 1993 was similar to previous years.*

- SMECO's Chalk Point Plant - *The withdrawal rates from the Patapsco Aquifer remained constant compared to the 1990 and 1991 rates.*

To track and evaluate the impacts of these withdrawals, three agencies — the Maryland Geological Survey (MGS), the U.S. Geological Survey (USGS), and PPRP — jointly operate ground water monitoring programs to track the **potentiometric surfaces** (water levels) in the aquifers over time.

Long-term monitoring indicates a decline in water levels in the Aquia Aquifer at Calvert Cliffs, in the Magothy Aquifer at Chalk Point, and in the Upper Patapsco Aquifer at Chalk Point. These impacts are considered negligible compared to the available drawdown in these aquifers. Water quantity impacts to each of these aquifers are summarized below:

- *In the Aquia Aquifer at Calvert Cliffs, water levels declined 30 feet over 11 years. The water level measured in observation well CA-Ed 47 in the Aquia has declined approximately 20 feet from 1990 to 1993. The recent acceleration in water level declines is due to withdrawals from well fields at Lexington Park and southern Calvert County. The impacts of the water level declines are considered negligible compared to the approximately 270 feet of drawdown available in the Aquia Aquifer.*

- *Water levels in the Magothy Aquifer at Chalk Point have declined by 16 feet from 1975 to 1993, and approximately three feet from 1990 to 1993. Water levels in the Magothy Aquifer are expected to recover to some extent with decreased pumping by PEPCO at Chalk Point.*

- *A decline of approximately six feet in the potentiometric surface of the Upper Patapsco Aquifer has been observed at Chalk Point from 1990 to 1993. Declines are expected to continue with increased withdrawal from this aquifer by both PEPCO and SMECO. However, these declines are not expected to significantly reduce the approximately 740 feet of water available in the Upper Patapsco Aquifer.*

Ground Water Quality Impacts

In addition to affecting ground water quantity, power plants can potentially impact the quality of ground water in three ways:

- *Chemical constituents of coal stored in piles at power plants can be leached out of the coal and infiltrate into the ground and eventually into the ground water.*

- *Similarly, chemical constituents can leach from ash and other by-products of coal combustion that utilities landfill in the state.*

- *Spills and leaks of liquid petroleum fuels that utilities transfer, store, and use can reach the ground water.*

PPRP has assessed the potential for coal piles to impact ground water quality at Maryland's seven coal-fired power plants. Coal piles placed on the ground surface are uncovered and exposed to precipitation. As water infiltrates the piles, acidic runoff (**leachate**) is produced. The acidic runoff contains constituents, especially iron and sulfate, that can degrade ground water quality in the vicinity of the piles. All seven of the power plants collect and treat their coal pile runoff to prevent ground water degradation. Although coal pile runoff at PEPCO's Morgantown plant is collected and treated, the runoff may still have some potential to degrade ground water because there are no clay liners beneath either the pile or collection basins to prevent infiltration, and there are no monitoring wells in place to detect a release of leachate constituents to ground water.

PPRP has also evaluated the impacts associated with landfilling coal combustion by-products. In general, these studies indicate that ground water quality can be degraded as constituents are leached from the landfills; however, when degradation does occur, it is localized, minimal, and does not appear to affect ground water users. PEPCO's Faulkner fly ash landfill, located near Zekiah Swamp Run in southern Charles County, is one example where there is some effect of coal combustion by-products on ground water quality. Water quality data obtained during studies there indicate that concentrations of major elements in ground water, including metals such as iron, manganese, nickel, and zinc, are higher than expected because constituents in the landfill ash are leaching out and infiltrating into the ground water. The extent of ground water affected by the leachate is limited to the ground water within 1,500 feet of the landfill. The leachate does not appear to have affected surface water quality in Zekiah Swamp Run or ground water users.

Spills and leaks of fuels during transport and storage at power plants also pose a risk to ground water quality. Petroleum fuels generally do not dissolve in water; however, some organic compounds contained in the fuels, such as benzene, are slightly soluble in water and can dissolve in the ground water. Releases of petroleum products have impacted ground water quality at BGE's Perryman combustion turbine facility in Harford County. Fuel oil was released to the subsurface when an underground pipeline connecting the fuel oil tanks to a combustion turbine failed. Investigations conducted by BGE indicate that some petroleum chemicals are floating on the water table surface, and contamination of the ground water covers an area of approximately five acres. The water table aquifer is not used for water supply downgradient of the site, so impacts to users are not expected. No impacts to surface water have been identified.

Terrestrial Impacts

Introduction

Maryland possesses a wide variety of wildlife that inhabit its **terrestrial** (or land) ecosystems. Some components of natural terrestrial ecosystems in Maryland include forests, wetlands, and non-aquatic wildlife. Components created by humans that have replaced Maryland's natural terrestrial ecosystems include agricultural land, residential development, and commercial development.

The construction and operation of power plants affect terrestrial ecosystems both directly and indirectly. Direct impacts result from the construction of power plants and their related **linear facilities** (transmission line rights-of-way, gas pipelines, water pipelines, access roads, etc.). Indirect impacts of plant construction and operation are often much harder to quantify or to distinguish from the effects of other factors, and are usually related to plant operations. Modes of indirect impact relate to pollution of air, water, and soil by power plants and their related facilities.

Direct Impacts

Terrestrial resources are affected by the construction and operation of power plants through physical modification or elimination of existing habitats, disturbance and displacement of wildlife, deposition of particulate matter or gaseous emissions to the atmosphere, and inadvertent spills and permitted releases of toxic materials. Permanent modification of existing terrestrial habitat occurs with the construction of transmission line corridors or when forested habitats are converted to **scrub/shrub** habitat or **herbaceous habitat**. Construction of underground facilities, such as gas pipelines or water pipelines, causes temporary disturbances to terrestrial habitat. If the right-of-way was previously forested, maintenance of the right-of-way in herbaceous or scrub/shrub vegetation also results in permanent habitat modification.

Direct impacts often adversely affect both nontidal and tidal wetlands. In the 1780s, Maryland possessed about 1,650,000 acres of wetlands (24.4% of its surface area); as of about 1989, Maryland possessed only about 440,000 acres of wetlands (6.5% of its surface area). These figures represent a 73% loss of wetlands in the state. The state is concerned with such losses, and now protects these resources. Through regulations developed under Maryland's 1991 Nontidal Wetlands Protection Act, many activities in nontidal wetlands are regulated under a policy of **no net loss**. Similarly, activities in tidal wetlands in Maryland are regulated under the 1994 Tidal Wetlands Regulations.

Compared to residential and other types of commercial construction, power plant construction has caused minimal direct wetlands impacts since the implementation of Maryland's nontidal wetlands law. Relatively small losses of wetlands are associated with recently licensed Maryland power plant facilities (Perryman, Dorchester, and Panda-Brandywine). Wetlands losses were minimized through the stringent CPCN process, requirements of the Nontidal Wetlands Protection Act, and cooperation from the utilities. To counter wetlands losses for the state's no net loss goal, mitigation is being required for these projects.

Forest resources are also adversely impacted by the development of power plants and their linear facilities. Maryland's forest resources are now protected under the 1991 Forest Conservation Act (FCA). New developments of 40,000 square feet or more are regulated in the state under the FCA. According to the FCA, tree conservation, replanting, and other environmental parameters must be considered prior to disturbance of forest resources. One important factor concerning the FCA is the exemption for rights-of-way and land for construction of electric generating facilities constructed by investor-owned utilities, municipals, or cooperatives, provided that CPCNs have been issued. Exemption status is lost if the developer of a proposed generating site or its linear facilities cannot demonstrate that cutting or clearing of forest will be minimized.

Steam Electric Power Plants

There are 14 steam electric power plants in Maryland greater than 100-MW capacity; nine are located in rural areas and five are in urban, developed areas. The total area of all rural sites is approximately 5,500 acres, the majority of which lies within the Coastal Plain province. This acreage amounts to less than 0.1 percent of Maryland's total land area (over six million acres).

Depending on the location of the facility and its design, the project footprint (buildings, structures, roads, etc.) may compose only a small portion of the total acreage of a plant site. From surveys of land utilization patterns at the 14 steam electric facilities, PPRP found that the footprints of all of the sites combined average about 54% of the total acreage, with a range of about 7% at Calvert Cliffs to 100% at Westport. The remaining land at the facilities comprises forests, wetlands, grassland/oldfield, and agricultural land. The proposed footprints of two recently licensed facilities in Maryland, Dorchester and Panda-Brandywine, are approximately 31% and 67% of the total site acreages, respectively.

As new power plants are sited and constructed in Maryland, it is likely that the footprint acres/total site acres ratio will become larger than in the past (i.e., footprints will be a larger proportion of smaller sites). This can be attributed in part to more stringent environmental regulations such as the Nontidal Wetlands Protection Act and the FCA that limit the number of suitable large sites, the lack of availability of suitable large tracts, and the rising costs of land.

Hydroelectric Facilities

Nine hydroelectric facilities are currently active in Maryland. Terrestrial habitats that are typically displaced by the impoundments created by dams are nontidal wetlands and riverine forests, which are known to support a diverse and valuable group of flora and fauna. The impoundment areas associated with the nine facilities (not including Conowingo Pond, which is partially located in Pennsylvania) total around 7,000 acres, representing a small percentage of the total land area of Maryland. The loss of existing terrestrial habitats by inundation has been mitigated to some degree by the formation of new habitat along the peripheries of the impoundments. Open water habitats, suitable for a variety of wildlife, including waterfowl, have also been provided by the impoundments.

The impoundments created by the hydroelectric facilities have not eliminated a significant portion of Maryland's total **riparian habitat**, which is on the order of half a million acres. Unaltered rivers, however, are becoming increasingly more valuable for recreational and educational purposes. Electricity is generated by peaking operations at three of the nine hydroelectric facilities in Maryland, and by **run-of-river** operations at the other six facilities. Peaking refers to the storage and subsequent release of water from the impoundment to the turbines at a hydroelectric facility. Peaking operations involve rapid fluctuation of impoundment and river water levels which may have adverse effects on wetlands vegetation and wildlife. These rapid water level fluctuations can expose and freeze plant roots in the winter, strand bird hatchlings on mudflats (making them more prone to predation), and increase streambank and impoundment erosion. Run-of-river operations are generally less ecologically harmful than peaking

Coal Ash Utilization

The amount of coal ash and flue gas desulfurization (FGD) by-products that are placed in landfills can be significantly reduced through utilization programs. Coal ash can be used in a variety of construction applications. A few examples of utilization of coal ash include additives for cement, structural fill for road base, cinder for ice control, soil stabilization agent, coal mine reclamation material, and raw material for production of bricks or grout. FGD sludge can be used in the manufacture of wallboard, land reclamation, and construction of artificial reefs.

Currently, only one-fourth of the fly ash and almost none of the FGD by-products generated in the United States are being utilized. The paucity of coal ash utilization is due primarily to: 1) the physical and chemical characteristics of the by-products versus other raw materials, and 2) the economics of using coal ash versus other raw materials. The physical and chemical properties of a particular ash may make the material less than ideal when compared to raw materials. For example, if a by-product has a particularly high free lime content, it may heat too rapidly during the production of concrete, reducing the strength of the material. From an economic standpoint, the relative cost of using by-product versus traditional raw materials depends largely on local availability of raw materials and transportation costs.

Coal ash is used for a variety of purposes in Maryland. BGE places coal ash from the Wagner and Brandon Shores power plants into the Brandon Woods Business Park Site as structural fill at a rate of approximately 400,000 tons per year. The site is being developed as an industrial park with buildings placed over top of the ash. Also, PEPCO and BGE sell coarser grained bottom ash for use in snow and ice control. The proposed AES Warrior Run facility plans to use 100 percent of its by-product for reclamation of the surface coal mines where the feed coal is extracted. PPRP is currently investigating the use of by-products in reclamation of abandoned deep mines as well. The amount of coal ash utilized will likely increase over time, as it becomes increasingly more difficult to construct and operate landfills due to regulatory and public opinion constraints.

operations, in that they simulate natural river flow by passing a minimum flow through the project at all times, and do not involve rapid, severe changes in water levels.

Combustion By-Product (Ash) Landfills

There are five active coal-fired power plant ash landfill sites occupying about 1,000 acres, and over 30 inactive or smaller sites in Maryland. These landfill sites are typically 50 to 100 acres in size, but vary depending on the type of coal used and the generation facility. The capacity of some of these sites may be 20 years; others may possess only a 5- to 10-year capacity. Over the next 40 years, Maryland's coal-fired plants could require between 1,100 and 2,300 acres for ash disposal. With several landfill sites near their capacities, additional landfill space must be identified. Several candidate landfill sites adjacent to existing sites are being considered as potential new landfill areas.

Terrestrial impacts of ash landfills are prolonged by the fact that landfills are rarely managed for habitat restoration purposes after closure. These sites are designed to be dry and elevated above the water table. Owing to the operation of the landfills, the fly ash and other materials are usually highly compacted, which tends to inhibit deep root growth; this precludes establishment and survival of woody vegetation. One closed landfill site in Anne Arundel County has been partially developed into a business park and has been landscaped, but this is an exception to the rule.

Transmission Line Rights-of-Way

Electric transmission line rights-of-way are distributed throughout the state. Both temporary and permanent impacts can occur due to transmission line and pipeline corridor construction and maintenance. To construct these corridors, land must first be cleared of vegetation, and sometimes graded. Once the linear facilities have been installed, the rights-of-way must be maintained in herbaceous or shrubby vegetation, resulting in permanent impacts to forest, wildlife, and wetlands resources.

With appropriate planning and construction techniques under ideal conditions, it has been shown that nontidal wetlands (excluding forested systems) can recover from linear facilities construction in as little as two years. Recent investigation by PPRP has indicated that construction of electric transmission line rights-of-way has had relatively little impact on nontidal wetlands in Maryland. Transmission line construction accounted for only 1 of the 92 wetlands permits and about 7 of the 682 Letters of Authorization approved by DNR from January 1991 (when State nontidal wetlands permitting activities began) to May 1994. In the same period, the construction of new transmission line rights-of-way has permanently impacted only about one acre of nontidal wetlands and temporarily impacted about eight acres. Many of these transmission line impacts represent conversion of one type of vegetation to another; for example, in some cases, forest is converted to scrub/shrub habitat. To put these numbers into context, permanent nontidal wetlands impacts for all projects in Maryland that were authorized from January 1991 through December 1993 totaled 76.9 acres. Temporary impacts authorized during that time period totaled 93.6 acres.

Under Maryland's nontidal wetlands regulations, permanent impacts to nontidal wetlands must be mitigated (i.e., new wetlands created, other disturbed wetlands restored, or payment made to the Wetlands Compensation Fund) at ratios of 3:1, 2:1, or 1:1, depending on the type of wetlands affected. A ratio of 3:1 is applied to scrub/shrub and forested wetlands of special state concern, a 2:1 ratio to scrub/shrub and forested wetlands and herbaceous wetlands of special state concern, and 1:1 for emergent wetlands. Mitigation ratio requirements are similar for state tidal wetlands. Temporary impacts and impacts to wetlands buffers do not usually have to be mitigated.

Considerable edge habitat (grasslands/shrublands) is created when transmission line rights-of-way are created in forested areas. While there is often an increase in the total number of species in a newly created edge habitat, some forest-dwelling species decrease in number. Often, new species of animals that have an affinity for brushy or oldfield habitats colonize the area and account for the increased total number of species. This positive benefit is offset by fragmentation of forests into smaller and smaller areas, however, which can result in population declines of migrant birds and other species that require large tracts of forest.

Biodiversity is the variety and variability among living organisms and the ecological complexes in which they occur. Forest fragmentation caused by construction and maintenance of right-of-way corridors can lead to a loss in biodiversity of a region through bisection and isolation of forest tracts. In general, large blocks of undisturbed habitat are better for conserving biodiversity than smaller ones.

Right-of-Way Maintenance: Herbicides vs. Mowing

Growth of woody vegetation on transmission line and other rights-of-way (such as natural gas pipelines) can present public safety hazards. Trees that grow too close to power lines ("danger trees") could fall on the lines in a storm event; deep roots from trees or other woody plants could jeopardize the integrity of underground pipes. Utilities most often manage vegetation through a combination of mechanical mowing and chemical herbicide application. State regulations permit the utilities to use only U.S. EPA-approved herbicides. These herbicides have been reported to pose little danger to the terrestrial environment if properly applied.

The herbicides that are most commonly used by the Maryland utilities, such as those with glyphosate as the active ingredient, persist in the environment for less than two months, and are generally not toxic to wildlife when they are applied appropriately. Improper use of chemical herbicides, however, can result in excessive amounts being carried by runoff and by wind transport into areas outside the right-of-way, and may damage untargeted vegetation and wildlife.

Several of Maryland's electric utilities have initiated maintenance programs to improve wildlife habitat in rights-of-way. Under these programs, stable oldfield (i.e., weedy, shrubby) habitats are established with few tree species that have the potential for becoming "danger trees." This is typically accomplished by only spot treating potentially undesirable trees with glyphosate herbicide every three to five years, instead of the more typical mowing every two to three years or broadcast spraying of herbicides. Preliminary results provided by the utilities indicate that such selective programs have created better, more stable habitats for wildlife, and have saved millions of dollars in maintenance costs.

Mechanical cutting of vegetation in rights-of-way is not necessarily benign; it can disturb and kill wildlife, and has the potential for polluting surface waters, depending on the type of equipment used. Right-of-way management, whether it is accomplished by mowing or by herbicides, often affects wildlife by altering the original vegetative community. Most Maryland utilities indicate that they use a combination of selective herbicide application and mechanical cutting rather than exclusively one or the other. It has been generally observed that spraying and cutting of entire corridors is more harmful to wildlife than selective cutting, selective application of herbicides, or a combination of both.

Indirect Impacts

Power plants affect terrestrial ecosystems through the deposition of airborne pollutants. These compounds can be in either gaseous or particulate form, and are emitted from stacks, coal and solid by-product handling activities, and ash landfill operations. As airborne pollutants from power plants are dispersed, some are deposited on land and surface waters. These pollutants can contribute to acidification of soils and waters; pollutants deposited onto land can also be taken up by crops and farm animals and incorporated into the food chain. No long-term studies are available on actual damage to plants and animals from existing emissions in Maryland.

Cooling towers are another source of air emissions that can affect terrestrial resources. Cooling tower emissions carry some of the chlorides and other solids that were dissolved in the cooling water. Deposition of these solids may impact terrestrial ecosystems by directly contacting plant tissue, and by elevating levels of chlorides and other salts in soils.

SO_2 and NO_x are also emitted by power plant stacks. Power plants in Maryland do not emit NO_x in quantities great enough to cause either acute or chronic injury to vegetation. SO_2 is known to cause acute injury to sensitive plants; however, direct evidence of such damage in ecological systems in Maryland is unavailable. Direct effects of sulfur or nitrogen oxides on animals in Maryland are unlikely to be significant at the present levels of emission.

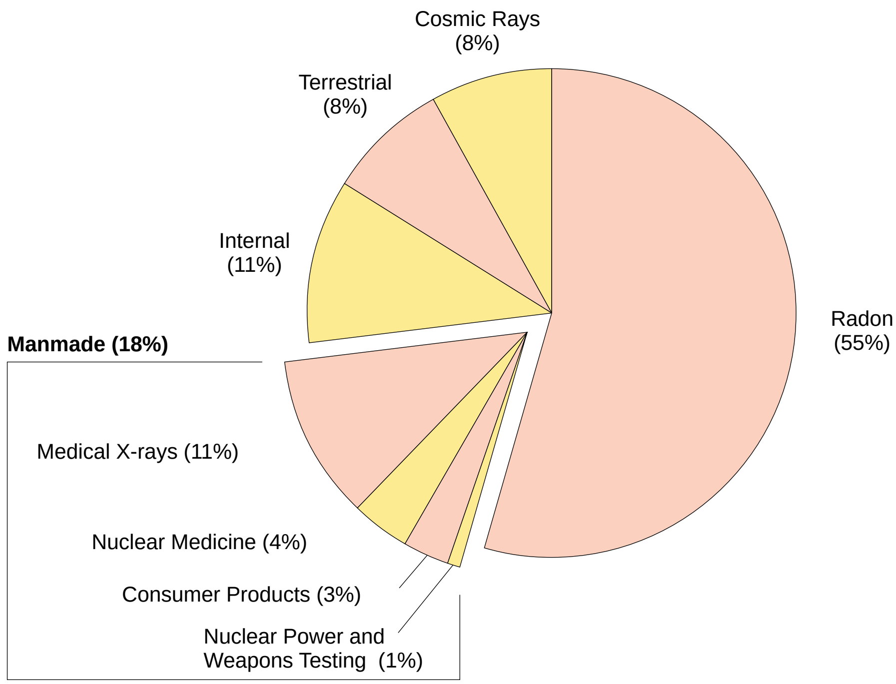
Radiological Impacts

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. The NRC regulates power plants according to the principle that releases be kept "as low as reasonably achievable" (ALARA).

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

Nuclear power plants are minor contributors to radiation exposure in the United States. As Figure 3-13 illustrates, natural radiation sources account for more than 80% of the average radiation dose. Of the approximately 18% of radiation dose provided by manmade sources, only 1% is attributed to nuclear power plants.

Figure 3-13
Estimated Effective Radiation Dose from Natural and Manmade Sources



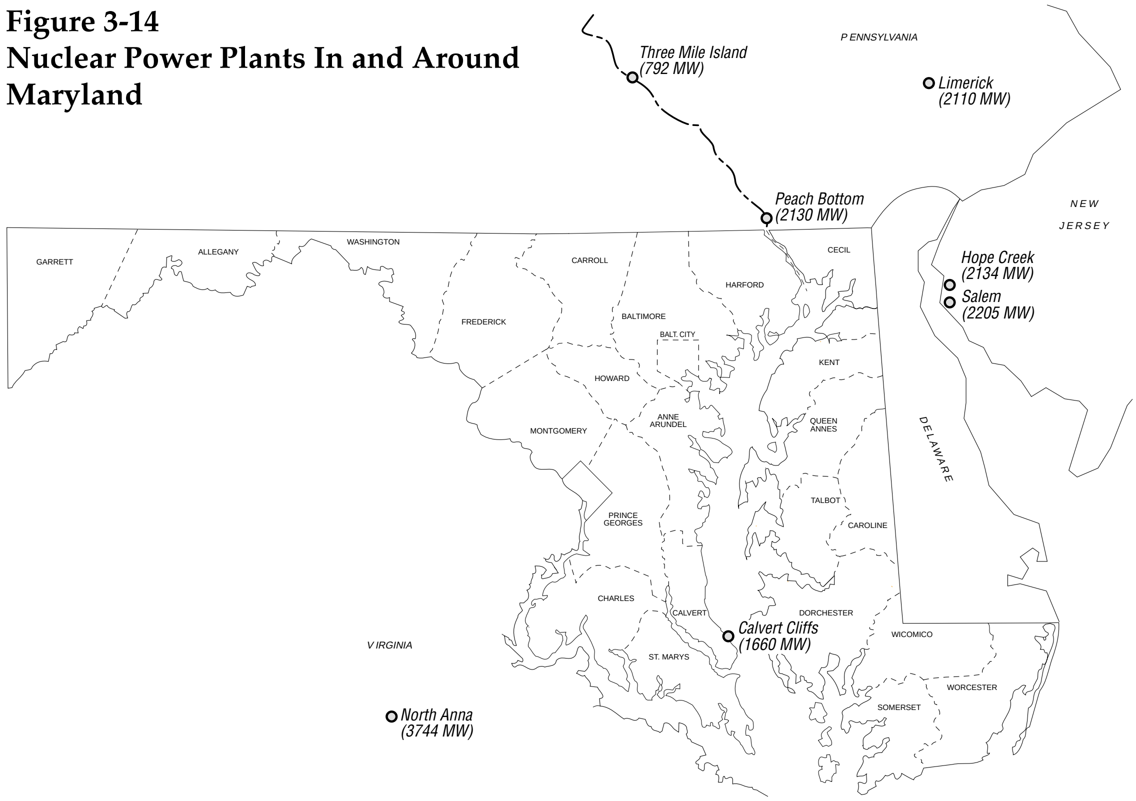
The locations of nuclear power plants located in and near Maryland are shown on Figure 3-14. Calvert Cliffs Nuclear Power Plant, in Calvert County, is the only nuclear station in the state. The next closest plant, Peach Bottom Atomic Power Station, is located on the Susquehanna River just north of the Pennsylvania/ Maryland border. These two facilities release radionuclides into Maryland's environment. BGE, PPRP, and MDE conduct environmental monitoring programs in the vicinity of Calvert Cliffs, and PECO, PPRP, and MDE conduct programs in the vicinity of Peach Bottom. 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

BGE 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 capacity of 830 MW. The units began service on 8 May 1975 and 1 April 1977.

Calvert Cliffs routinely releases low-level gaseous 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 3-14
Nuclear Power Plants In and Around Maryland



Radioactive **noble gases**, primarily xenon, krypton, and argon, constitute the great majority of 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; therefore, the noble gases do not represent a significant threat to human or ecological health. Results of the most recent environmental monitoring (from 1992 through 1993) 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 cesium, cobalt, silver, and zinc. These radionuclides are notable because 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 that were released and subsequently detected in fish and Bay sediments were quite small.

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 in the vicinity of Calvert Cliffs, and they have the greatest potential for providing a human radiation dose through seafood consumption. On a quarterly basis, PPRP immerses oysters on trays in the vicinity of the Calvert Cliffs liquid effluent discharge, and then collects them for tissue analysis of radionuclide content. Radiosilver continues to be the principal plant-related radionuclide accumulated by oysters; it has consistently been detected in test oysters as well as oysters located on natural beds.

Chesapeake Bay sediments are also useful indicators of environmental radionuclide concentrations because they serve as natural sinks for both stable and radioactive metals. Sediment samples are collected seasonally by PPRP from eight transects extending bayward north and south of the Calvert Cliffs plant. Cobalt-60 was the plant-related radionuclide detected most frequently in Bay sediments during 1992 and 1993. Radiosilver was also detected sporadically during this period at concentrations similar to levels detected in previous years.

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.

A comparison of radionuclide concentrations in environmental samples collected between 1992 and 1993 with levels detected since 1978 shows the following:

- *In general, the levels of plant-related radionuclides detected during 1992 and 1993 are similar to 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 small compared with background radioactivity from natural sources and the fallout from weapons tests.*
- *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

The Peach Bottom Atomic Power Station, located on the Conowingo Pond just north of the Pennsylvania/Maryland border, is owned jointly by PECO, Public Service Gas and Electric Company, Delmarva Power, and Atlantic Electric Company. The plant is operated by PECO. Its two operating units, Units 2 and 3, are boiling water reactors, each with a currently licensed capacity of approximately 1,065 MW, and have been in service since 1974.

Radioactivity Released

Like Calvert Cliffs, the Peach Bottom plant routinely releases low-level gaseous 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 indicates that in recent years radionuclides of xenon and krypton accounted for nearly all of the radioactivity released to the atmosphere by the Peach Bottom plant. These particular radionuclides are chemically inert and, therefore, are of little environmental concern. Based on environmental monitoring from 1992 and 1993, no radioactivity attributable to atmospheric releases by the Peach Bottom plant 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 1992 and 1993, 99% was tritium (a radioactive form of hydrogen) in a form that is not bioaccumulated and is of limited environmental concern. Very small quantities of radioactive chromium, cobalt, iron, zinc, and cesium 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 area (including the Conowingo Pond and Conowingo Dam tailrace) contained both plant-related and fallout-related radionuclides. Peach Bottom plant-related radioactivity was also detected in sediments collected down-river of the plant, similar to 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 less than 20% of the radioactivity released in Peach Bottom water discharge is found in surface sediments of the Conowingo Reservoir. The remaining radionuclides appear to be transported downstream to the Chesapeake Bay.

Estimates of radiation dose 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 1992 to 1993 with monitoring results since 1978 indicates 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 the amount of material from natural sources and fallout from weapons tests.*
- *No long-term accumulation of plant-related radioactive material in river biota is evident.*
- *Long-term operation of the Peach Bottom plant has not caused significant accumulation of radioactive material within the Conowingo Pond.*
- *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.*

Socioeconomic Impacts

Power plants in Maryland have influenced more than the physical environment. Power plants have integrated themselves into local economies as employers, as purchasers of goods and services, and as taxpayers. These facilities have also imposed social costs on their neighbors in the forms of increased traffic, compromised viewsheds, and various aesthetic and nuisance impacts. In recognition of this, PPRP's environmental assessments of utility power plants and transmission lines include the analysis and consideration of social impacts.

Social impacts encompass a number of concepts. In general, there are potential economic impacts, expressed in terms of employment and income; demographic impacts, such as population and housing; fiscal impacts, both in terms of revenues and expenditures; transportation and land use impacts; cultural impacts; and aesthetic impacts. This section concentrates primarily on three social impact categories that are relevant to several recent power plant siting projects: economic/fiscal impacts, property value impacts, and transportation impacts.

Power Plants and the Economy

Power plants affect the economy in numerous ways. During construction, they employ hundreds of construction workers and purchase millions of dollars worth of goods and services. Construction of a power plant is a major investment that results in the concentration of workers, equipment, and materials for periods of time ranging from months to years. Although a portion of construction dollars are spent outside of Maryland, construction of a power plant usually results in a net infusion of income into host economies and the state.

Power plant impacts extend beyond their direct effects upon construction employment and industry sales. Income from construction workers is spent on food, housing, and other consumption goods, which increase the sales of retail and service establishments. These establishments may subsequently add workers or extend the hours of its current employees to satisfy the added demand, which generates additional income that results in more consumption, and so on. On the industry side of the ledger, additional sales of goods and services from power plant construction contracts may induce supplying industries to increase production, adding to payrolls in the form of new employment or longer hours, and increasing purchases from industries that supply them with raw materials. In other words, power plant construction expenditures for goods and services ripple through the economy through inter-industry linkages when businesses respond to increased demand by increasing production and purchasing of inputs to their production processes. This concept is known as the **multiplier**, which measures the total economic effect from a direct stimulus to the economy.

Although the economic impacts from power plant construction are generally positive, the impact on host communities depends upon a number of factors, such as the availability of a skilled construction work force within commuting distance of the site. Furthermore, although power plant construction boosts local economies with the jobs and income it generates, its temporary nature limits its impacts on host communities. All job and income creation attributable to construction effectively ends when construction ends.

Goods and Services Provided by Generation O&M Expenditures of Maryland Utilities, 1993 (thousands of dollars)

	PEPCO	Delmarva Power	COPCO[(2)]	BGE	PE	TOTAL
Generation O&M	$724,643	$404,221	$54,662	$831,389	$395,122	$2,018,855
less: Fuel	$339,183	$203,055	0	$349,926	$153,587	$1,035,751
less: Labor	$58,817	$26,096	0	$136,373	$16,327	$237,613
less: Other (1)	$276,582	$98,066	$54,662	$198,740	$198,425	$826,475
Goods & Services	$50,061	$77,004	0	$146,350	$36,783	$310,198

(1) Other power supply expenses, comprising purchased power plus system control and dispatching.

(2) COPCO purchased all power from PECO Energy in 1993.

Once operational, power plants are important sources of payrolls and tax revenues for host communities. On a broader scale, power plants interact with the economy through purchases of goods and services as part of ongoing operations and maintenance.

Fuel accounts for the majority of power plant operations and maintenance (O&M) expenses. However, power plants also purchase materials and supplies for maintenance. Maryland utilities are estimated to have spent over $300 million on goods and services in 1993. This represents an increase of more than 12% over 1992 and a nearly 40% increase since 1989. Accounting for inflation, O&M expenditures by Maryland utilities have risen by an average of 4% annually since 1989.

The major suppliers of goods and services to the electric utilities industry are fuel-related (coal mining, crude petroleum and natural gas, petroleum refining and related industries, and transportation and warehousing), or are related to purchases of electricity (electric utilities and federal government enterprises). Expenditures are also made for maintenance and repair construction, and for manufactured goods such as machinery associated with the generation of electricity, including instrumentation. Finally, power plant O&M consumes services, particularly those related to finance and insurance, and business services.

Expenditures for manufactured goods, such as machinery associated with the generation of electricity, make up a lower proportion of Maryland utility purchases than at the national level. This indicates that utility O&M expenditures leak from the Maryland economy for purchases of manufactured goods, such as engines and turbines, and other goods and services which are not produced in the state.

Electricity Generation and Property Values

How and Why Power Plants Affect Property Values

Utility impacts on nearby properties have been subject to research for many years. In general, power plants and their associated facilities such as transmission lines, substations, by-product disposal areas, and fuel storage and transshipment facilities have been considered undesirable to nearby property owners because of the real or perceived **externalities** they generate. Externalities associated with these facilities include the host of factors subject to review by PPRP, such as the air, water, terrestrial, socioeconomic, aesthetic, and other impacts that are discussed in this report. Generally, utilities have attempted to control externalities by minimizing impacts or by mitigating their effects.

Most undesirable impacts from power plants decline with distance. As a result, landowners in proximity to power plants are affected more often and more severely by power plant construction and operation than those at greater distances. As the cumulative environmental impact of power plants is generally perceived to be undesirable, its effect upon nearby properties can be to reduce their value. However, little consensus has evolved over the degree to which power plants affect property values.

Electric Transmission Lines and Property Values

The associated facilities of power plants, particularly high voltage overhead electric transmission lines, have also been suspected of influencing property values. In the past, the primary effects of transmission lines were considered to be aesthetic in nature, relating in a negative sense to the visual intrusion of power lines and transmission towers, and in a positive sense to the open space afforded to adjacent property owners provided by the transmission line right-of-way. More recently, issues related to perceived health risks from **electromagnetic fields** (EMF) have been examined in the literature.

Public awareness of controversies over the possible relationship between electricity and health has been fairly consistent, suggesting awareness among approximately 30% of the public. However, most surveys have found the public to be relatively uninformed about EMF, and to harbor misperceptions such as the rate at which EMF levels fall with distance.

Although suggestive of a link between property values and perceived risk from EMF, research in this area is far from conclusive. Current understanding has not yet evolved to where it can assist in project siting and design, impact prediction, or the prescription of mitigation measures.

Transportation Issues

Importance of Transportation Infrastructure in Power Plant Siting

Accessibility is an important consideration in power plant siting. Power plants require a well-developed transportation infrastructure for carrying its workers, supplies, fuel, and other inputs to the plant site, and for discharging by-products and other waste streams.

Road accessibility has traditionally been an important factor in power plant siting because roads servicing the plant must be able to support automobile traffic of construction workers and O&M employees, as well as trucks delivering goods and services to the plant site. The existence of adequate regional highways connecting power plant sites to major labor markets in Maryland has helped to minimize socioeconomic impacts from power plant construction.

Rail accessibility is also a consideration in siting coal-fired power plants. Railroads are also often used to transport large power plant components to the site during construction. For natural gas-fired facilities, proximity to a gas pipeline is an essential site factor.

Accessibility to water transportation facilities can be an important consideration in power plant siting. Barges can transport higher tonnage than other conventional transportation modes, and fuel and maintenance costs are generally lower than for rail or trucks. However, barges require waterfront development and access, both of which are limited under Maryland's Chesapeake Bay Critical Areas program. Furthermore, fuel for power plants not adjacent to unloading facilities must be transshipped via truck or rail, which increases fuel supply costs.

Transportation and Electric Generation

The primary role that transportation plays in electric generation is in the transport of fuel to generation sites. Transportation can also be critical for removing combustion by-products from coal-fired facilities to solid waste disposal areas.

Maryland utilities use several combinations of modes to transport fuel to their generating facilities. Coal is shipped by rail, barge, and truck. For two facilities, coal is shipped via rail to intermediate terminals and then barged to power plant sites. Fuel oil is transported by barge, truck, and pipeline; natural gas is transported by pipeline.

Trends in fuel deliveries to Maryland utilities are evident from recent historical data (Figure 3-15). Although coal deliveries have remained relatively constant, natural gas deliveries in 1993 were less than one-third of the 1989 total. Fuel oil deliveries have declined, reducing the use of pipeline and barge transportation modes. Rail and truck traffic, on the other hand, has remained mostly unchanged over the past five years, although year-to-year fuel deliveries to individual power plants show considerably more variation.

Figure 3-15
Fuel Deliveries to Maryland Utilities 1989-1993