composed of sand. The perched and lower saturated zones are separated throughout most of the site by a low-permeability silty clay layer.

Since 1982, when ash placement began, no leachate constituents derived from the coal ash fill have been detected in downgradient monitoring wells screened in the perched or lower saturated zones (Keating *et al.* 1989). Since 1982, when placement of the ash started, quarterly monitoring of ground water monitoring wells at the Brandon Woods site has shown no adverse impact on ground water quality.

Faulkner Ash Landfill

The Faulkner Ash Landfill, located adjacent to Zekiah Swamp in southern Charles County, has been operated by PEPCO since 1970 to handle the large quantities of fly ash generated by the Morgantown Power Plant. PPER is evaluating the effects of the facility on surface and ground water quality (Price and Keating 1991). Fly ash is placed in embankments on a valley slope, which are designed to reduce water infiltration in order to minimize leachate generation as well as to ensure structural stability. A coarse drainage layer is placed beneath the embankments during construction to drain leachate from the fly ash fill toward leachate collection ponds at the toe of the embankment.

The Faulkner landfill is constructed on Pleistocene-Age sediments consisting primarily of sand and gravel, which form a shallow aquifer beneath the site. The Calvert Formation, which is composed of sandy silt and shell fragments, underlies the Pleistocene sediments. The Calvert Formation is lower in permeability than the overlying sediments and is considered to be a semi-confining to confining layer.

Water quality data obtained during the study indicate that concentrations of major ions and metals such as iron, manganese, nickel, and zinc in ground water are elevated above background levels, which is attributed to leachate generated in the fly ash embankment. The areal extent of ground water affected by the leachate is limited to the proximity of the ash fill. It does not appear to affect surface water quality in Zekiah Swamp a few hundred feet downgradient of the embankment through ground water baseflow and does not affect ground water users. Consequently, there is no adverse impact to ground water resources.

Ritchie Road Site

The six-acre Ritchie Road site was originally a marshy, low-lying parcel of land adjacent to Ritchie Branch. The property owner accepted fill consisting primarily of fly ash from PEPCO's Buzzard Point and Benning Road facilities, as well as construction debris, in order to raise the level of the site for future commercial development. Fly ash was not compacted during emplacement, as is the current practice. The site was not lined, but the fill was graded, covered with clean fill, and seeded when landfilling was completed.

The site is located in the recharge area of the Aquia aquifer, where the unconsolidated sediments of the aquifer are exposed at the surface. Results of a hydrogeologic investigation indicated that ground water quality at shallow depths beneath the site was affected by leachate from the fly ash fill. However, the ground water quality degradation was localized and did not appear to cause adverse impacts to potential receptors downgradient of the site (Bandoian and Simek 1983).

Vienna Fly Ash Site

The site formerly used to landfill fly ash from the Vienna Power Plant between 1966 and 1972 is located on the east side of the Nanticoke River across from the power plant. The site, which consisted of approximately 100 acres of diked wetland area, was neither lined nor covered. Fly ash was sluiced under the river and allowed to spread freely within the diked area. When use of the site was discontinued in 1972, approximately 80 percent of the diked area was covered with fly ash. The dike was breached at several locations, allowing tidal flushing and flooding of the landfill when river levels were high. After landfilling was terminated, the area gradually became revegetated.

Results of a site study indicated that shallow ground water was contaminated with low concentrations of sulfates and some metals, but that most of the soluble components in the fly ash had been leached from the fill. Contaminants that may have previously leached into ground water from the fill likely discharged to the Nanticoke River and were diluted to concentrations below detectable limits. The degradation of shallow ground water from soluble constituents in the fly ash had no significant effect on surface water quality. Although leachate from the fly ash affected ground water quality beneath the site, degradation appeared to be localized; thus there were no adverse impacts to ground water users (ERM 1982).

Cumulative Power Plant Impacts on Ground Water Quality

The results of PPER evaluations of coal storage and combustion by-product disposal practices in southern Maryland demonstrate that leachates from some of these sources have adversely affected localized shallow (i.e., water table) aquifers. However, due to a combination of engineering design, management practices, and site-specific hydrogeologic conditions, as well as a lack of potential users in the immediate vicinity, the ground water quality degradation that has occurred is localized and has not caused adverse impacts to ground water receptors.

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F. Glossary

Aquifer. A geologic stratum composed of saturated permeable rock or sediment that will yield economical quantities of water to wells or springs.

Aquitard. An impermeable geologic stratum composed of rock or sediment through which water will not flow.

Baseflow. The portion of surface water flow in a stream that is derived from ground water discharge.

Basin yield. The maximum withdrawal rate that can be supported by a hydrogeologic system without creating unacceptable changes in the system, including declines in hydraulic head or other changes to the hydrogeologic system.

Cone of depression. An inverted cone-shaped depression that forms in the water table or potentiometric surface of an aquifer as the result of withdrawing water from a well.

Confined aquifer. A geologic formation in which ground water is isolated from the atmosphere at the point of discharge by impermeable formations; ground water in a confined aquifer is under pressure greater than atmospheric pressure.

Confining layer/unit. A geologic stratum of rock or sediment that does not readily transmit water into or out of an adjoining aquifer. Such a unit confines an aquifer.

Drawdown. The distance between the static water level and the surface of the cone of depression in a well.

Ground water basin. A ground water reservoir that is more or less separate from neighboring ground water reservoirs.

Ground water discharge. The removal of water from the saturated zone of a hydrogeologic system, either naturally to surface water bodies such as springs and streams, or artificially by withdrawal from wells.

Ground water recharge. The addition of water to the saturated zone of a hydrogeologic system.

Heterogeneous aquifer. An aquifer that is nonuniform in structure, composition, and hydraulic properties throughout its extent.

Hydraulic head. The height of a water column above a datum plane, which in a ground water system is composed of elevation head and pressure head.

Land subsidence. The sinking or settling of the land surface, often caused by withdrawal of fluids, which can be caused by withdrawal of ground water among other activities.

Leachate. A liquid produced by water percolating through solid waste and dissolving soluble constituents in the waste.

Overdraft. Withdrawal of ground water from a hydrogeologic system that exceeds the safe yield.

Outcrop. An unconsolidated or bedrock geologic unit exposed at the land surface.

Potentiometric contour. A line on a potentiometric surface that represents points of equal hydraulic head.

Potentiometric surface. An imaginary surface representing the total hydraulic head of ground water in a confined aquifer as defined by the level to which the water will rise in a well.

Recharge area. An area in which components of hydraulic head are downward in the aquifer, thus replenishing water to deeper portions of the aquifer via infiltration.

Safe yield. The annual quantity of ground water that can be withdrawn from a ground water basin without causing adverse impacts.

Saturated zone. The zone in which the voids in soil or rock are filled with water at a pressure that exceeds atmospheric pressure. In an unconfined aquifer, the water table is the top of the saturated zone.

Semi-confining layer. A partially confining layer.

Solutes. Dissolved substances.

Unconfined aquifer. An aquifer in which the water table is exposed to the atmosphere through openings in the overlying materials.

Unsaturated zone. The zone between the land surface and the water table in which the voids in soil and rock contain water at a pressure less than atmospheric pressure.

Water table. The surface in an unconfined aquifer at which the water pressure in voids in soil and rock is equal to atmospheric pressure.

CHAPTER 7

TERRESTRIAL IMPACT

A. Introduction

Power plant construction and operation can affect terrestrial ecosystems in many ways. Figure 7-1 illustrates the general modes of potential impact. Direct impacts result from the construction of the facility and of ancillary facilities or supporting structures such as transmission lines. A certain amount of the local terrestrial ecosystem is destroyed, and the creation of rights-of-way for transmission line towers may modify portions of the existing ecosystem. The indirect impacts of plant construction and operations tend to be more subtle. Such effects are often difficult to quantify or to distinguish from the effects of other factors. Indirect modes of impact include surface water run-off from fly ash storage piles and particulate and gaseous emissions from the plant.

Elements of terrestrial ecosystems that are exposed to impacts include vegetation and vertebrate and invertebrate organisms, whose sensitivity differs considerably by species and habitat type. In order to provide a comprehensive picture of impacts on terrestrial ecosystems in Maryland, the ecosystems characteristic of different portions of the state are first described. Categories of impacts are then discussed, together with potential for impact. Many of the potential impact modes have not been studied in Maryland, and as a result cumulative impacts have not been quantified. This chapter therefore covers the information that is available on actual impacts, and discusses potential impacts on different elements of terrestrial ecosystems.

Future changes in the global climate, which have been projected to result from increasing atmospheric carbon dioxide and other trace gases, will also affect terrestrial ecosystems, power plants, and the interactions between them. Fossil fuel power plants contribute to the production of carbon dioxide, which may be limited by international accords in the future. Some limitations imposed to control atmospheric changes may actually increase power demand: existing limits on chlorinated fluorocarbons (CFCs) are likely to result in the use of less efficient refrigerants. The increased carbon dioxide itself may be beneficial to plant growth, but is likely to be associated with temperature and precipitation changes that could seriously affect the ecosystem balance, if not change its character completely. A warmer climate could increase demand for air-conditioning and refrigeration while reducing winter heating. This would shift the power production load more into the growing season, when terrestrial ecosystems are most sensitive. An associated rise in sea level could imperil coastal installations and ecosystems. These impacts are all somewhat speculative, but are coming under increasing study due to the perceived reality of impending change and the need to make long-term decisions based on the projected impacts. (See discussion of the greenhouse effect in Chapter 3.)

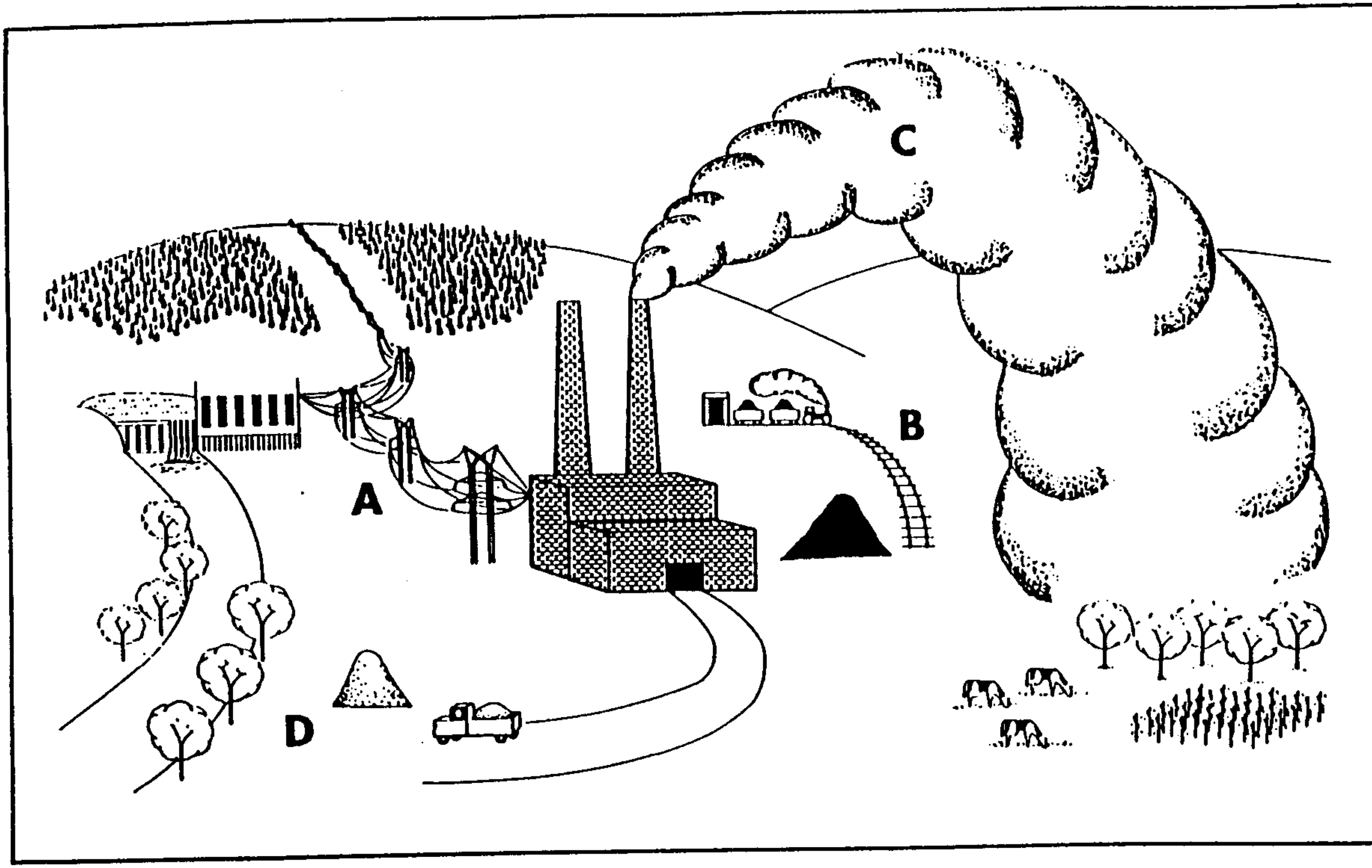

Figure 7-1. Modes of power plant impact on terrestrial ecosystems

A. Modifying or eliminating habitat
B. Mining, handling and storing coal
C. Emissions from stacks and cooling towers
D. Disposal of wastes

B. Geographical Provinces and Ecosystem Types

Maryland has considerable physiographic diversity, encompassing within its borders portions of the eastern Coastal Plain, Piedmont, and Appalachian physiographic provinces (Figure 7-2). These provinces comprise distinct associations of soils, geologic formations, and topography, and support a diverse native flora and fauna. There are approximately 2,400 species of native plants in the state, of which 800 species are potentially rare (Norden *et al.* 1984). The Maryland Department of Natural Resources (DNR) (1987) lists 8 of the 63 native species of mammals as endangered, threatened, or in need of conservation. Similarly, 2 of the 108 species of native freshwater fish fall in one of those three categories, as do 5 of the 40 species of native amphibians, 3 of the 54 species of native reptiles, 17 of the 348 species of native birds, 12 of an unknown number of species of native invertebrates, and 129 of approximately 2,000 species of plants. Seventeen species of animals and 138 species of plants have been extirpated from Maryland since records have been kept.

The terrestrial ecosystems of Maryland have been greatly modified from their pre-European settlement conditions. Forests older than 150 years are rare, and most are less than 100 years old. Disturbances to the native vegetation include clearing for agriculture, mining, lumbering, urbanization, and industrialization (Brush *et al.* 1977). Human population is concentrated in the upper Coastal Plain and lower Piedmont, along the western shore of the Chesapeake Bay and in the Baltimore-Washington metropolitan corridor.

Despite centuries of intense disturbance, geography still significantly determines the patterns of existing landscapes. Pronounced differences in substrates and hydrologic characteristics among the physiographic provinces are reflected in the distribution of species and biotic communities. The terrestrial habitats of Maryland are described below for each of the major physiographic provinces.

Coastal Plain Province

The Coastal Plain encompasses nearly 5,000 square miles from the fall line to the Atlantic Ocean (Figure 7-2). Its topography is low and uniform, with extensive floodplains and alluvial terraces. Substrates are unconsolidated sedimentary deposits overlaying crystalline bedrock, and range from silts and clays to gravels. Because substrates are so heterogeneous, hydrologic conditions vary greatly, from inundated mucks to well-drained gravels. Siltation across alluvial plains and along estuarine margins has formed numerous and extensive wetlands. Mean monthly precipitation ranges from 2.7 in. (February) to 5.4 in. (August), and mean monthly temperatures range from 36.1°F (February) to 77.3°F (July) (NOAA 1986).

The heterogeneous landscape of the Coastal Plain province is primarily due to the variability of its substrates and their hydrologies (Brush *et al.* 1977). Poorly drained soils (alluvial silts and mucks) and riparian plains support vegetation communities characterized by moisture-tolerant canopy species (bald cypress, sycamore, river birch, tulip poplar, and basket oak). Drier sands, clays, and

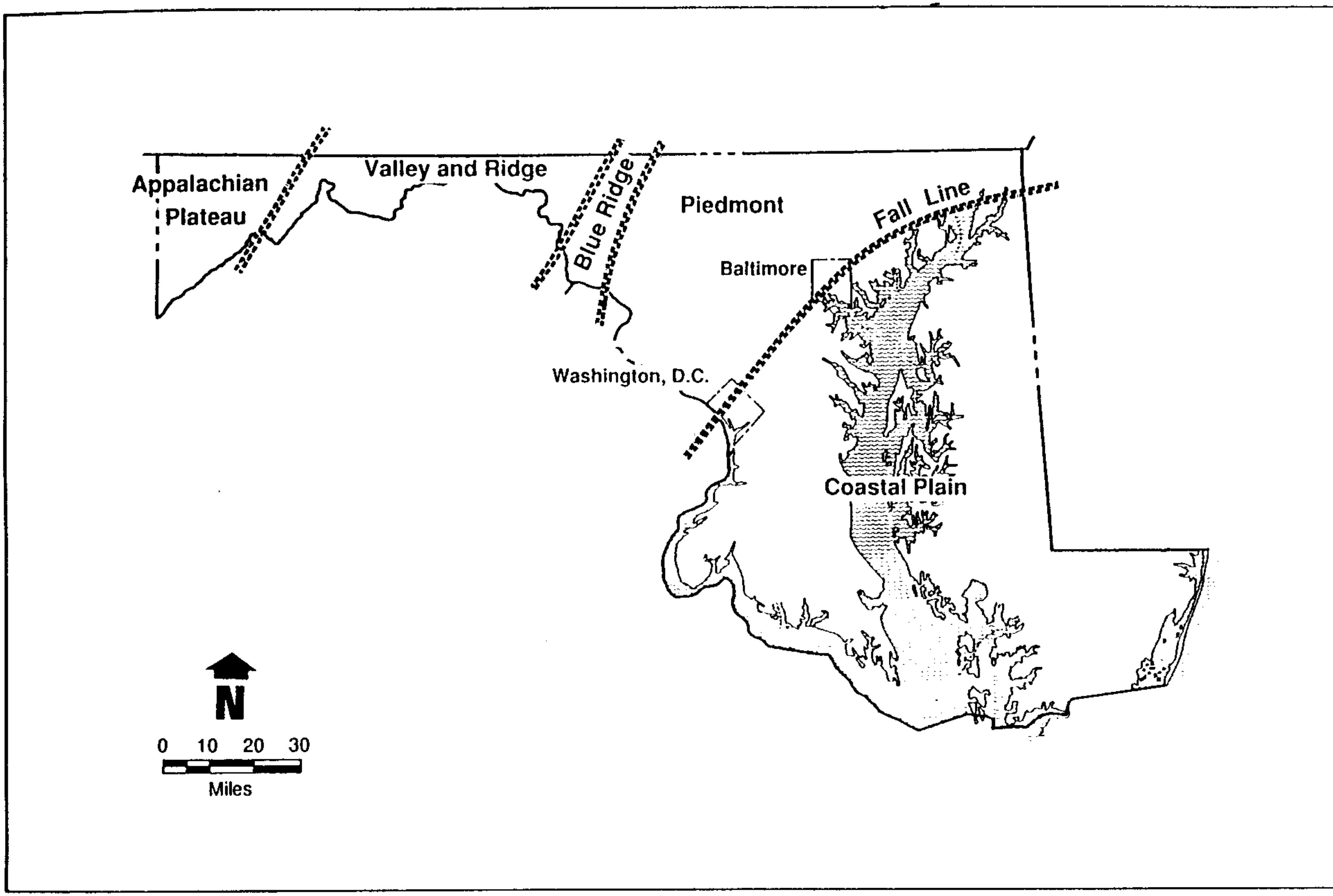

Figure 7-2. Maryland's physiographic provinces

loamy substrates support forest communities that include willow oak, loblolly pine, chestnut oak, blackjack oak, and post oak. Extensive tidal marshes support characteristic grasses (e.g., *Spartina*, *Distichlis*) and shrubs (e.g., *Iva*, *Baccharus*), with loblolly pine communities on higher areas where freshwater lenses perch on the saline estuarine ground water. The northern and southern Coastal Plain support distinct vegetation communities. Northern Coastal Plain forests are composed of beech, dogwood, pignut and mockernut hickories, tulip poplar, black cherry, black locust, and ironwood. Southern forests include loblolly pine; sweetbay magnolia; water oak, basket oak, and willow oak; sweet gum; and holly. Bald cypress communities are restricted to the southern Coastal Plain, primarily on the Eastern Shore (Brush *et al.* 1977).

Several rare and sensitive plant communities exist in the Coastal Plain. Maryland has over 300,000 acres of wetlands, most of which are tidal marshes. There are also several nontidal swamps and bogs in the Coastal Plain region (Sipple and Klockner 1984), ranging in size from one to thousands of acres (Table 7-1). The smaller sites are quite sensitive to physical disturbance or perturbation of adjoining "buffer" habitats. The small watersheds associated with these tiny wetlands and the acidic, possibly nutrient-poor, status of their substrates suggests that they may also be sensitive to run-off and chemical pollutants.

Vertebrate species common in the Coastal Plain province are generally found throughout the entire state, notable exceptions being waterfowl and the bald eagle. Waterfowl are more common in the Coastal Plain because it contains more marsh and shore habitat. The province supports a high diversity and abundance of waterfowl throughout the year and also provides over-wintering habitat for migratory species. Common residents of the areas include egrets, gulls, bitterns, and ducks. Mallards, blue-winged teal, black duck, and wood duck are common duck species present. Over-wintering species include ring-necked duck, hooded merganser, and red-breasted merganser.

The Coastal Plain is the only province where bald eagles are currently known to nest. Historically, their nesting range also included adjacent portions of the Piedmont province along the Potomac River west of Washington, D.C., and along the Susquehanna River north of Havre de Grace. Their habitat requirements include open, discontinuous stands of forest located near open water but not directly on shoreline. Approximately 28 percent of the Coastal Plain province in Maryland is believed to be suitable bald eagle nesting habitat (Taylor and Therres 1981).

Aside from birds, vertebrate species common in low-lying, wet habitats of the coastal plain include nutria, muskrat, southern bog lemming, beaver, and river otter. These species are present in the other provinces but in lesser numbers because habitat is less abundant. Raccoons, skunks, white-tailed deer, eastern chipmunk, and red and gray foxes are fairly common species existing in drier areas.

Table 7-2 shows the approximate percentages of land in each of 12 land use classes for each of the geographical provinces; Figure 7-3 illustrates those

Table 7-1
Unique wetland systems of Maryland
(tidal and nontidal)

Name	County	Acres	Type*
Severn Run Tributaries	Anne Arundel	3,000	T,N
Jug Bay	Anne Arundel	4,800	T,N
Eagle Hill Bog	Anne Arundel	320	T,N
South River Headwaters	Anne Arundel	9,500	T,N
Round Bay Bog	Anne Arundel	90	T,N
Sullivan's Cove Marsh	Anne Arundel	20	T
Deep Pond	Anne Arundel	350	T
Fresh Pond/Angle's Bog	Anne Arundel	200	N
Cypress Creek Cedar Swamp and Savannah	Anne Arundel	5	N
South Gray's Bog	Anne Arundel	2	N
Gunpowder Delta Marsh	Baltimore	1,350	T,N
Black Marsh	Baltimore, Harford	500	T
Zekiah Swamp	Charles Prince George's	17,800	T,N
Mattawoman Creek	Charles, Prince George's	6,000	T,N
Broad/Hensen Creek Marsh	Prince George's	200	T,N
Piscataway Creek	Prince George's	2,450	T,N
Suitland Bog	Prince George's	25	N
Chaptico Run	St. Mary's	1,050	T,N
Millpeck/Trent Hall Creek	St. Mary's	450	T,N
Battle Creek Cyprus Swamp	Calvert	125	N
Cove Point	Calvert	210	N
Bush Creek Marsh	Harford	300	T
Church Creek Marsh	Harford	300	T
Otter Point Creek Marsh	Harford	900	T
Swan Creek Marsh	Harford	325	T
Big Marsh/Howell Point	Kent	850	T,N
Eastern Shore Potholes	Kent, Queen Anne's, Caroline	1-5	N
Pocomoke River	Somerset, Worcester, Wicomico	18,700	T,N
Potomac Shoreline Marshes	Montgomery	500	N
Finzel (Cranberry) Swamp	Garrett	100	N

Source: Sipple and Klockner 1984; DSP 1981.
* T - tidal/ N - non-tidal

Table 7-2
Estimated Maryland land use
(percent)

	Appalachian	Piedmont	Coastal Plain	TOTAL
Water	1.16	1.60	6.2	4.08
Forest	60.74	24.89	36.	38.38
Barren Land	0.30	0.49	0.68	0.56
Strip Mines	0.70	0.20	0.32	0.37
Urban	0.20	1.25	0.65	0.70
Commercial	0.66	2.47	2.91	2.34
Trans/Comm/Util	0.54	1.03	0.75	0.78
Forested Wetland	0.08	0.03	2.16	1.21
Nonforest Wetland	0.00	0.10	4.85	2.68
Feedlots	0.00	0.01	0.12	0.07
Residential	1.86	8.74	10.50	8.29
Agriculture	33.76	59.17	34.75	40.55
TOTAL	20.61	24.60	54.79	100.00

Source: DNR 1989c

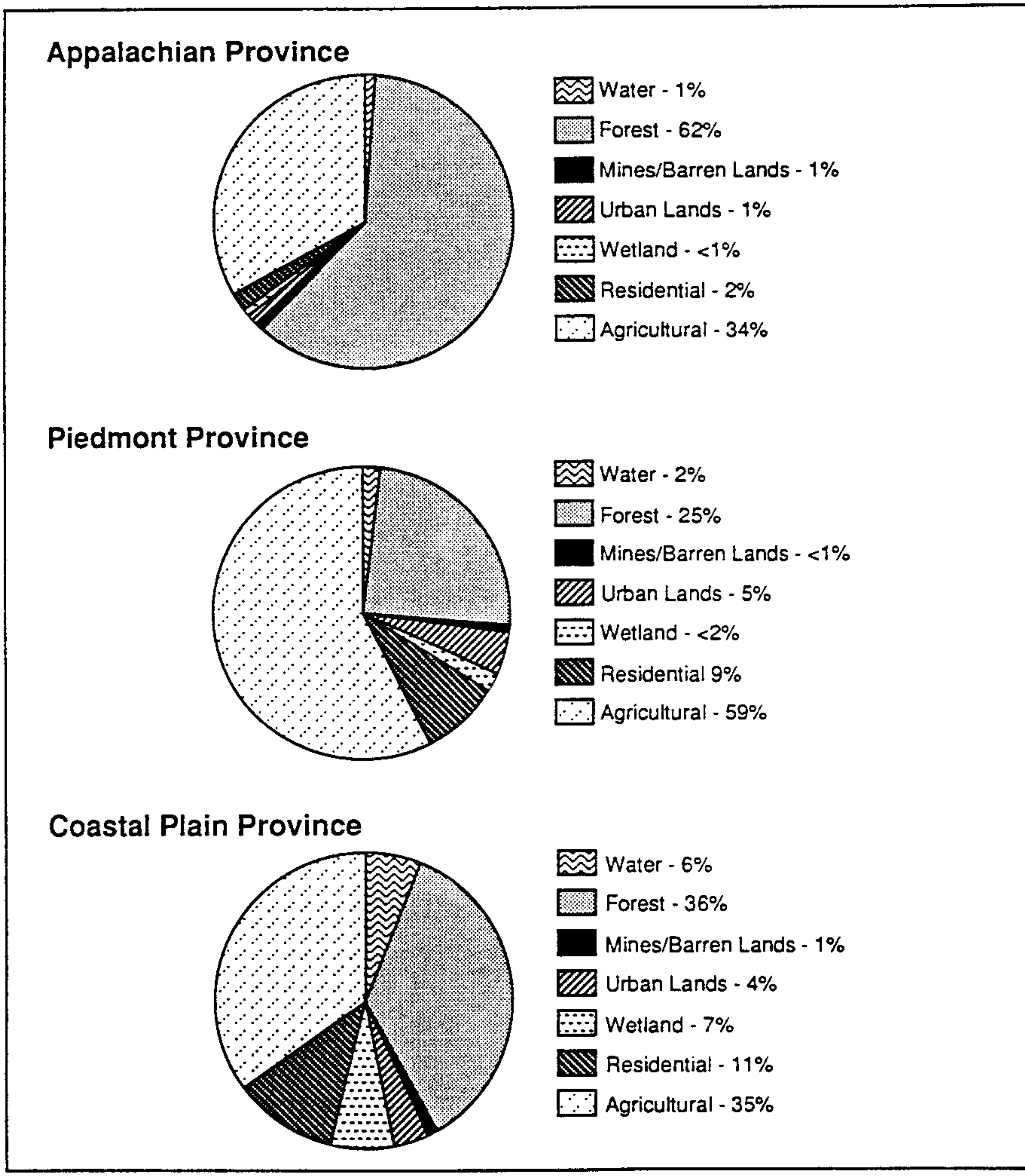

Figure 7-3. Land use by province

percentages. The major land use classes in the Coastal Plain province are forests and agriculture, each accounting for about 35 percent of the total area. The next most significant classes are residential and wetlands, both of which account for significantly more area than they do in other regions of the state.

Piedmont Province

The Piedmont includes approximately 3,000 square miles of area extending from the fall line west to the Catoctin Mountains in Frederick County (Figure 7-2). The land is hilly throughout, with greater topographic relief in the west. Soils are mainly saprolitic, formed in place by weathering of the underlying crystalline bedrock. Along the fall line, sedimentary deposits of sand and gravel predominate, and throughout the Piedmont there are well-developed floodplains. Soils are generally well- to moderately well-drained, due to the topographic relief. Mean monthly precipitation ranges from 2.7 in. in February to 4.6 in. in August, with an annual average of approximately 44 in. The range of mean monthly temperatures is from 33.7°F in January to 75.4°F in July, with an annual average of 54.2°F (NOAA 1986).

Tulip poplar associations cover much of the lower Piedmont, being found on schist, granite, and gneiss soils. Shingle and chestnut oak communities predominate in the upper Piedmont on diabase, quartzite, and coarse textured schists. Wetlands of the Piedmont are primarily river floodplain swamps and marshes (Table 7-1). On dry and nutrient-poor gravels and serpentenite soils, canopies are dominated by mixed oak communities -- including chestnut, post, blackjack, red, white and black oaks -- and a variety of hickories and other species that require relatively little moisture.

Several rare and sensitive biotic communities are found in the Piedmont province. Scattered serpentine barrens support unusual metal-tolerant species (Whittaker 1954), and a rare and sensitive flora inhabits limestone barrens in Frederick County (Reifner and Hill 1984). Urbanization is the major general threat to unique habitats and animal populations in the Piedmont. All Piedmont counties in Maryland are growing rapidly in human population density: the Baltimore-Washington corridor is one of the fastest developing areas of the United States.

Vertebrates in the Piedmont province are similar to those found in the Coastal Plain province except as noted previously. Additional species inhabiting the Piedmont include the longtailed shrew, hairytailed mole, and eastern cottontail (Burt and Grossenheider 1976). In addition, the endangered Indiana bat may exist in the western portion of the province.

Land use in the Piedmont province (Table 7-2, Figure 7-3) is heavily weighted toward agriculture (about 60 percent). About 25 percent of it is in forests, and most of the remaining 15 percent is residential, urban, or commercial.

Appalachian Province

The Appalachian province in Maryland extends from the Piedmont in Frederick County to the western border of the state, and encompasses approximately 5,180 square miles. It is composed of three subregions: 1) the Blue Ridge, in western Frederick and eastern Washington counties, 2) the Valley and Ridge, in western Washington and eastern Allegany counties, and 3) the Appalachian Plateau in western Allegany and Garrett counties. Elevations in the province range from 1,400 to over 3,000 ft, with higher elevations confined to the west. Topography is diverse, with broad alternating ridges and valleys in the east and a high upland plateau in the west. Eastern valleys are underlain by limestone and/or shale, while ridges are underlain by sandstone and quartzite. Substrates on the Appalachian Plateau are mostly shale high in calcite and readily weathered; sedimentary substrates there are frequently coal-bearing.

Soils in slope areas are saprolites (formed from the disintegration of rock), and extensive floodplains and other depositional environments are confined to the eastern portions of the province where topography is less rugged. Most soils in the province are well-drained, although some basins on the Plateau support saturated substrates and bog vegetation. Mean monthly precipitation ranges from 2.2 in. in February to 4.6 in. in July, and mean monthly temperatures range from 28.3°F in January to 74.2°F in July (NOAA 1986).

Natural vegetation in the Appalachian province is patterned spatially in response to local topography (including such natural disturbances as landslides and snowfall) and hydrology. Soil types also reflect topography, as saprolites predominate in the region. Eastern valleys are dominated by sugar maple-basswood communities, with chestnut oak and burr oak assemblages on ridges. More mountainous western areas also support hemlock and birch forests of boreal affinities. Sycamore, river birch, and ash forests inhabit riparian corridors and alluvial plains throughout the province. Bogs on the Appalachian Plateau may support tamarack. Human disturbances of the natural landscape mosaic include agricultural, lumbering, mining, and increasing residential and industrial development.

Several rare and sensitive biotic communities are found in the Appalachian province of Maryland (Norden *et al.* 1984). In the Valley and Ridge subregion, shale barrens on dry slopes host a number of endemic, rare, and disjunct populations of plants. Limestone areas, as described above, also occur in the province, although outcrops west of Frederick County are small and localized. Various kinds of peatlands, including some riverbottom swamps and mountain bogs, are found in Garrett County (Table 7-1). These habitats are generally small, nutrient-poor, acidic, and poorly drained. They support a unique flora, and are sensitive to both physical and chemical disturbance.

Many of the vertebrate species in the Appalachian province are unique to this region. Such boreal and mountain forms as the green salamander, mountain earth snake, coal skink, winter wren, dark-eyed junco, porcupine, spotted skunk, fisher, and other species do not occur in other provinces of Maryland. Streams in western Garrett County are part of the Mississippi drainage. As a result, some species that are rare or nonexistent elsewhere in Maryland, including several fish species and the hellbender salamander, are found in those streams. In addition, eastern portions of the province have southern and Piedmont faunal affinities, so that overall faunal diversity of the Appalachian province is quite high.

The Appalachian Province is dominated by forests (about 60 percent of the total land area; Table 7-2, Figure 7-3). Almost all of the rest of the land is devoted to agriculture (about 35 percent), and a small fraction is used for residential and other human activities.

C. Modes of Impact

Direct Habitat Alterations

The construction and operation of power plants, whether steam electric or hydropower, may have terrestrial impacts through physical modification or displacement of existing habitats (including wetlands), disturbances to wildlife during both construction and operation, deposition of materials emitted to the atmosphere, and spills of harmful materials. Ancillary facilities and structures, such as transmission corridors and combustion by-product landfills, similarly eliminate or modify additional habitat. The zone of influence of an apparently small habitat modification may be quite large if it fragments the habitat into sections smaller than the critical size for species survival. Excluding Conowingo Dam, there are currently 14 power plants in Maryland greater than 100 MW capacity, nine of which are located in rural areas and five of which are in urban, developed areas. The total area of all the non-urban sites is over 5,000 acres, the majority of which is within the Coastal Plain province (PPSP 1975). Much of the habitat in these sites is not directly impacted by the power plant facilities.

The State of Maryland is particularly conscious of impacts on nontidal wetlands. Under regulations implementing the Nontidal Wetlands Protection Act (DNR 1989), most activities in such areas are regulated under a policy of no net loss. After 31 December 1990, a Nontidal Wetland Permit will be required for most activities in or affecting nontidal wetlands. Until then, interim controls are effected through the waterway construction program. Any alteration of water level or water drainage or flow patterns in a wetland are subject to regulation under the Nontidal Wetlands Protection Act.

In general, permits may be granted for activities that are "water dependent" or have no practical alternative. Specific exemptions are provided for the maintenance, repair, or installation of transmission lines, or for particularly small areas with no significant plant or wildlife value. In most cases, the Act requires mitigation through rectification after disturbance, wetland acreage replacement, or enhancement of existing wetlands. Assuming that power plants are able to comply with these regulations, the result should be no net overall loss in nontidal wetland acreage, and possibly a net gain over present conditions.

• Steam Electric Power Plants

Table 7-3 identifies the physiographic province within which each of the steam electric plant sites is located and the habitat type typical of that area. Approximately 5,550 acres are occupied by steam electric station power plant sites, which amount to less than 0.1 percent of Maryland's total land area (over 6 million acres). In addition, facilities situated in urban areas did not displace native vegetation and habitats, and thus have had no direct impact on Maryland's terrestrial ecosystems. Even within specific plant sites, buildings and structures on the site typically occupy only a small percentage of the total acreage. At Calvert Cliffs, for example, 90 percent of the site is maintained as natural native habitat or agricultural land, providing substantial protected terrestrial habitat occupied by typical Coastal Plain flora and fauna (PPSP 1975). Caution must be exercised, however, since the loss of sensitive or valuable habitat due to future power plant or cooling facilities construction may have considerable site specific impact. For example, construction of a cooling lake in a wetlands area, which would impact bird population distributions, would be carefully regulated under Maryland's new nontidal wetlands act.

• Hydroelectric Facilities

Maryland hydroelectric facilities are listed in Table 7-4. Impoundments created by their dams were not located in urban areas, and hence displaced existing terrestrial habitats (although most of the dams were not built exclusively for hydropower). The largest impoundment, formed by the Conowingo Dam, lies primarily in Pennsylvania. Excluding Conowingo, the area inundated by impoundments created for or with hydroelectric facilities totals 7,790 acres, representing approximately 0.1 percent of Maryland's total acreage. The habitats inundated by the impoundments were generally riparian corridors, which are known to support diverse and valuable flora and fauna. This loss has been mitigated by the formation of additional riparian habitat along the new water line of the impoundment, and the impoundments have also provided new open water habitat suitable for a variety of wildlife, including waterfowl. New recreation areas associated with the impoundments may also be considered a positive social and cultural impact.

None of the hydroelectric sites is known to have been constructed in a critical or unique habitat, and the existing facilities cannot be considered to have eliminated a significant portion of Maryland's total riparian habitat. However, unaltered rivers are increasing in recreational value. Variable flow downstream from a dam (especially a peaking facility) can harm the riparian corrider by washing away streambank vegetation during high-flow periods, which can be almost as severe as, and more frequent than, natural floods on unimpeded streams and rivers.

Table 7-3
Power plant sites in Maryland

Site	Geographic Province	Vegetation Association Type	Acreage
R. P. Smith	Appalachian	river birch-sycamore, sugar maple, basswood	NA
Chalk Point	Coastal Plain	river birch-sycamore, tulip poplar	1,149
Calvert Cliffs	Coastal Plain	Loblolly Pine, chestnut oak-post oak	1,140
Dickerson	Piedmont	river birch-sycamore, tulip poplar	1,003
Perryman*	Coastal Plain	tulip poplar	708
Morgantown	Coastal Plain	chestnut oak-post oak	427
Brandon Shores	Coastal Plain	urban	375
Vienna	Coastal Plain	Loblolly pine, river birch-sycamore	296
Notch Cliff	Piedmont	sycamore-green ash, tulip poplar	
C.P.Crane	Coastal Plain	chestnut oak-post oak-blackjack oak	443
Riverside	Coastal Plain	urban	
Westport	Coastal Plain	urban	
Gould Street	Coastal Plain	urban	
Wagner	Coastal Plain	urban	
		Total	5,541

Source: PPSP 1975; Brush *et al.* 1977.
* Existing combustion turbine facility; steam cycle has been proposed.
NA=Not Available

Table 7-4
Hydroelectric facilities in Maryland

Site	Date Operational	Drainage Area (square miles)	Impoundment Area (acres)
Deep Creek	1925	65	4,500
Brighton	1985	77	800
Jennings Randolph	*	287	952
Potomac #4	1909	5,900	675
Parker Pond	1950s	9	41
Conowingo	1926	27,100	8,960
Gilpin Falls	1984	23	3
Potomac #3	1922	6,236	325
Potomac #5	1919	5,100	490
Gores Mill	1950s	11	1
Wilson Mill	1983	180	3
	TOTAL	44,988	16,750 (26 sq. mi)

Source: Weisberg *et al.* 1985.
* Preliminary permit application submitted.

• Transmission Rights-of-way

Transmission rights-of-way are distributed throughout the state, connecting sources of power, distribution centers, and consumers. The corridors require 12 to 24 acres per mile (PPSP 1975) and currently occupy a total of about 33,000 acres, with the majority within the Coastal Plain province (PPSP 1978). Utilities may either hold title to the lands or hold easements granting them rights of access to the lines constructed within them.

The ecological impacts of power lines are very site-specific and may be either positive or negative. Clearings must be created to establish transmission line corridors, and the corridors must be maintained in grass or brush. With proper construction techniques, even sensitive wetlands can recover from the disturbance within two years (Grigal 1985).

Maintenance of the transmission corridors may have a long-term impact on the ecosystem in which it is located. This impact can be minimized with appropriate procedures. Improper use of chemical herbicides to control plant growth can result in run-off into noncorridor areas and consequently cause damage to nontargeted vegetation (DeMuro *et al.* 1987; PPSP 1978; FWS 1979). A recent study of herbicide-based right-of-way maintenance procedures used by Maryland's utilities indicates that all utilities currently comply with EPA, Maryland Public Service Commission, and Maryland Department of Agriculture herbicide standards. Only registered EPA-approved herbicides are used by the utilities in Maryland. These herbicides are reported to pose little danger to the environment if properly applied (DeMuro *et al.* 1987).

When transmission line corridors are created in forested areas, considerable edge habitat is created, and alternative ecosystems (e.g., grass, shrubs) introduced, sometimes resulting in temporary increases in species diversity of both flora and fauna (PPSP 1978; Thibodeau and Nickerson 1986). On the other hand, construction of transmission corridors may cause wildlife to emigrate in response to noise, and can disrupt forage, breeding, and migration areas. Fragmentation of such areas to below critical size is a concern for some species. In general, however, as long as transmission corridors are sited to avoid sensitive or unique ecosystem types, proper erosion control measures are taken during and following construction, and approved herbicides are properly applied to right-of-way areas, adverse impacts of transmission lines on terrestrial ecosystems in Maryland will be minimal.

• Combustion By-product Landfills

The land area required by conventional pulverized coal-fired power plants for ash disposal depends on both the type and amount of coal used. The land area required for fly and bottom ash has been estimated (FWS 1978) at between 0.005 ac/MW/yr (Northern Appalachian Coal) and 0.01 ac/MW/yr (Eastern Interior Coal). Due to improvements in combustion technology, the lower estimate is probably more representative of current power plant needs in Maryland. At the present time, there are six active power plant ash sites in Maryland, occupying approximately 1,200 acres, and over 30 inactive or insignificant ash sites (PPSP 1984). At the rate of 0.005 ac/MW/yr, Maryland's coal-fired plants, with a total capacity of 5,680 MW, will require approximately 1,140 landfill acres over a 40-year period. Thus, the active sites will probably be adequate for future use by these plants. If the required land area is 0.01 ac/MW/yr for a conservative case, the total land needed over 40 years would be about 2,300 acres. In this case, new landfill acreage would have to be identified. However, the need for new landfill acreage could be partially offset by efforts of utilities to market coal ash.

The need for landfills could increase if acid rain controls were implemented, since potentially large volumes of flue gas desulfurization sludges would be generated. The introduction of coal gasification combined cycle (GCC) facilities would also generate additional solid wastes and consequent landfill requirements. At least two GCC units have been proposed (PEPCO's Station H project) for the state, which will require the construction of an additional landfill sited on an area of 200 to 300 acres. This will accommodate approximately 20 million tons of slag and ash over its 30-year life (DNR 1989a).

There are a number of potential environmental impacts associated with the development and operation of a combustion by-product landfill, depending on its location, design, and operating practices. Site clearing, grubbing, and subsequent fill placement at a by-product landfill can destroy vegetation or wetlands; modify habitats of rare, threatened, or endangered species; displace wildlife; and destroy smaller animals.

Current fly ash landfill techniques use engineered embankments designed to immobilize the material and render it environmentally innocuous while providing immediate development capability on the site or leaving open the possibility of recovery for future use. Prior to ash placement a thick permeable drainage blanket is placed over existing soils to direct seepage to sedimentation ponds. Following ash emplacement and compaction, a soil cap is installed and seeded with a grass-legume mixture to promote evapotranspiration and surface water run-off without erosion. Leachate generation is also minimized by limiting the size of open areas and controlling the amount of water that may run onto the ash piles.

Coal gasification facilities could potentially generate a variety of solid wastes, including slag from the gasifier; ash from the raw syngas scrubber; elemental sulfur from the Claus unit; spent catalyst and filter cake from sulfur recovery units; sludges, resins, and filter cake from wastewater treatment; and sludges from the cooling towers (DNR 1989a). Slag and ash are the largest constituents (by volume) of these materials and can be handled like conventional power plant fly ash. The actual type, volume, and chemical characteristics of the solid waste stream are a function of the process design, coal type, operating schedules, and pollution abatement procedures used. Leaching tests of slag and ash by-products from Texaco-type GCC facilities have been shown to be nonhazardous under current waste regulations. Normal landfilling techniques minimize waste leaching and contact with the food chain. Thus the primary terrestrial impact is through habitat destruction and alteration.

The potential for a terrestrial community's eventual recovery at an abandoned site, and the site's long-term impact on the community, have not been evaluated. Engineered sites are generally designed to be dry and elevated above the water table, and to contain a highly compressed layer of ash or other materials, which could inhibit deep root growth. These conditions constrain the long-term vegetative cover and make the sites largely unsuited for wildlife.

Non-point Sources: Coal Piles and Solid Wastes

Several aspects of coal-fired power plant operations other than regulated effluent discharges can cause surface and ground water contamination. Non-point source water contamination from power plants can result from leaching and run-off from coal storage piles and ash landfill sites. Chapter 6 describes these processes in ground water contamination.

Leachate from coal piles and ash landfills is chemically similar to acid mine drainage, and can have similar impacts on streams receiving the effluent. A study of the effects of PEPCO's Faulkner ash landfill, which takes ash from the Morgantown plant, found elevated levels of total dissolved solids, sulfate, and several major cations as well as depressed pH in surface and ground water immediately around and downslope of the landfill (Simek *et al.* 1983). The biological effects of these impacts in the nutrient-poor Zekiah Swamp appear to be insignificant. Trees immediately adjacent to the ash disposal site had higher tissue content of arsenic and manganese than trees from control sites, but the concentrations were still within the natural ranges for these elements (Klose and Potera 1984).

Air Emissions Impacts

Coal-fired power plants can also affect terrestrial ecosystems through emissions of gaseous and particulate matter to the air, from their stacks or from coal handling activities. Much of their impact is covered in Chapter 3, which discusses air emissions primarily in terms of ambient air quality standards. However, as airborne pollutants from power plants are dispersed, some are eventually deposited on land and surface waters. These pollutants may pose ecological risks such as acidification of soils and waters (see Chapter 8, Acid Deposition), or they may be toxic to plants or wildlife. Pollutants in surface waters can be absorbed by aquatic life, and may be incorporated into aquatic food chains of terrestrial wildlife and humans. Similarly, pollutants deposited onto land can be incorporated directly into terrestrial food chains, including uptake by crops and farm animals (Figure 7-4). No long-term studies in Maryland currently monitor the health of ecosystems near power plants, so no data are available on actual damage to plants and animals from existing emissions. This section, therefore, focuses on the types of emissions that can affect terrestrial ecosystems, and the potential impacts that those emissions can have.

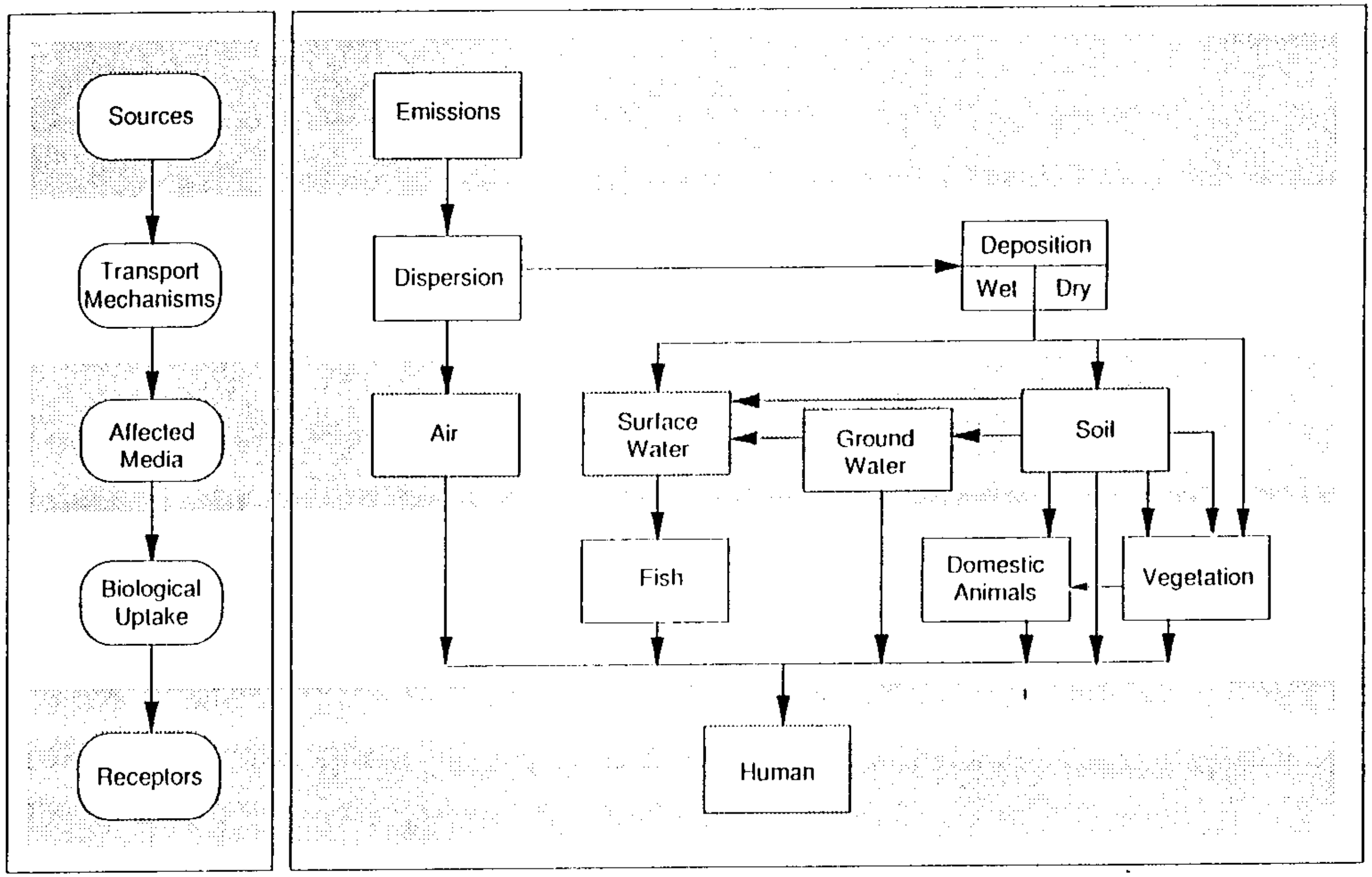

Figure 7-4. **Exposure pathways**

• Particulate Emissions

Particulate matter may be introduced into the atmosphere in a variety of ways by the operation of fuel-burning power plants, primarily those using coal as fuel. Primary modes include fugitive emission of coal dust during loading, transport, unloading and storage on site, and the emission of particulate material from the plant's stacks. Stack emissions are generally controlled very effectively by existing emission control technology, particularly precipitators. The overall level of control, however, is more effective (95 to 97 percent) on large particles (>5 μm diameter) than on small particles (72 percent for <5 μm diameter). Power plant emission rates and total emissions are discussed in detail in Chapter 3.

No studies have been conducted in Maryland to assess the impacts of fugitive or stack emissions of particulates on terrestrial biota, and so no evidence of impacts is available. In the extensive background discussions provided by EPA to support revisions to national ambient air quality standards for particulate matter (EPA 1987), the only relevant impacts concerned human health, soiling and nuisance effects, and reduced visibility.

Some information is available on other types of impacts, however. Particles in the air, particularly when they land on the surface at concentrations above 1 g/m^2/day, can impact vegetation and animals in a number of ways. Plant stomata (openings in the leaves) may be clogged, interfering with gas exchange and enhancing penetration of healthy tissues by pathogens. Radiation reflectance and absorption properties of vegetation can be altered, affecting heat exchange and photosynthesis. Germination may be reduced and uptake of harmful substances may be increased. Terrestrial invertebrates may be affected by direct deposition of fine particulates on soft integumental tissues, causing abrasion damage. Vertebrates may inhale particulates, which interfere with oxygen transfer across mucous membranes and cause physical irritation of soft tissues (FWS 1978).

Dust loading in excess of 1 g/m^2/day, however, would require the settling of 6,700 m^3 of air with a 150 $\mu g/m^3$ concentration of total suspended particulates. Particulate concentrations measured or modeled in Maryland have not reached this level, with the exception of one instance in Baltimore (see Chapter 3). The only real potential for damage by particulates appears to be as dry deposition of toxic materials, which is described more fully below.

• Cooling Tower Aerosols

Cooling towers operate by passing a continuous flow of heated water over a large surface exposed to the air. As evaporation occurs, the rising water vapor carries with it some of the solids that were dissolved in the liquid water. Residual liquid flowing from the cooling surfaces is mixed with additional makeup water and recirculated. Concentration and vaporization cause a plume of water vapor carrying salts and other solids to leave the cooling tower and pass over the landscape. These solids may have an impact on terrestrial ecosystems. In general, those impacts are believed to occur within 1,800 m of the tower (Weil *et al.*

1985). In some field studies, elevated levels of chlorides, possibly associated with cooling tower drift, have been found in foliage of sensitive species located 1,600 m from working natural draft cooling towers (Curtis *et al.* 1976). However, no evidence of damage from Maryland power plants has been found.

At present, only three fossil fuel power plants in Maryland (Chalk Point, Vienna, and Brandon Shores) operate with cooling towers. Chalk Point's towers were studied for their impact because the drift consists of concentrated estuarine water with an initial salinity of between 3 and 15 ppt. Studies summarized in Mulchi *et al.* (1977) indicate that the Chalk Point cooling tower drift has measurable effects on tissue and possibly soil chloride concentrations, but that immediate impacts to vegetation are unlikely. Accumulation of elevated salts in soils could have long-term effects, but no current information is available. No studies assessed the potential impacts of other constituents of drift, such as biocides and descaling compounds.

- Gaseous and Toxic Atmospheric Emissions Impacts

Combustion processes release a number of gases to the atmosphere. Although the largest volume is composed of nominally harmless gases like carbon dioxide, the build-up of these gases in the atmosphere over the long term may have devastating ecological effects by causing physical changes in the climate itself. These impacts are discussed separately below; in this section, only the direct impacts of atmospheric emissions are considered.

The gaseous power plant emissions with the greatest short-term terrestrial impacts are sulfur and nitrogen oxides. Only the direct effects of these gases are addressed here; acidic deposition impacts associated with them are discussed in Chapter 8. As with particulates, actual evidence of damage is not currently available, and actual concentrations of the pollutants appear to be too low to be likely to cause long-term effects.

Power plants do not emit nitrogen oxides in quantities great enough to cause either acute or chronic injury to vegetation (FWS 1978). Nitrogen oxides do contribute to formation of secondary pollutants (e.g., ozone, peroxyacyl nitrates), which can harm many plant and animal species. The contribution of combustion power facilities to the atmospheric NO_x load, however, is insignificant relative to other sources such as automobiles and manufacturing (FWS 1978).

Sulfur oxides may have caused damage to some plant communities in Maryland, but direct evidence of damage is unavailable. Sulfur oxides can damage populations of lichens at annual average concentrations of 40 $\mu g/m^3$, although episodic higher concentrations may be the actual cause of destruction (FWS 1978). It has been hypothesized that the lichen flora of Maryland may be depleted due to air pollution (Skorepa and Norden 1984), but no quantitative historical information is available to confirm or refute this.

Sulfur oxides can cause acute injury to sensitive higher plant species at doses of approximately 1 to 2 ppm (130 to 5,000 $\mu g/m^3$) for 3- to 24-hr exposure (FWS 1978).

Some measurements indicate that concentrations in this range may be experienced for short intervals in localized areas in Maryland (see discussion of measured concentrations, below). Symptoms of acute sulfur oxide injury include bleaching and necrosis of leaves, reduced production and death (ASA 1976). Chronic injury occurs when plants are exposed to sublethal concentrations for long periods of time. Symptoms of chronic injury include chlorosis, discoloration, bleaching, and reduced productivity. Recovery is likely if the source is removed (Bell 1982; Katainen *et al.* 1987). In general, native plant species are less susceptible to sulfur oxide damage than are ornamental and crop species. Tables 7-5 and 7-6 list some representative plants and their relative sensitivity and observed response to sulfur oxide toxicity.

Extremely high concentrations of sulfur and nitrogen oxides may affect animals and humans in a variety of ways, including impaired bronchial clearance, increased susceptibility to infection, increased pulmonary resistance, damage to bronchial structures, and death (FWS 1978). In Maryland, the only health-effect threshold likely to be exceeded by ground level concentrations is the chronic reversible concentration (500 $\mu g/m^3$) of sulfur dioxide. This concentration may be exceeded for a few hours near power plants under inversion or plume fumigation conditions, but is unlikely to occur for the long periods of time necessary to induce chronic symptoms. Thus, direct effects of sulfur or nitrogen oxides on animals in Maryland are unlikely to be significant at present levels of emission.

Measured Pollutant Concentrations

To our knowledge, no long-term studies in Maryland monitor the health of plant communities in the areas around existing power plants, and so no data on actual damage to plants from existing emissions exist. In the absence of long-term studies to address the terrestrial impacts of power plant-related air pollutants, air quality measurements taken near individual power plants may be used to give some indication of the potential for impact.

There are a number of monitoring stations located in the impact area of PEPCO's Dickerson Station. PEPCO itself operates an air quality monitoring network near the site. In addition, the National Park Service operates continuous SO_2 monitors on Dickey Ridge, in the northern portion of Shenandoah National Park. Table 7-7 lists the EPA standards and observed SO_2 concentrations for the vicinity of Dickerson, Sugarloaf Mountain, the Catoctins, and Shenandoah National Park.

Additional data are available from Maryland Air Quality Data reports, which indicate that maximum 3-hour ambient SO_2 concentrations monitored in Montgomery County (in which Dickerson is located) ranged from 490 $\mu g/m^3$ in 1980 to 165 $\mu g/m^3$ in 1985. Based on data collected from the 6-station PEPCO Station H Prevention of Significant Deterioration (PSD) monitoring network from July 1987 through June 1988, the maximum 3-hour ambient SO_2 concentration was 410 $\mu g/m^3$. (See Chapter 3, Section B for detailed discussion of PSD requirements for new or expanded sources.) Maximum 1-hour concentrations of ozone (O_3) for the state monitoring stations ranged from 319 $\mu g/m^3$ in 1980 to 271

Table 7-5
Relative SO_2 sensitivity of woody plants grown in Maryland (native and introduced)

Sensitive Species

red ash *(Fraxinus pennsylvanica)*
European birch *(Betula pendula)*
gray birch *(Betula populifolia)*
white birch *(Betula papyrifera)*
yellow birch *(Betula alleghanensis)*
bitter cherry *(Prunus emarginata)*
Chinese elm *(Ulmus parvifolia)*
larch (tamarack) (*Larix* sp.)
eastern white pine *(Pinus strobus)*
red pine *(Pinus resinosa)*
Lombardy poplar *(Populas nigra)*
staghorn *(Rhus typhina)*
Black willow *(Salix nigra)*

Intermediate Species

basswood *(Tilia americana)*
boxelder *(Acer negundo)*
eastern cottonwoood *(Populas deltoides)*
American elm *(Ulmus americana)*
balsam fir *(Abies balsamea)*
red hawthorn *(Crataequs columbiana)*
red maple *(Acer rubrum)*
white oak *(Quercus alba)*
Austrian pine *(Pinus nigra)*

Tolerant Species

Forsythia *(Forsythia Viridissima)*
Ginkgo *(Ginkgo biloba)*
black hawthorn *(Crataequs douglasii)*
common juniper *(Juniperus communis)*
silver maple *(Acer saccharinum)*
sugar maple *(Acer saccharum)*
pin oak *(Quercus palustris)*
red oak *(Quercus rubra)*
London plane *(Platanus acerifolia)*
Carolina poplar *(Populas canadensis)*
blue spruce *(Picea pungens)*
smooth sumac *(Rhus glabra)*

Source: Davis and Wilhour 1976.

Table 7-6
Effects of sulfur dioxide on vegetation

Concentration (ppm)	Exposure	Plant	Effect
0.4 (1,062 μg/m^3)	3 hour	Oats	Threshold leaf injury
0.35 (992 μg/m^3)	3 hour	Trembling aspen	2% foliar injury
0.2 (531 μg/m^3)	2 hour	Kentucky blue grass	Foliar injury
0.01 (27 μg/m^3)	annual	Oats	Light leaf injury
0.011 (29 μg/m^3)	annual	White birch	Trace foliar injury
0.0006-0.018 (16-48 μg/m^3)	annual	Lichens	Decreased growth
0.01 (27 μg/m^3)	annual	Lichens	Mortality

Source: 40 CFR 52, Subpart V.

Table 7-7
Observed SO_2 concentrations
($\mu g/m^3$)

Averaging Time **Area**	**1-hour**	**3-hour**	**24-hour**	**1-year**
(EPA Standard)	NR	1300	365	80
Dickerson Vicinity	810	411	136	29
Sugarloaf	495	199	89	14
Catoctins	385	199	113	24
Shenandoah National Park	NR	249	81	18*

Source: KBN 1989.
NR - Not reported.

* Averaged from the quarterly values reported by the National Park Service.

$\mu g/m^3$ in 1985. The Station H network does not collect data on ozone concentrations. Maximum or near-maximum short-term concentrations occur several times a year (ESE 1989). Previous studies that measured SO_2 concentrations near the Dickerson, C.P. Crane, and Chalk Point plants also showed that they were all well below EPA standards (PPRP 1987), with concentrations highest near Dickerson.

The EPA SO_2 standards were set for human health and welfare, and exceed the damage threshold for many sensitive plant species for both chronic and acute exposure (Tables 7-5 and 7-6). Sulfur dioxide concentrations near Dickerson are within the range that may affect sensitive plants. There is some potential for damage to Kentucky bluegrass in the vicinity of the station. The annual concentrations measured for the Catoctins indicate potential for damage to some other plant species, including oats and white birch. All of the annual averages, including those for Sugarloaf Mountain, the Catoctins, and Shenandoah National Park, are within the range that may cause decreased growth of lichens.

There is no direct evidence that any individual power plant is causing these pollutant concentrations, or that they are actually responsible for ecosystem damage. Nonetheless, the cumulative concentrations from all sources are in the range that have the potential for adverse impacts, and hence are a cause for concern.

- Other Toxic Pollutants

Some additional potentially toxic substances for which ambient air quality standards have not been established (known as noncriteria pollutants), such as gaseous fluoride, arsenic, and mercury, are associated with Maryland power plant emissions. Relatively few monitoring or modeling studies of noncriteria pollutants from power plants have been conducted to date. Given the amount of available information or predictions of quantities of pollutants emitted and deposited, it is difficult to provide an accurate assessment of actual power plant impacts. In general, however, coal-fired power plants appear to be a minor source of heavy metals compared to smelters and automobiles. Some research (e.g., FWS 1978) suggests that fuel-burning power plants contribute little, if any, measurable quantities of most trace elements to the environment.

Direct Impacts

Among all noncriteria trace emissions, fluorides occur in the highest concentrations. The actual concentrations produced by power plants have not been measured in Maryland. Gaseous fluorides are potentially more harmful than are particulate fluorides (Hill 1969), and significant concentrations could threaten several of Maryland's important crops (including corn, cucumbers, and sorghum) and many conifers (FWS 1978). Some sensitive species of lichens can also be eliminated (Perkins and Miller 1987). Cattle may show symptoms of fluoride toxicity from ingesting forage with concentrations below phytotoxic levels (FWS 1978).