LEVEL III AND IV ECOREGIONS OF DELAWARE, MARYLAND, PENNSYLVANIA, VIRGINIA, AND WEST VIRGINIA

by

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BACKGROUND

Environmental resources research, assessment, monitoring, and, ultimately, management typically require appropriate spatial structures. Ecoregion frameworks are well suited to these purposes.

Ecoregions are defined as areas of relative homogeneity in ecological systems and their components. Factors associated with spatial differences in the quality and quantity of ecosystem components, including soils, vegetation, climate, geology, and physiography, are relatively homogeneous within an ecoregion. Ecoregions separate different patterns of human stresses on the environment and different patterns in the existing and attainable quality of environmental resources. They have proven to be an effective aid for inventorying and assessing national and regional environmental resources, for setting regional resource management goals, and for developing biological criteria and water quality standards (Environment Canada, 1989; Gallant and others, 1989; Hughes and others, 1990, 1994; Hughes, 1989b; U.S. Environmental Protection Agency, Science Advisory Board, 1991; Warry and Hanau, 1993).

Ecoregion frameworks have been developed for the United States (Bailey, 1976, 1983; Bailey and others, 1994; Omernik, 1987, 1995a; U.S. Environmental Protection Agency, 1996), Canada (Ecological Stratification Working Group, 1995; Wiken, 1986), New Zealand (Biggs and others, 1990), the Netherlands (Klijn, 1994), and other countries. North American ecoregion frameworks have evolved considerably in recent years (Bailey, 1995; Bailey and others, 1985; Omernik, 1995a; Omernik and Gallant, 1990). The first compilation of ecoregions in the conterminous United States by the U.S. Environmental Protection Agency (U.S. EPA) was performed at a relatively cursory scale of 1:3,168,000 and was published at a smaller scale of 1:7,500,000 (Omernik, 1987). Subsequently, this ecoregion framework was revised and made hierarchical (U.S. Environmental Protection Agency, 1996). It was also expanded to include Alaska (Gallant and others, 1995) and North America (Omernik, 1995b).

The approach we have used to compile ecoregion maps is based on the premise that ecological regions can be identified by analyzing the patterns and composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity (Wiken, 1986; Omernik, 1995a). These phenomena include geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. We do not begin by treating any one phenomena with more weight than any other. Rather, we look for patterns of coincidence between geographic phenomena that cause or reflect differences in ecosystem characteristics. The relative importance of each factor varies from one ecological region to another, regardless of the hierarchical level. Because of possible confusion with other meanings of terms for different levels of ecological regions, a Roman numeral classification scheme has been adopted for this effort. Level I is the coarsest level, dividing North America into 15 ecological regions. At level II, the continent is subdivided into 52 classes, and at level III, the continental United States contains 104 ecoregions. Level IV ecological regions are further subdivisions of level III units. The exact number of ecological regions at each hierarchical level is still changing slightly as the framework undergoes development at the international, national, and local levels.

The ecoregions defined by Omernik (1987) have proved to be useful for stratifying streams in Arkansas (Rohm and others, 1987), Nebraska (Bazata, 1991), Ohio (Larsen and others, 1986), Oregon (Hughes and others, 1987; Whittier and others, 1988), Washington (Plotnikoff, 1992), and Wisconsin (Lyons, 1989). Omernik's ecoregion map (1987) was used to set water quality standards in Arkansas (Arkansas Department of Pollution Control and Ecology, 1988), to identify lake management goals in Minnesota (Heiskary and Wilson, 1989), and to develop biological criteria in Ohio (Ohio EPA, 1988). However, state resource management agencies found the resolution of the 1:7,500,000-scale map inadequate to meet their needs, which led to a number of collaborative projects to refine and subdivide ecoregions at a larger (1:250,000) scale. These projects have involved states, U.S. EPA regional offices, and the U.S. EPA - National Health and Environmental Effects Research Laboratory, Western Ecology Division, in Corvallis, Oregon. Completed projects cover Colorado, Florida, Georgia, Indiana, Iowa, Massachusetts, Mississippi, Montana, North Dakota, Ohio, South Dakota, Tennessee, Wisconsin and parts of Alabama, Mississippi, Oregon, and Washington. Projects still in progress for Georgia, Kansas, Nebraska, Utah, and South Carolina and the rest of Alabama have included participation by the U.S. Department of Agriculture (USDA) - Natural Resources Conservation Service and the USDA - Forest Service as part of an interagency effort to develop a common framework of ecological regions.

In this paper we have refined level III ecoregions and delineated the more detailed level IV subdivisions in a cooperative project with U.S. EPA Region 3, the Delaware Department of Natural Resources and Environmental

Control - Division of Water Resources, the Maryland Department of the Environment, the Pennsylvania Department of Conservation and Natural Resources, the Pennsylvania Department of Environmental Protection, the Virginia State Water Control Board, and the West Virginia Department of Natural Resources. The original impetus for this project was to provide a spatial framework for developing biological criteria. Hence, selection of regional reference sites was a critical aspect and generally followed the approach outlined in Hughes (1995) and Hughes and others (1986); it was carried out primarily under the direction of U.S. EPA Region 3. Later, U.S. EPA Region 3's interest in ecoregions evolved from creating a regional biocriteria framework across state lines to serving the more comprehensive needs of the developing Mid-Atlantic Highlands Project (MAHA).

This project comprised four major stages. Initially, only the parts of Maryland, Pennsylvania, West Virginia, and Virginia located in the Blue Ridge Mountains (66), the Ridge and Valley (67), and the Central Appalachians (69) were studied. As part of this stage, ecoregions were refined and subdivided and stream reference sites were selected for ecoregions 66, 67, and 69 in Maryland, Pennsylvania, West Virginia, and Virginia. Next, the Pennsylvania Department of Environmental Protection negotiated with the U.S. EPA and its Environmental Monitoring and Assessment Program (EMAP) to complete the ecoregionalization of the remainder of Pennsylvania. Later, the level IV ecoregions of the Western Allegheny Plateau (70) portion of Western Virginia were identified. Finally, the ecoregions of the Coastal Plain and Piedmont portions of Delaware, Maryland, and Virginia were refined and subdivided.

Evaluation of the ecoregion framework presented in this paper is a necessary future step. U.S. EPA ecoregions have been evaluated extensively in the past and the most meaningful of these efforts have involved the use of indices of water quality and biotic integrity (IBI) (Hughes, 1989a; Larsen and others, 1986, 1988; Whittier and others, 1987; Yoder and Rankin, 1995). A better tool would be a more encompassing index of ecological integrity (IEI) (Omernik, 1995a, 1995b); although an IEI is not available yet, there is considerable interest in at least two states to begin its development. Verification of ecoregions cannot be done by considering individual ecosystem components; this is because the ecoregion framework was not intended to show regional patterns specific to either the flora or fauna of terrestrial ecosystems nor was it intended to show patterns of fish or aquatic macro invertebrates.

METHODS

In brief, the procedures used to accomplish the regionalization process followed that of similar ecoregion projects (Griffith and others, 1994a, 1994b, 1994c) and consisted of compiling and reviewing relevant materials, maps, and data; outlining regional characteristics; drafting level III and IV ecoregion boundaries; digitizing boundary lines, creating digital coverages, and producing cartographic products; and revising as needed after review by state managers and scientists. In our regionalization process, we employed primarily qualitative methods. In other words, we applied expert judgment throughout the selection, analysis, and classification of data to form the regions. We based our judgment on the quantity and quality of component data and on interpretation of the relationships between the data and other associated environmental factors. This approach is similar to that commonly used in soils mapping (Hudson, 1992). More detailed explanations of the methods, materials, rationale, and philosophy for this regionalization process can be found in Omernik (1995a), Omernik and Gallant (1990), and Gallant and others (1989).

We based our ecoregion delineations on several criteria: (1) climate, (2) elevation, (3) land use/land cover, (4) land form, (5) potential natural vegetation, (6) soil, (7) structural/bedrock geology, and (8) surficial/Quaternary geology. General growing season and precipitation data came from Cuff and others (1989), Raitz and others (1984), U.S. National Oceanic and Atmospheric Administration, 1974, and from county soil surveys (U.S. Soil Conservation Service, various dates; Natural Resources Conservation Service, various dates). Land use/land cover information came from the general classification of Anderson (1970), from county soil surveys (U.S. Soil Conservation Service, various dates; Natural Resources Conservation Service various dates), and from 1:250,000-scale topographic maps of the U.S. Geological Survey. Physiographic information was gathered from many sources including Ciolkosz and others (1984), Cuff and others (1989), Fenneman (1938), Geyer and Bolles (1979, 1987), Guilday (1985), Hack (1982), and Hammond (1970). Information on natural vegetation was obtained from several sources, including Cuff and others (1989), Kuchler (1964), Brush and others (1980), and county soils surveys (U.S. Soil Conservation Service, various dates; Natural Resources Conservation Service, various dates). Soil information came from regional overviews (Buol, 1973; Ciolkosz and Dobos, 1989; Cunningham and Ciolkosz, 1984; Makewich and others, 1990), from 1:250,000-scale State Soil Geographic maps (STATSGO) (Natural Resources Conservation Service, no date), from state soil maps (Higbee, 1967; U.S. Soil Conservation Service, 1972, 1973, 1979a, 1979b), and from county soil surveys (U.S. Soil Conservation Service, various dates; Natural Resources Conservation Service, various dates). Geological information came from Berg and others (1980), Cardwell and others (1968), Cleaves and others (1968), county soil surveys (U.S. Soil Conservation Service, various dates; Natural Resources Conservation Service, various dates), Fullerton and Richmond (1981), and Virginia Division of Mineral Resources (1963, 1993). Topographic data were taken from 1:100,000 and 1:250,000-scale maps published by the USGS. The 1:250,000-scale topographic maps were also used as base maps on which level III and level IV ecoregion boundaries were plotted.

REGIONAL DESCRIPTIONS

Delaware, Maryland, Pennsylvania, Virginia, and West Virginia have been divided into 13 level III ecoregions and 49 level IV ecoregions. Many of the boundaries of these ecoregions are transitional, and the ecoregion map (Figure 1) should be interpreted with that in mind. Ecoregion descriptions follow and include differentiating criteria; their detail varies and depends on available information. Appendix 1 contains ecoregion data summaries.

45. Piedmont

The Piedmont (45) is largely wooded and consists of irregular plains, low rounded hills and ridges, shallow valleys, and scattered monadnocks. It is a transitional area between the mostly mountainous ecoregions of the Appalachians to the west and the lower, more level ecoregions of the coastal plain to the east. Crestal elevations typically range from about 200 to 1,000 feet (61 - 305 m) but higher monadnocks occur and reach 2,000 feet (610m). The Piedmont (45) is underlain primarily by deeply weathered, deformed metamorphic rocks that have been intruded by igneous material; sedimentary rocks also occur locally but are much less dominant than in the Middle Atlantic Coastal Plain (63) or the Southeastern Plains (65). Ultisols occur widely and have developed from residuum; they are commonly clay-rich, acid, and relatively low in base saturation. These soils and the region's humid, warm temperate climate originally supported Oak-Hickory-Pine Forest that was dominated by hickory (*Carya* spp.), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), white oak (*Quercus alba*) and post oak (*Quercus stellata*)) (Kuchler, 1964). Following settlement, much of the area was cultivated causing significant soil loss (Trimble, 1974). Today, many fields have reverted to pine and hardwoods or are in the process of doing so.

Piedmont (45) fish habitats strong reflect stream gradient which, in turn, mirrors local relief. Low and moderate gradient streams characteristically occur in the Piedmont; moderate gradient streams are concentrated especially in the hillier areas of the Northern Inner Piedmont (45e). Moderate gradient Piedmont streams resemble larger streams in the Valley and Ridge Province, but generally are more silty and sandy. Falls, islands, and rapids and associated fish assemblages are found in the Fall Zone along the eastern border of Ecoregion 45. Chiefly or strictly Piedmont fish species include *Notropis alborus*, *Notropis altipinnis*, *Fundulus rathbuni*, *Etheostoma vitreum*, and *Etheostoma collis* (Jenkins and , 1993).

The boundaries of the Piedmont (45) are shown on Figure 1. The Fall Line forms the border between the Piedmont and the lower, more poorly-drained Southeastern Plains (65); to the east of the Fall Line, Ecoregion 65 is composed of sedimentary rocks that are lithologically distinct from those of Ecoregion 45. The boundary of the Piedmont (45) with the Blue Ridge Mountains (66) is based on elevation and topography; Ecoregion 66 is higher and far more rugged than Ecoregion 45. The boundary between the Piedmont (45) and the cooler Northern Piedmont (64) was determined by forest type; Braun's (1950) Oak – Pine Forest Region encompasses Ecoregion 45 and her Oak – Chestnut Forest Region includes Ecoregion 64.

On the ecoregion map (Figure 1), the Piedmont (45) contains four level IV ecoregions: the Carolina Slate Belt (45c), Northern Inner Piedmont (45e), Northern Outer Piedmont (45f), Triassic Uplands (45g). Descriptions of the individual characteristics of these four ecoregions follow.

45c. Carolina Slate Belt

The Carolina Slate Belt (45c) is an irregular plain with low rounded ridges and shallow ravines. It is characteristically underlain by deeply weathered, fine-grained metavolcanic and metasedimentary rocks of the

Carolina Slate Belt that have been intruded by igneous rock. Within the Piedmont (45), only the sedimentary rocks of the Triassic Basins are finer-grained and less metamorphosed. Aaron Slate, phyllite, metasiltstone, metatuff, felsic volcanic rocks, and Virgilina Greenstone underlie Ecoregion 45c in Virginia. These rocks are somewhat less resistant to erosion than those of the adjoining Northern Outer Piedmont (45f) and physiography reflects these differences; Ecoregion 45c has lower crestal elevations, greater valley widths, and more favorable sites for reservoirs than adjoining ecoregions (Hunt, 1967, p. 257). Clay-rich weathering products (i.e. saprolite) have developed on bedrock but are typically thinner than in neighboring parts of the Piedmont. As a result, bedrock is close enough to the surface to impede both valley incision and erosion (Trimble, 1974). Local relief is 50 to 250 feet (15-76 m) and elevations range from 350 to 625 feet (107-191 m). The soils of the Carolina Slate Belt (45c) were derived from residuum and have a high silt content. They are primarily fine, kaolinitic, thermic, typic Hapludults of the Georgeville-Herndon association.

The boundary between Ecoregion 45c and the Northern Outer Piedmont (45f) is near the mapped limit of both the Carolina Slate Belt and the Georgeville-Herndon soil association (Virginia Division of Mineral Resources, 1993; Soil Conservation Service (various dates), Natural Resources Conservation Service (various dates); Natural Resources Conservation Service, no date, State Soil Geographic Data Base (STATSGO)). It follows the innermost of these two lines and extends from the southern part of Virginia to eastern Georgia. In North Carolina, groundwater recharge rates can be slow in the Carolina Slate Belt and summer streamflow can be extremely limited (Dave Penrose, personal communication to Glenn Griffith, NRCS, 7/13/98).

45e. Northern Inner Piedmont

Ecoregion 45e is a dissected upland composed of hills, irregular plains, and isolated ridges and mountains; monadnocks are far more common in Ecoregion 45e than in the Northern Outer Piedmont (45f). General elevations become higher towards the western boundary and to the south the Roanoke River where the land rises to become a broad, hilly upland. Elevations typically range from 200 to 1,000 feet (61-304 m) but higher elevations of up to 2,000 feet occur on scattered monadnocks. Local relief is typically 100 to 400 feet (30-121 m) but, on monadnocks, can be as much as 1,100 feet; in general, relief is markedly greater than in the Northern Outer Piedmont (45f) but less than in the Blue Ridge Mountains (66) to the west.

The Northern Inner Piedmont (45e) is characteristically underlain by highly deformed and deeply weathered Cambrian and Proterozoic feldspathic gneiss, schist, and melange. It is intruded by plutons and is veneered by clay-rich weathering products (i.e. saprolite). Ultisols occur widely and have developed from residuum; they are typically clay-rich, acid, and relatively low in base saturation. Higher, more westerly soils have a mesic temperature regime; they contrast with the thermic soils of the Carolina Slate Belt (45c), Outer Piedmont (45f), and Triassic Uplands (45g).

Streams have silt, sand, gravel, and rubble bottoms materials and bedrock is only occasionally exposed; overall, streams are more silty and sandy than in the Ridge and Valley (67). Differences in stream gradient considerably affect fish habitat in the Piedmont (Jenkins and , 1993). Gradients are usually low to moderate in the Northern Inner Piedmont (45e) and are usually greater than those of the Outer Piedmont (45f) or the Middle Atlantic Coastal Plain (63).

The potential natural vegetation is mapped as Oak-Hickory-Pine Forest by Kuchler (1964). Dominants include hickory *(Carya* spp.), shortleaf pine *(Pinus echinata*), loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)* and post oak *(Quercus stellata)*. The potential natural vegetation is distinct from the Appalachian Oak Forest of the adjacent Triassic Lowlands (64a), Northern Igneous Ridges (66a), and the Northern Sedimentary and Metasedimentary Ridges (66b).

Today, loblolly – shortleaf pine forests are common. Dominant landuses are forestry and agricultural activity. Urban and suburban areas occur especially in the extreme northeast. ("Good" timber production areas are more common in the Inner Piedmont (45e) than in the Outer Piedmont (45f) (U.S. Soil Conservation Service, 1981a). Chestnut oak *(Quercus prinus)* is abundant on the level and gently sloping uplands of Ecoregion 45e but becomes less common in the Outer Piedmont (45f) where it is regarded as an outlier from farther west (Clark and Ware, 1980). Livestock, poultry, and dairy farms occur and corn, small grain, rye, tobacco, and hay are grown.

Figure 1 shows the boundaries that divide the ecoregions. The Inner Piedmont (45e) and Outer Piedmont (45f) were separated using topographic, soil temperature, and geologic rationale. The line between them is transitional and roughly divides more rugged terrain from less rugged; it also approximates the eastern limit of monadnocks (Terwilliger and Tate, 1994), the foresters' line for natural regeneration of loblolly pine (*Pinus taeda*) (US Soil Conservation Service, 1981a), the Tallapoosa-Rappahannock lithofacies line (Hack, 1982), and the broad transitional, boundary between mesic and thermic soils (Marc Crouch, Natural Resources Conservation Service, June, 1998). The Northern Inner Piedmont (45e) and the Triassic Uplands (45g) line was drawn on the basis of geology and separates the Triassic sedimentary strata of Ecoregion 45g from the much older, mostly metamorphic rocks of Ecoregion 45e. The boundary between the Northern Inner Piedmont (45e) and the Blue Ridge Mountains (66) is based on topography; Ecoregion 66 has far greater relief, steeper slopes, and much higher elevations than Ecoregion 45e. The Northern Inner Piedmont (45e) extends southward into North Carolina.

45f. Northern Outer Piedmont

The Northern Outer Piedmont (45f) is an irregular plain with low rounded ridges and shallow ravines; ranges of low hills are scattered across Ecoregion 45f but monadnocks are much rarer than in the Inner Piedmont (45e). An area of rapids, cascades, waterfalls, and islands (the Fall Zone) occurs along the eastern boundary of Ecoregion 45f and contains urban and industrial areas. Elevations range from 200 to 675 feet (61-206 m) and relief varies from 100-250 feet (30-76 m); maximum relief and elevation are less than in the Northern Inner Piedmont (45e) to the west and greater than in the Middle Atlantic Coastal Plain (63) to the east.

The Northern Outer Piedmont (45f) is underlain mostly by deformed, deeply weathered gneissic rock that is intruded by plutons and veneered with saprolite; it is lithologically distinct from the Carolina Slate Belt (45c) and the sedimentary rock of the Southeastern Plains (65) and Triassic Uplands (45g). Ultisols are common and have developed from residuum; they are commonly clay-rich, acid, and relatively low in base saturation. Soils have a thermic temperature regime and contrast with the mesic soils found in higher portions of the Northern Inner Piedmont (45e).

Channel gradients generally reflect the surrounding terrain and considerably affect fish habitat in the Piedmont (Jenkins and , 1993). In Ecoregion 45f (outside of the Fall Zone) channel gradients and flow velocities are usually in between those of the sluggish streams of the Middle Atlantic Coastal Plain (63) and those of Ecoregion 45e; stream flow velocity tends to be moderately slow, both runs and riffles are short and infrequent, and substrates are chiefly composed of sand, silt, clay, and detritus. In the Fall Zone, Ecoregion 45f has a variety of aquatic habitats including pools, swampy streams, rapids, cascades, and waterfalls; here rapids are more common and better developed than in the adjacent portions of ecoregions 45f and 65m. Some cascades and waterfalls can deter or prevent upstream fish movement especially during low water.

Potential natural vegetation is mapped as Oak-Hickory-Pine Forest (Kuchler, 1964). Dominants include hickory *(Carya* spp.), shortleaf pine *(Pinus echinata*), loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)* and post oak *(Quercus stellata)*. Marshes and wetlands are not as common as in the Middle Atlantic Coastal Plain (63).

Today, forestry and agricultural activity dominate most of the ecoregion. "Good" timber production areas are less common in the Outer Piedmont (45f) than in the Inner Piedmont (45e) (U.S. Soil Conservation Service, 1981a). Shortleaf, loblolly, and Virginia pine woodlands are common in old fields. Pastures are common. Chestnut oak *(Quercus prinus)* is less common in the Northern Outer Piedmont (45f) than on the gently sloping uplands of the Northern Inner Piedmont (45e); it is regarded as an outlier from farther west (Clark and Ware, 1980). Livestock, poultry, and dairy farms occur and corn, oats, rye, tobacco, and hay are grown. Fast growing urban areas are found in the Northern Outer Piedmont (45f) including Fredericksburg, Richmond, and Petersburg.

The boundary between Ecoregion 45f and the Rolling Coastal Plain (65m) occurs at the Fall Line. The Line roughly separates uplands with moderately slow streams from much flatter lowland with sluggish streams; it also roughly divides hard metamorphic rocks from younger, less resistant sedimentary rocks that interfinger with them. The Outer Piedmont (45f) and the Northern Inner Piedmont (45e) were separated using topographic, soil temperature, and geologic rationale. The line between them is transitional and roughly divides more rugged terrain from less rugged; it also approximates the eastern limit of monadnocks (Terwilliger and Tate, 1994), the foresters' line for natural regeneration of loblolly pine (*Pinus taeda*) (US Soil Conservation Service, 1981a), the Tallapoosa-Rappahannock lithofacies line (Hack, 1982), and the broad transitional, boundary between mesic and thermic soils (Marc Crouch, Natural Resources Conservation Service, June, 1998). The boundary between Ecoregion 45f and the Carolina Slate Belt (45c) is near the mapped limit of both the Carolina Slate Belt and the Georgeville-Herndon soil association and follows the innermost of these two lines (Virginia Division of Mineral Resources, 1993; county soils surveys from the Soil Conservation Service (various dates) and Natural Resources Conservation Service (various dates); State Soil Geographic Data Base (STATSGO) from the Natural Resources Conservation Service, no date). The Northern Outer Piedmont (45f) extends southward into North Carolina.

45g. Triassic Uplands

The Triassic Uplands (45g) ecoregion is an irregular plain with low rounded hills, gentle ridges, and shallow valleys. The underlying sedimentary strata is characteristic and is distinct from the metamorphic rocks of the surrounding portions of the Piedmont. Ecoregion 45g includes three discrete areas in Virginia, the Danville, Farmville, and Richmond basins. Each basin consists of unmetamorphosed Mesozoic rocks that were downfaulted into much older metamorphic and igneous material. Red, Triassic sandstone, conglomerate, siltstone, shale, and breccia of the Newark Supergroup dominate and scattered dikes and sills composed of diabase occur (Hunt, 1967, p. 258; Virginia Division of Mineral Resources, 1993).

Elevations range from 200-875 feet (61-267 m) and local relief is 75 to 450 feet (23-137 m). In the Farmville and Richmond basins, physiography is generally similar to surrounding crystalline rock areas but there is slightly less relief (Hack, 1982; Frye, 1986). Parts of the Danville Basin, on the other hand, are higher and have more relief than adjacent portions of the Piedmont because they are underlain by relatively resistant rocks including conglomerate and graywacke (Hack, 1982; Virginia Division of Mineral Resources, 1993).

The isolated sedimentary rock formations that occur in the Piedmont are known to promote faunal diversity (Jenkins and Burkhead, 1993 (1994), p. 80). The middle Dan and Roanoke rivers drain metamorphic areas of the Northern Inner Piedmont (45e), flow through the Danville Basin portion of the Triassic Uplands (45g), and feed the lower metamorphic area of the Northern Outer Piedmont (45f). The relative resistance of the bedrock in the Danville Basin has retarded downcutting in Ecoregion 45g and, as a result, the channels must slope steeply after leaving the Danville Basin. For example, the reach of the Roanoke River immediately downstream of the Danville Basin to near Brookneal contains several swift water fishes that are more characteristic of the Blue Ridge Mountains (66) and the Ridge and Valley (67) than the Northern Outer Piedmont (45f); the fish diversity of this reach is probably "suppressed by fluctuating flow from Leesville Dame and by turbidity and siltation" (Jenkins and Burkhead, 1993 (1994), p. 80-81). High turbidity and siltation also reduce faunal diversity in the Dan River above and below Danville (Jenkins and Burkhead, 1993 (1994), p. 81). At Danville, the Dan River had an average turbidity of 1314 ppm between 1925 and 1930 (the period of earliest records), 268 ppm for 1930-1940, 134 ppm for 1940-1950, 129 ppm for 1950-1960, and 63ppm for 1960-1970. By 1974, filling of stream channels and valleys had stopped and the dissection and the removal of deposits to locations farther downstream had begun (Trimble, 1974, p. 113-118).

The potential natural vegetation of Ecoregion 45g is mapped as Oak-Hickory-Pine Forest (Kuchler, 1964). Dominants include hickory *(Carya* spp.), shortleaf pine *(Pinus echinata*), loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)* and post oak *(Quercus stellata)*.

Today, a mosaic of woodland, pastureland, and cropland occurs in Ecoregion 45g. Shortleaf pine, loblolly pine, Virginia pine, and mixed hardwood are common in old fields. Corn, tobacco, cotton, soybeans, small grains, and truck crops are grown.

Figure 1 shows the boundaries that divide the ecoregions. The border of the Triassic Uplands (45g) is near the mapped limit of the Mesozoic Newark Supergroup (Virginia Division of Mineral Resources, 1993) and the limit of Mayodan - Creedmoor soil association that is shown as STATSGO polygon VA042 on the State Soil Geographic Data Base (Natural Resources Conservation Service, no date). The Triassic Uplands (45g) are also found in North Carolina and South Carolina.

58. Northeastern Highlands

The Northeastern Highlands comprise a relatively sparsely populated region characterized by nutrient poor soils blanketed by northern hardwood and spruce fir forests. Land-surface form in the region grades from low mountains in the southwest and central portions to open high hills in the northeast. Many of the numerous glacial lakes in this region have been acidified by sulfur depositions originating in industrialized areas upwind from the ecoregion to the west.

58h. Reading Prong

The Northeastern Highlands (58) extends from Canada through New England, New York, and New Jersey to Wernersville Ridge in northeastern Pennsylvania. On the ecoregion map (Figure 1), the Northeastern Highlands (58) contains one level IV ecoregion: the Reading Prong (58h).

The Reading Prong (58h) is contiguous with the Taconic Mountains and the New England Upland (Fenneman, 1938, p. 368). Its rounded summits typically range from 700 to 1,000 feet (213-305 m) and are about 200 to 550 feet (61-168 m) above the intervening valleys. Maximum elevation, about 1,400 feet (427 m), occurs on the Cambrian quartzite knobs of Wernersville Ridge. Elsewhere, Precambrian granitic gneiss, Precambrian hornblende gneiss, and fanglomerate are common (Berg and others, 1980). The metamorphic and igneous rocks are covered by slightly acidic, moderately fertile, residual soils which originally supported a native vegetation of Appalachian Oak Forest, dominated by white and red oaks (Cunningham and Ciolkosz, 1984; Cuff and others, 1989, p. 52). Today, we see a mosaic of rural residential development, woodland, and general farmland. Forest dominates only the more rugged, stony, or elevated locations, and overall it is less dense than that of the Diabase and Conglomerate Uplands (64b) or the higher Blue Ridge Mountains (66).

Figure 1 shows the boundaries of Ecoregion 58h. Its dissected, rugged, crystalline hills are higher and both physiographically different and lithologically distinct from ecoregions 64a, 64d, and 67a.

60. Northern Appalachian Plateau and Uplands

Ecoregion 60, in northeastern Pennsylvania, is a plateau made up of horizontally bedded, nonresistant shales and siltstones and moderately resistant sandstones of Devonian age. It is often lower and less forested than the adjacent Glaciated Allegheny High Plateau (62c) and crestal elevations are typically 1,300 to 2,000 feet (396-610 m). Its rolling hills, open valleys, and low mountains are partly covered by Olean Till of Wisconsinan age and support a mosaic of cropland, pastureland, and woodland. Soils are derived from till and are mostly mesic Inceptisols (Cunningham and Ciolkosz, 1984). Stoniness and seasonal wetness are common limitations of these soils (Higbee, 1967). The natural vegetation was primarily Appalachian Oak Forest, dominated by white and red oaks. Some Northern Hardwoods occurred away from the Susquehanna River at higher elevations; dominant trees included sugar maple *(Acer saccharum),* yellow birch *(Betula allegheniensis)*, beech *(Fagus grandifolia),* and hemlock *(Tsuga canadensis)* (Cuff and others, 1989, p. 52).

The boundaries of the Northern Appalachian Plateau and Uplands (60) are shown on Figure 1. Its border with the North Central Appalachians (62), is based on topography, soils, and land use; Ecoregion 62 has greater forest density and is often more rugged and more elevated than the more fertile Northern Appalachian Plateau and Uplands (60). Its border with the folded and faulted, forested Ridge and Valley (67) follows the break in woodland density, physiography, and geologic structure.

On the ecoregion map (Figure 1), the Northern Appalachian Plateau and Uplands (60) is composed of two level IV ecoregions: the Glaciated Low Plateau (60a) and the Northeastern Uplands (60b). Each is a mosaic of cropland, pastureland, and woodland on nearly horizontal shales and sandstones. Descriptions of the individual characteristics of these two ecoregions follow.

60a. Glaciated Low Plateau

The Glaciated Low Plateau (60a) is a mosaic of farmland, woodlots, and lakes upon low, rolling hills. The terrain has been glacially smoothed, stream gradients are low, and the valleys are open. Hilltop elevations are commonly 1,300-1,800 feet (395-550 m), and are often lower than those of adjacent ecoregions. Local relief is typically 300-500 feet (91-153 m). The growing season varies inversely with elevation, increasing from 100 days in the northwest to 160 days in the southeast. A corridor that is "favored from a climatic standpoint" (Murphy and Murphy, 1937, p. 371) bisects Ecoregion 60a along the entrenched Susquehanna River at elevations of less than about 820 feet (250 m).

The Catskill and Lock Haven (Chemung of New York) formations of Devonian age comprise the local bedrock (Berg and others, 1980). These rocks are less resistant than the Mississippian and Pennsylvanian strata of the higher Glaciated Allegheny High Plateau (62c) and are not deformed like those of the Sandstone Ridges (67c). Olean Till of Wisconsinan age partly covers the uplands and slopes and Quaternary glacial, lacustrine, and outwash deposits fill the valleys.

Mesic and frigid Inceptisols (Fragiaquepts, Fragiochrepts, Dystrochrepts) developed on the drift deposits (Cunningham and Ciolkosz, 1984). Leached and stony, they commonly have fragipans and poor drainage.

The topography, climate, and soil make Ecoregion 60a much more suitable for dairy farming and livestock raising than for general crops. The crops that are grown tend to be directly related to the dairy-livestock regime and include hay, corn for silage, and oats. Idle farms are increasing and woodland is common. The native vegetation was mostly Appalachian Oak Forest (dominated by white and red oaks), with some Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) occurring away from the Susquehanna River at higher elevations (Cuff and others, 1989, p. 52). Bogs and marshes are common throughout Ecoregion 60a.

The boundaries of the Glaciated Low Plateau (60a) are shown on Figure 1. Its eastern boundary with the Northeastern Uplands (60b) follows the break in elevation, relief, channel gradient, valley-side slope angle, forest density, and stream density that are shown on the Scranton 1:250,000-scale topographic map; all these are greater in Ecoregion 60b than in Ecoregion 60a. Its western border with the Glaciated Allegheny High Plateau (62c) is marked by a change in forest density and elevation; both are greater in Ecoregion 62c. Its southern border with the Northern Sandstone Ridges (67c) occurs at the break in forest density, elevation, and geological structure; there is less woodland density in Ecoregion 60a than in Ecoregion 67c which is folded and faulted and higher in elevation.

60b. Northeastern Uplands

The Northeastern Uplands (60b) shares many environmental characteristics with the Glaciated Low Plateau (60a). However, these ecoregions can be distinguished by lake density, slope angle, elevation, channel gradient, and the ratio of woodland to farmland; all these are greater in Ecoregion 60b than in Ecoregion 60a.

Ecoregion 60b is a dissected and glaciated plateau characterized by low, rolling hills of moderate relief and slope. More than half of the area is woodland, and lakes and bogs are very common. Crestal elevations are commonly 1,400-2,000 feet (427-610 m), increasing to a maximum of approximately 2,700 feet (823 m) at Mt. Ararat. Elevations are great enough to insure a short growing season of 130-140 days. Near the bottoms of valleys, frost occurs late in the spring and early in the autumn. Local relief typically ranges from roughly 650 feet (198 m) down to about 130 feet (40 m), whereupon lakes and wetlands become particularly common. Associated flora and fauna are found here. Bird life includes mallards *(Anas platyrhynchos),* Canada geese *(Branta canadensis),* wood ducks *(Aix sponsa),* and the American bittern *(Botaurus lentiginosus)*, which is threatened in Pennsylvania (Gill, 1985, p. 310).

The Inceptisols (Fragiaquepts, Fragiochrepts, Dystrochrepts) of Ecoregion 60b are derived from Wisconsinan drift and often suffer from poor drainage and stoniness (Cunningham and Ciolkosz, 1984; Higbee, 1967). The soil, climate, and terrain of Ecoregion 60b support a larger percentage of woodland and a smaller percentage of dairy and livestock farms than do those of Ecoregion 60a. Furthermore, farming is of declining importance; between 1982 and 1987, the number of farms in Ecoregion 60b declined by about 13% and the number of acres in farms has lessened by more than 10% (Pennsylvania Crop Reporting Service, 1983, p. 81; Pennsylvania Agricultural Statistics Service, 1990-1991, p. 82). Vacation cabins are increasingly common, but they are not surrounded by extensive forest as they are in the Low Poconos (62b).

The soils have formed on Olean Till and Quaternary glacial outwash. These in turn overlie Devonian age sandstone, siltstone, and shale of the Catskill Formation (Berg and others, 1980). The proportion of resistant sandstone is greater in Ecoregion 60b than in Ecoregion 60a, which explains the difference in elevation between the two ecoregions. The strata of Ecoregion 60b is undeformed, unlike the rocks of the Northern Sandstone Ridges (67c); as a result, Ecoregion 67c also has more relief and forest density than Ecoregion 60b.

The natural vegetation was mostly Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock), exemplified by the Woodbourne Forest and Wildlife Sanctuary near Montrose, Susquehanna County (Erdman and Wiegman, 1974, p. 49). Some Appalachian Oak Forest occurs near the Susquehanna River (Cuff and others, 1989, p. 52). Wetlands such as Madisonville and Mud Pond swamps are very common in areas of low relief, especially on the Morris-Wellsboro and Morris-Wellsboro-Oquaga soil associations.

Figure 1 shows the boundaries that divide the ecoregions. The western boundary between the Glaciated Low Plateau (60a) and Ecoregion 60b follows the break in elevation, relief, channel gradient, valley-side slope angle, forest density, and stream density; all these are greater in Ecoregion 60b than in Ecoregion 60a. The eastern boundary between Ecoregion 60b and the more dissected Low Catskills (62e) occurs at the forest density and topography break shown on the Scranton 1:250,000-scale topographic map; Ecoregion 62e is much more rugged and wooded than Ecoregion 60b. The southern boundary between ecoregions 60b and the Low Poconos (62b) occurs at the forest density break shown on the Scranton 1:250,000-scale topographic map; Ecoregion 62b is more wooded than Ecoregion 60b. In places, the border also follows the lithological break between coarser and finer members of the Catskill Formation and is near the potential natural vegetation line dividing Northern Hardwoods from Appalachian Oak Forest (Cuff and others, 1989, p. 52).

61. Erie/Ontario Hills and Lake Plain

Ecoregion 61, in northwestern Pennsylvania, is characterized by nearly level to rolling terrain. Deposits from successive Pleistocene ice sheets and lakes cover the horizontally bedded sedimentary rock. In places, beach ridges, hummocky stagnation moraines, kettles, and kames can be found. Many wetlands still occur in the west and a high percentage of the threatened or endangered species in Pennsylvania reside there. Local relief ranges from less than 50 feet (15 m) on the former lake plain to about 400 feet (122 m) on the till plain. Elevations range from about 570 feet (174 m) at Lake Erie to 2,000 feet (609 m) inland.

The most common soils are Alfisols and Inceptisols; they tend to be acidic and are derived mainly from till and lacustrine material. The lake plain and the wetter soils of the southwest originally supported a Beech-Maple Forest dominated by sugar maple *(Acer saccharum)* and beech (*Fagus grandifolia)*; elsewhere, Northern Hardwoods occurred, with sugar maple *(Acer saccharum),* yellow birch *(Betula allegheniensis*), beech *(Fagus grandifolia)*, and hemlock *(Tsuga canadensis)* as dominant trees (Cuff and others, 1989, p. 52).

The Erie/Ontario Hills and Lake Plain (61) is the most important agricultural area in the Allegheny Plateaus physiographic province (Cuff and others, 1989, p. 24). The lake plain produces specialty crops, including fruits, vegetables, and nursery stock. The inland till plains, with their much shorter growing season and wetter soils, are dominated by dairy farming. Associated erosion and stream pollution occur (Omernik and Gallant, 1988, p. 37).

The boundary of Ecoregion 61 with the North Central Appalachians (62) and the Western Allegheny Plateau (70) roughly corresponds to the Wisconsinan till limit. It also approximates the natural vegetation transition between Beech-Maple Forest and Northern Hardwoods in the west and Appalachian Oak Forest in the east (Cuff and others, 1989, p. 52).

On the ecoregion map (Figure 1), the Erie/Ontario Hills and Lake Plain (61) is composed of two level IV ecoregions: the Mosquito Creek-Pymatuning Lowlands (61b) and the Low Lime Drift Plain (61c). Each is dominated by agriculture and each has been glaciated in contrast to neighboring ecoregions. Descriptions of the individual characteristics of these three ecoregions follow.

61b. Mosquito Creek/Pymatuning Lowlands

The glaciated Mosquito Creek-Pymatuning Lowlands (61b) has nearly level to undulating terrain. It is characterized by poorly drained terrain caused by low relief, clayey substrate, and fragipans. The soils are mostly Alfisols (Fragiaqualfs, Fragiudalfs) and the substrate is primarily clayey Hiram till of late-Wisconsinan age with some glacial outwash, alluvial, and lacustrine deposits. Numerous wetlands and broad, flat-bottomed valleys occur on the silt and silty clayey loams. Low-gradient streams are common, have few riffles, and lack associated stream organisms. Crestal elevations vary from about 900 to 1,300 feet (274-396 m) and local relief is usually less than 150 feet (46 m).

The dairy industry is well suited to Ecoregion 61b's general soil, climate, and topography, and there are many pastures. However, on well-drained outwash soils, corn, potatoes, wheat, and oats are sometimes grown; very poorly drained sites contain trees, idle land, brush, or wetlands.

Natural vegetation was composed primarily of Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) on the better drained sites and Beech-Maple Forest was found elsewhere. Remnants of the Beech-Maple Forest are preserved at Tyron's Woods (southwest of Conneaut Lake) (Brenner, 1985, p. 14; Erdman and Wiegman, 1974, p. 4). Marshes are common and contain many species, including cattails *(Typha* spp.), bullrushes *(Cladium jamaicensis),* sedges *(Carex* spp.), and reed grasses *(Phragmites communis)* (Brenner, 1985, p. 11). Shrub swamps and swamp forests cover large areas of the Mosquito Creek-Pymatuning Lowlands (61b) and are more extensive than elsewhere in Pennsylvania (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995). The shrub swamps are composed of species such as buttonbush *(Cephalanthus occidentalis),* swamp rose *(Rosa palustris),* poison *sumac (Rhus vernix),* and silky dogwood *(Cornus ammomum)*. Swamp forests contain species such as red maple *(Acer rubrum),* white pine *(Pinus strobus),* and larch *(Larix laricina)*. State Game Lands 214 near Hartstown contains marshes, shrub swamps, and swamp forests and is the last remnant of the Pymatuning Swamp, once about 16 square miles (42 km2) in area (Erdman and Wiegman, 1974, p. 13).

The northern bald eagle *(Haliaeetus leucocephalus alascanus)* and the marsh-dwelling king rail *(Rallus elegans elegans)* (Gill, 1985, pp. 301-304), endangered in Pennsylvania, inhabit the Mosquito Creek-Pymatuning Lowlands (61b). Several species threatened in Pennsylvania are also found in the marshes and lakes of Ecoregion 61b, including the least bittern *(Ixobrychus exilis exilis)*, the American bittern *(Botaurus lentiginosus)*, and the black tern *(Chlidonias niger surinamensis)* (Gill, 1985, pp. 307-314).

Figure 1 shows the boundary between Ecoregion 61b and the Low Lime Drift Plain (61c). Very poorly drained areas that are flat and often underlain by clayey Hiram till are included in the Mosquito Creek-Pymatuning Lowlands (61b); adjacent marshes and former marshes as shown on 7.5 minute quadrangles are also included in Ecoregion 61b.

61c. Low Lime Drift Plain

The glaciated Low Lime Drift Plain (61c) is characterized by ground moraines, rolling terrain, broad over-fit valleys, and numerous dairy farms. Terminal moraines, kettles, kames, and poorly drained depressions are present locally. Glacial drift, primarily Kent till of late-Wisconsinan age, overlies acidic, sedimentary rock of varying ages and types. Most soils have fragipans and are poorly drained; they are typically rocky at the surface, low in carbonate, and not especially fertile. The climate is continental and is not influenced by Lake Erie, except in northernmost locations. The soil attributes and the short growing season make Ecoregion 61c poorly suited for cropland. Most of Ecoregion 61c is best adapted to hay, oats, silage corn, and pasture. Many ridges and lowlands are wooded or idle. Hilltop elevations range from about 1,100 feet to 2,000 feet (335-610 m) and local relief is typically 250-400 feet (76-122m).

The natural vegetation of the till plains was composed primarily of Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) on the better drained sites and Beech-Maple Forest elsewhere. Near the Wisconsinan limit, the Appalachian Oak Forest (dominated by white and red oaks) began and extended eastward into the Unglaciated Allegheny High Plateau (62d) and the Pittsburgh Low Plateau (70c) (Cuff and others, 1989, p. 52). Marshes, swamps, and bogs occur in areas of poor drainage (Geyer and Bolles, 1979, pp. 36-38). Muddy Creek Research Natural Area in Crawford County contains virgin Northern Hardwoods and fine marshes (Erdman and Wiegman, 1974, p. 12). Columbus Bog-Tamarack Swamp in State Game Lands 197 in Warren County, one of the best examples of a northern (kettlehole) bog in western Pennsylvania, has a floating peat mat of sphagnum, sedges *(Carex* spp.), and sundew *(Drosera rotundifolia),* second growth tamarack *(Larix laricina)*, and hemlock *(Tsuga canadensis)* (Cuff and others, 1989, p. 55; Erdman and Wiegman, 1974, p. 9).

At least two plant species that are endangered in Pennsylvania inhabit Ecoregion 61c, the Kalm's lobelia *(Lobelia kalmii)* and the spreading globe flower *(Trollius laxus)*. Both are found in alkaline wet meadows (Wiegman, 1985, pp. 59, 71). Also inhabiting Ecoregion 61c are several species that are threatened in Pennsylvania, including the eastern sand darter *(Ammocrypta pellucida)* and the northern brook lamprey *(Ichthyomyzon fossor)* (Cooper, 1985, pp. 179, 182).

Figure 1 shows the boundaries of the Low Lime Drift Plain (61c). To the east, Ecoregion 61c extends to the approximate Wisconsinan ice limit, whereupon the potential natural vegetation changes, dairy farming declines in importance, the terrain becomes more hilly, and the loamy Kent till ends; in the Unglaciated Allegheny High Plateau (62d), forest land predominates and in the Pittsburgh Low Plateau (70c) general farming is dominant. To the north, Ecoregion 61c abuts the Erie Lake Plain (83a); here lacustrine deposits begin, natural vegetation changes, and the climate moderates. To the northwest, Ecoregion 61c continues until the landscape becomes flatter and dominated by both wetlands and the clayey Hiram till of the Mosquito Creek-Pymatuning Lowlands (61b).

62. North Central Appalachians

Ecoregion 62, in northcentral and northeastern Pennsylvania, is part of a vast, elevated plateau composed of horizontally bedded sandstone, shale, siltstone, conglomerate, and coal. It is made up of plateau surfaces, high hills, and low mountains, and was only partly glaciated. Both the southwest and the glaciated east are low in comparison to the central section, which rises to a general elevation of about 2,300 feet (701 m) on erosion resistant sandstones. The climate can be characterized as continental, with cool summers and cold winters. Average annual precipitation is from 33 to 50 inches (84-127 cm) and there can be as few as 100 days without killing frost, the shortest period in Pennsylvania. Soils are often frigid and were derived from sandstone, shale, and till; they are low in nutrients, and support extensive forests. The original vegetation was primarily Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock), but scattered Appalachian Oak Forest (dominants: white and red oaks) and isolated highland pockets of spruce/fir forest also occurred. Land use activities are generally tied to forestry and recreation but some coal and gas extraction occurs in the west.

The boundary with the Erie/Ontario Hills and Lake Plain (61) is near the Wisconsinan till limit, which approximates land use and natural vegetation breaks; Ecoregion 62 is much more forested than Ecoregion 61 and it originally lacked the beech/maple component that once dominated the Erie/Ontario Hills and Lake Plain (61). The border with the Western Allegheny Plateau (70) and the Central Appalachians (69) approximates the land use and elevation breaks; Ecoregion 62 is more forested, cooler, and higher than the adjacent ecoregions. The boundary with the Ridge and Valley (67) occurs at the junction of folded and horizontal strata and also approximates the border between the Northern Hardwoods and the Appalachian Oak Forest. The border with the Northern Appalachian Plateau and Uplands (60) occurs at the limit of resistant strata, which causes elevation, climate, and forest density to change.

On the ecoregion map (Figure 1), the North Central Appalachians (62) is composed of five level IV ecoregions: the Pocono High Plateau (62a), the Low Poconos (62b), the Glaciated Allegheny High Plateau (62c), the Unglaciated Allegheny High Plateau (62d), and the Low Catskills (62e). Each is forested and each is underlain by nearly horizontal rock, predominantly sandstone. Descriptions of the individual characteristics of these five ecoregions follow.

62a. Pocono High Plateau

The Pocono High Plateau (62a) is a forested highland of little relief. It is studded with lakes and wetlands and is underlain by undeformed, noncarbonate strata. Elevations are great enough to make Ecoregion 62a higher and cooler than the nearby lowlands. Glacial advances and retreats have smoothed the terrain, disrupted drainage, produced hummocky morainal topography, and carved many potholes. Numerous resort and suburban developments occur, especially around the glacial and artificial lakes. Local relief is limited and commonly ranges from 50 to 175 feet (20-53 m). Stream gradients thus are also low and there are few riffles or riffle inhabiting species.

Wisconsinan till, glacial outwash, Recent alluvium, and, in the south, Illinoian till overlie gently dipping Devonian and Mississippian strata. The Duncannon and Poplar Gap-Packerton members of the Catskill Formation predominate and contain sandstone and conglomerate. These rocks are more resistant to erosion than the finer material of Ecoregion 62b. As a result, the crestal elevations of Ecoregion 62a, ranging from about 1,800 to 2,300 feet (549-701 m), are markedly higher than those of Ecoregion 62b, which range from about 1,300 to 1,500 feet (396-457 m). An escarpment over 300 feet (91 m) high marks the juncture between ecoregions 62a and 62b and their respective lithologies. High-gradient streams and a few waterfalls, such as Indian Ladder Falls, occur on the escarpment (Geyer and Bolles, 1979, p. 202).

The Pocono High Plateau (62a) is a famous year around resort region because of its pleasantly cool summers, abundant snowfall, persistent winter snow cover, numerous lakes, extensive woodland, public lands, tourist facilities, and proximity to urban centers. In recent years, Ecoregion 62a has also experienced substantial suburban growth, resulting in stress to environmental systems.

Soils derived from Wisconsinan drift are widespread and often very stony, acidic, low in fertility, and poorly drained; these Inceptisols are almost always better suited to trees, wildlife, and recreation than to other uses (Fisher and others, 1962, p. 2). The short growing season of 125-140 days reinforces this situation and, therefore, almost no commercially viable farming occurs in Ecoregion 62a. Limited areas are underlain by Illinoian till and have different soils than occur further north on the younger tills; these soils are mostly Ultisols (Hapludults, Fragiudults) and support the ecologically significant Pocono till barrens (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995).

The natural vegetation of the Pocono High Plateau (62a) was predominantly Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock), with some Appalachian Oak Forest (dominants: white and red oaks) on the southern periphery. By 1870, almost all the original forest had been cut over or burnt (Murphy and Murphy, 1937, p. 364). Today, the mixed hardwood forest is mostly second or third growth. Mature Northern Hardwoods still can be found in Gouldsboro State Park and virgin northern hardwood forest/spruce still occurs in Hickory Run State Park (Brenner, 1985, p. 14; Erdman and Wiegman, 1974, p. 63). Wetlands are widespread and include marshes and swamps such as those in Gouldsboro State Park and along Two Mile Run. Numerous kettlehole bogs occur, including those at Pine Lake Natural Area and Bruce Lake; they are composed of floating peat mats that grade into mixed hardwood swamps (Erdman and Wiegman, 1974, pp. 62-65; Van Diver, 1990, p. 97). "Mesic to hydric Pocono till barrens presently cover some 6,000 acres near the southern rim of the Pocono Plateau, adjacent to xeric ridge top barrens overlying sandstone covering an additional 6,000 acres. The glacial till barrens are a mosaic of shrublands with scattered pitch pines variously dominated by scrub oak *(Quercus ilicifolia),* sheep-laurel *(Kalimia angustifolia),* and rhodora *(Rhododendron canadense);* a small proportion of the barrens consists of pitch pine woodlands. The Pocono till barrens and adjacent swamps comprise the largest concentration of globally rare communities and species in Pennsylvania; the area is The Nature Conservancy's highest priority for biodiversity conservation in the state (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995)." These barrens have a high diversity of moth and butterfly species (Cuff and others, 1989, p. 56).

The border between Ecoregion 62a and the Low Poconos (62b) follows the break in elevation, potential natural vegetation, and topography that occurs where coarser and finer members of the Catskill Formation abut at the Pocono Plateau Escarpment. The division between the Ridge and Valley (67) and Ecoregion 62a occurs where the high glaciated plateau ends.

62b. Low Poconos

The Low Poconos (62b) is a forested and glaciated plateau. Pleistocene ice sheets smoothed its terrain, disrupted its drainage, and formed many shallow kettle lakes and wetlands. In addition, it has many vacation and suburban developments, widespread public land, very little agriculture, and extensive woodland. Local relief ranges from about 800 feet (244 m) down to 50 feet (15 m), where lakes and wetlands become particularly common. Areas of greatest relief occur adjacent to the Delaware River; here, high-gradient streams and waterfalls occur, including Dingman's Falls, which is the highest waterfall in Pennsylvania (Erdman and Wiegman, 1974, p. 50; Geyer and Bolles, 1987, p. 253; Oplinger and Halma, 1988, p. 27).

Olean Till, glacial outwash, glacial lake deposits, and Recent alluvium partly overlie gently dipping Devonian age sandstone, siltstone, claystone, and shale. These rocks of the Long Run and Walcksville Members of the Catskill Formation are much less resistant to erosion than those of Ecoregion 62a. As a result, Ecoregion 62b is markedly lower in elevation than Ecoregion 62a; crestal elevations of Ecoregion 62b are about 1,300 to 1,500 feet (396-457 m) whereas those of Ecoregion 62a are 1,800 to 2,300 feet (549-701 m).

Inceptisols are common in Ecoregion 62b. They are derived from Wisconsinan drift and are often poorly drained, acidic, very stony, and low in fertility. As a result, these soils are seldom suitable for agriculture and over 90% of the area is wooded.

Vacation and suburban developments occur throughout the region, especially near the larger lakes. These developments have rapidly expanded in number to keep pace with population growth, which has more than doubled in the last 25 years.

The natural vegetation of the Low Poconos (62b) was mostly Appalachian Oak Forest (dominated by white and red oaks). Wetlands are very common and include marshes like those of the Stillwater Natural Area and swamps such as Saw Creek Headwaters Swamp, Nebo Swamp, Bald Hill Swamp, Tannersville Cranberry Bog Preserve, and Walker Lake Swamp (Cuff and others, 1989, p. 54; Erdman and Wiegman, 1974, pp. 49-61). Kettlehole bogs also occur, such as those at Lake Lacawac Sanctuary and Little Mud Pond; they are composed of floating peat mats that grade into hardwood swamp (Erdman and Wiegman, 1974, pp. 50, 55; Geyer and Bolles, 1979, p. 182). The bog turtle *(Clemmys muhlenbergii*) is found in the marshy meadows and sphagnum bogs of Monroe County and is endangered in Pennsylvania (McCoy, 1985, p. 272). The king rail *(Rallus elegans elegans)* is found in the marshes of Monroe County and is also endangered in Pennsylvania (Gill, 1985, p. 303).

The boundary between Ecoregion 62b and the Northeastern Uplands (60b) is found where woodland density changes; it is much greater in Ecoregion 62b. The border between ecoregions 62b and 62a follows the break in elevation, potential natural vegetation, and topography that occurs where coarser and finer members of the Catskill Formation abut. The division between the Ridge and Valley (67) and Ecoregion 62b occurs where the glaciated plateau ends.

62c. Glaciated Allegheny High Plateau

Ecoregion 62c is a deeply dissected and forested highland composed of plateau remnants, rounded hills, low mountains, and narrow valleys. Locally, especially in the south, the terrain has been noticeably smoothed by glaciation. Here, many closed depressions and blocked valleys occur and contain small lakes or shallow ponds. Nearly horizontal, resistant strata of Mississippian to Devonian age underlie Wisconsinan drift and are responsible for the highland. The Burgoon Sandstone is a prominent ridge former. Hilltop elevations are commonly 1,900-2,300 feet (579-701 m), which is high enough to ensure a short growing season of 100-165 days. Local relief is about 300-700 feet (91-213 m) and reaches approximately 800 feet (244 m) in Pine Creek Gorge. Mean annual precipitation ranges from 33 to 39 inches (84-99 cm). Most of the soils are frigid Inceptisols, derived from acidic glacial drift, that are stony, acidic, low in fertility, and often steep (Ciolkosz, 1989; Cunningham and Ciolkosz, 1983; Higbee, 1967).

The soils, climate, and ruggedness make the area well suited to trees and poorly suited to agriculture. Hardwood forests are predominant. The natural vegetation was primarily Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) with some intermixed bogs, swamps, and marshes. Appalachian Oak Forest (dominants: white and red oaks) also occurred, especially on the eastern margin of Ecoregion 62c (Cuff and others, 1989, p. 52). Rickets Glen State Park in northwestern Luzerne County contains approximately 2,000 acres of virgin northern hardwood forest, as well as numerous hemlock swamps (Erdman and Wiegman, 1974, p. 43). Pennsylvania's only spruce bald occurs on Bartlett Mountain, western Wyoming County (Roger Latham, Department of Geology, University of Pennsylvania, written communication, 1995).

In terms of rock type, elevation, relief, natural vegetation, and prevailing land use, Ecoregion 62c is similar to the Unglaciated Allegheny High Plateau (62d). However, like the Glaciated Low Plateau (60a), Ecoregion 62c was covered with ice and has soils that were derived from acidic glacial drift. Lakes and marshes and their associated flora and fauna occur in ecoregions 62c and 60a, but not in 62d. The American bittern *(Botaurus lentiginosus),* which is threatened in Pennsylvania, is found in the marshes of southern Ecoregion 62c (Gill, 1985, p. 310).

Ecoregion 62c's boundaries are shown on Figure 1. Its western border with the Unglaciated Allegheny High Plateau (62d) occurs at the westward limit of Wisconsinan Olean Till (Berg and others, 1980) whereas its northwestern boundary occurs at an elevation break. The eastern border with the Glaciated Low Plateau (60a) is based on forest density, elevation, and rock type; Ecoregion 60a has much less forest, is more than 300 feet (91 m) lower, is less rugged, and has less resistant surficial rock than Ecoregion 62c. The southern boundary is drawn along Huckleberry Mountain and North Mountain, where terrain changes, folding begins, and elevation changes by over 550 feet (168 m).

62d. Unglaciated Allegheny High Plateau

Ecoregion 62d is a deeply dissected highland composed of plateau remnants, rounded hills, low mountains, and narrow valleys. It is characterized by extensive forests, a short growing season, nutrient-poor residual soils, high local relief, nearly horizontal strata, resistant rock, and oil wells. Overall, the area is very rugged with steep valley sides, entrenched streams, high-gradient channels, and many waterfalls. Local relief is typically 550-700 feet (168-213 m) and reaches about 1,300 feet (396 m) in valleys that were cut by large volumes of glacial melt water. The terrain is nowhere muted by glaciation, although its western-most parts were covered by at least two pre-Wisconsinan glaciations. Hilltop elevations increase northeastward across Ecoregion 62d. They are commonly 1,700-2,200 feet (518-671 m) and are high enough to insure a cool, humid climate with long winters. The growing season lasts only 100-160 days, depending on elevation and other microclimatic controls. Mean annual precipitation ranges from 35 to 44 inches (89-112 cm) and increases westward. Most of the soils are frigid Ultisols and Inceptisols that are low in fertility, often steep, stony, and acidic, and were derived from noncarbonate sedimentary rock.

Extensive woodland occurs and national and state forests are common. Oaks, maples, and other hardwoods predominate, but hemlock *(Tsuga canadensis),* pitch pine *(Pinus rigida)*, and white pine *(Pinus strobus)* are also found.

The natural vegetation was primarily Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) with some intermixed bogs and a perimeter of Appalachian Oak Forest (Cuff and others, 1989, p. 52). Extensive logging and burning removed most of the natural vegetation during the nineteenth century. Remnants still occur, however, including those at Tionesta Research Natural Area in southwestern McKean County, Cook Forest State Park in eastern Clarion and southern Forest Counties, Hearts Content Scenic Area in southern Warren County, Algerine Tamarack Swamp in northwestern Lycoming County, and the Pine Creek Gorge Natural Area in western Tioga County (Cuff and others, 1989, p. 53; Erdman and Wiegman, 1974, as reported in Brenner, 1985, p. 14; Geyer and Bolles, 1979, p. 67).

Oil wells are common throughout Ecoregion 62d and account for more than 50% of Pennsylvania's total production. There is also surface coal mining in the south and localized valley agriculture in the northeast. Pollution from mine drainage and oil production is a significant problem locally and has degraded stream habitat (Biesecker and George, 1966, Plate 1; Churchill, 1969, p. 3; Dyer, 1982a, pp. 117-118)

The western boundary between Ecoregion 62d and the Low Lime Drift Plain (61c) is associated with the breaks in topography, soil, and forest density that occur near the Wisconsinan ice limit. The eastern boundary between Ecoregion 62d and the Glaciated Allegheny High Plateau (62c) is at the limit of the Olean Till of Wisconsinan age. The southeastern border is drawn 3-6 miles (5-10 km) north of the West Branch of the Susquehanna River and Bald Eagle Creek, where the terrain and elevation markedly change. The southwestern boundary with the Pittsburgh Low Plateau (70c) is drawn where elevation, forest density, and soil changes; Ecoregion 70c has lower elevations, less woodland density, and more Gilpin soils than Ecoregion 62d. The southern border divides the cooler, more heavily forested Ecoregion 62d from the Uplands and Valleys of Mixed Land Use (69b).

62e. Low Catskills

The Low Catskills (62e) is a forested and highly dissected ecoregion less than 5 miles (8 km) wide in northeastern Pennsylvania. Here, the Delaware River has deeply entrenched into the glaciated Appalachian Plateau, creating cliffs and steep-walled valleys. Many high-gradient tributaries occur and stream organisms associated with riffles are common. Topography is rugged for this part of the commonwealth and local relief ranges from about 450 to 800 feet (137-244 m). Crestal elevations are from approximately 1,300 to 1,800 feet (396-549 m) and are high enough to insure a short growing season of about 130 days, varying according to local topography and slope aspect.

The soils of Ecoregion 62e are mostly Inceptisols. Most formed on Olean Till and some developed on Quaternary alluvium. They overlie nearly horizontal, Devonian age sandstone, siltstone, and shale of the Catskill Formation. The soils are characterized by stoniness, shallowness, low fertility, and acidity, which, together with the rugged terrain and brief growing season, make the area best suited to woodland (Higbee, 1967). The natural vegetation was mostly Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Cuff and others, 1989, p. 52). Some wetland vegetation occurs on poorly drained sites, and northern rock plants grow on the Delaware River cliffs in northeastern Wayne County (Erdman and Wiegman, 1974, p. 50).

The boundary between Ecoregion 62e and the less dissected Northeastern Uplands (60b) occurs at the forest density and topography break shown on the Scranton 1:250,000-scale topographic map; Ecoregion 62e is much more rugged and wooded than Ecoregion 60b. Ecoregion 62e extends across the Delaware River into New York, where it becomes much more extensive.

63. Middle Atlantic Coastal Plain

The Middle Atlantic Coastal Plain (63) ecoregion is a low, nearly flat plain, with many swampy or marshy areas that extends northeastward from Georgia to New Jersey. Forest cover in the region is predominantly loblolly-shortleaf pine with patches of oak, gum, and cypress near major streams. Poorly drained soils are common especially in lowest areas.

Elevations range from 0 to 100 feet elevation and local relief is less than 50 feet and often nearly level; Ecoregion 63 is characteristically lower flatter than inland ecoregions. Its low terraces, marshes, dunes, beach ridges, barrier beaches, and beaches are underlain by unconsolidated sediments. Mesic and thermic Ultisols and Histosols typically underlie the ecoregion. They support a potential natural vegetation of Appalachian Oak Forest, Northern Cordgrass Prairie, Southern Floodplain Forest, Live Oak-Sea Oats, and Oak-Hickory-Pine Forest (Kuchler, 1964). Wetlands are common; salt estuarine bay marshes occur.

The boundary between the Middle Atlantic Coastal Plain (63) and the Northern Piedmont (64) occurs at the Fall Line. Its border with the Southeastern Plains (65) is based on elevation, topography, and drainage; Ecoregion 63 is typically lower, flatter, more poorly drained, and more marshy than Ecoregion 65. In addition, although both ecoregions 63 and 65 are underlain by unconsolidated sediments, Holocene-age deposits are restricted to the Middle Atlantic Coastal Plain (63).

On the ecoregion map (Figure 1), the Middle Atlantic Coastal Plain (63) contains six level IV ecoregions: the Delaware River Terraces and Uplands (63a), Chesapeake-Albemarle Silty Lowlands and Tidal Marshes (63b), Dismal Swamp (63c), Barrier Islands-Coastal Marshes (63d), Mid-Atlantic Flatwoods (63e), and Delmarva Uplands (63f). Descriptions of the individual characteristics of these six ecoregions follow.

63a. Delaware River Terraces and Uplands

Ecoregion 63a is a narrow, marshy, nearly level to rolling lowland adjacent to the Delaware River estuary and Delaware Bay that extends from southeastern Pennsylvania to southeastern Delaware. It is characterized by low, nearly level terraces, an ocean modified climate, a long growing season, freshwater intertidal marshes, saltwater marshes, and small, sluggish, meandering streams; physiography is distinct from that of the higher, less level, and much less marshy Delmarva Uplands (63f), Piedmont Uplands (64c), and Northern Rolling Inner Coastal Plain (65n). Low lying areas are commonly saturated during the growing season or flooded. Saline marsh deposits dominate; alluvial and estuarine sand and silt are also widespread. These deposits are underlain by unconsolidated and easily eroded Quaternary gravels, sands, and silts. Elevations are less than 60 feet (18 m), local relief is less than 35 feet (11 m); streams have low gradients and are often tidally influenced. Erosion, dredging, filling, and the construction of embankments and bulkheads has eradicated many wetlands; regulations since the 1970s have reduced annual wetland loss substantially.

Before settlement, freshwater intertidal, and brackish marshes were common. In addition, Appalachian Oak Forest (dominated by white and red oaks) grew on uplands in the north and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) grew on uplands in the south (Kuchler, 1964). Today, most of the original forests are gone, but some mature, second growth occurs in the Wissahickon Valley, Philadelphia (Erdman and Wiegman, 1974, p. 99).

The northern part of the Delaware River Terraces and Uplands (63a) is dominated by Philadelphia, Wilmington, and their suburbs; these cities developed on the Fall Line next to the Delaware River estuary. In this area, urban and industrial activities have caused extensive pollution and habitat modification. Erosion, urban development, dredging, filling, and bulkheading have eradicated many wetlands and continue to have an impact on the few that still exist. The remaining freshwater intertidal marshes in the Pennsylvania portion of Ecoregion 63a are home to globally rare species; this habitat is severely endangered in Pennsylvania and the state's only extinct plant, *Micranthemum micranthemoides*, was found there (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995). Wetlands between Andalusia and Bristol, Pennsylvania, including Neshaminy State Park, are reported to contain several plant species that are endangered in the State including the arrowhead *(Sagittaria calycina),* coast violet *(Viola brittoniana),* river bank quillwort *(Isoetes riparia),* and swamp beggar-ticks *(Bidens bidentoides)* (Wiegman, 1985, pp. 44-48, 66-67, 74). The freshwater intertidal and saltwater Tinicum Marshes, near the mouth of Darby Creek, contain several amphibian, reptile, and bird species that are endangered in Pennsylvania, including the coastal plain leopard frog *(Rana utricularia),* red-bellied turtle *(Pseudemys rubriventris),* bog turtle *(Clemmys muhlenbergii),* king rail *(Rallus elegans elegans),* and short-eared owl *(Asio flammeus flammeus)* (Gill, 1985, pp. 303-305; McCoy, 1985, pp. 263-271). These marshes are also the wintering ground for many ducks and provide summer habitat for herons, egrets, gallinules, and bitterns, including the least bittern *(Ixobrychus exilis exilis)* and the American bittern *(Botaurus lentiginosus),* which are threatened in Pennsylvania (Geyer and Bolles, 1979, p. 469; Gill, 1985, pp. 307-310). The Delaware River itself has been severely affected by domestic and industrial pollution. As a result, many associated species have been lost or are threatened with extinction in Pennsylvania. For example, the pirate perch *(Aphredoderus sayanus),* the mud sunfish *(Acantharchus pomotis),* the blackbanded sunfish *(Enneacanthus chaetodon),* and the swamp darter *(Ertheostoma fusiforme)* have been extirpated from the lower Delaware River of Pennsylvania (Cooper, 1985, pp. 239-256). The shortnose sturgeon *(Acipenser brevirostrum)* probably still exists in the Delaware River, but is endangered in Pennsylvania (Cooper, 1983, p. 5; 1985, pp. 171-172). In Pennsylvania, the Coastal Plain boundary approximates an elevation of 59 feet (18 m) (Geyer and Bolles, 1979, p. 467; Guilday, 1985, p. 19). This border is near the Fall Line, which divides the Lower Paleozoic schist and gneiss of Ecoregion 64c from the much younger, less resistant, and flat-lying sedimentary rocks. The boundary between the Piedmont Uplands (64c) and Ecoregion 63a also approximates the juncture of the Chester and Glenelg soils with the Howell and Fallsington soils (U.S. Department of Agriculture, 1972).

Ecoregion 63a's boundaries are shown on Figure 1. Its western border with the Piedmont Uplands (64c) is at the Fall Line. Its western border with the Delmarva Uplands (63f) was drawn from surficial geology maps, topographic maps, and county soil survey information; saline marsh deposits and low terraces with alluvial-estuarine sand and silt were included in Ecoregion 63a (Richmond et al., 1987). Where marsh symbols on the topographic maps extended west of the alluvial-estuarine sand and silt deposits shown on Richmond and others (1987), the ecoregion 63a-63f line followed the marsh symbols. The boundary between ecoregions 63a and 63d is near the boundary between marine and alluvial-estuarine deposits (Richmond and others (1987)) and follows a natural break in marsh distribution; Ecoregion 63a lacks the strand, beach ridges, swales, and barrier islands of the Barrier Islands-Coastal Marshes (63d). The boundary between Ecoregion 63a and the Chesapeake Rolling Coastal Plain (65n) is based on physiography; Ecoregion 63a is lower, more poorly drained, and more marshy than Ecoregion 65n.

63b. Chesapeake – Albemarle Silty Lowlands and Tidal Marshes

Ecoregion 63b is universally low in elevation and is characterized by nearly flat terrain, terraces, tidal marshes, ponds, and swampy streams. Brackish wetlands are common and serve as habitat for fish, shellfish, and wildfowl. Elevations range from 0 to 50 feet (0-15 m) and relief is less than 35 feet (11 m); surrounding ecoregions are both higher and better drained. Ecoregion 63b is underlain by unconsolidated lower terrace sediments of Quaternary age. Alluvial sand and silt, estuarine sand and silt, saline marsh deposits, and marine sand, silt, and clay are common; swamp deposits occur (Richmond and others, 1987). Ultisols and Histosols have commonly developed from residuum. They support a potential natural vegetation of Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak), Northern Cordgrass Prairie, and Southern Floodplain Forest (Kuchler, 1964).

Streams are usually low in gradient, sluggish, tidally influenced, poorly incised, and lack a defined channel; they are fed by shallow groundwater aquifers and become brackish as they begin to mix with the Chesapeake Bay. Wide riparian wetlands occur and channelization is common (White, 1997). Stream water is often high in both natural acidity and dissolved organic carbon and is often stained.

Extensive tidal marshes and salt estuarine bay marshes are found on the poorly drained soils of the silty low terraces of Ecoregion 63b. The tidal marshes are most extensive on the lower Eastern Shore of the Chesapeake Bay; here, the terrain is low and tidal marshes extend farther inland than in other coastal areas (White, 1997). Dominant brackish marsh plant species are: a) big cordgrass along margins of tidal creeks and ponds; b) hightide bush along the higher periphery of marshes; c) saltmeadow cordgrass in marsh meadows; d) saltmarsh cordgrass - saltmeadow cordgrass on well-drained tidal flats; e) olney three-square in extensive, poorly drained, shallow depressions normally covered with surface water; and f) saltgrass. Salt estuarine bay marshes are found in lower Chesapeake Bay waters where salinity is relatively high and tidal fluctuations are narrow (Lippson, 1973).

Today, forests and agriculture including corn and soybean farming are found where natural or artificial drainage is sufficient. Urban and industrial areas are found near large harbors and poultry operations are locally common.

Ecoregion 63b's boundaries are shown on Figure 1. Ecoregion 63b's boundary sometimes follows the scarp dividing low terraces from interior uplands and typically includes areas that have a high concentration of tidal marshes. The border between Ecoregion 63b and the Dismal Swamp (63c) was based primarily on the swamp deposit polygon (qsp) of Mixon and others (1989); qsp is exclusively limited to the Dismal Swamp (63c). The boundary between Ecoregion 63b and the Rolling Coastal Plain (65m) was defined on the basis of topography, surficial deposits, and soils; Ecoregion 63b is confined to the low terraces and its boundary with Ecoregion 65m is near the line surrounding STATSGO polygon VA005 (Natural Resources Conservation Service, no date) and the alluvial and estuarine sand and silt polygon (aeb) of Richmond and others (1987). The border of Ecoregion 63b and the Delmarva Uplands (63f) roughly follows the inner limit of the STATSGO MD005 polygon (silty Othello, Elkton, and Mattapex soils) (Natural Resources Conservation Service, no date, State Soil Geographic Data Base) and is near the aeb polygon (alluvial and estuarine sand and silt) on Richmond and others (1987). The boundary of Ecoregion 63b with the higher, hillier, Chesapeake Rolling Coastal Plain (65n) is near the line surrounding STATSGO polygon MD005 (silty Othello, Elkton, and Mattapex soils) (Natural Resources Conservation Service, no date) and the alluvial and estuarine sand and silt polygon (aeb of Richmond and others, 1987).

63c. Dismal Swamp

The Dismal Swamp (63c) is a large, forested wetland with extensive organic deposits that is now a national wildlife refuge. Ecoregion 63c is nearly flat, poorly drained, and is underlain by lagoonal strata and impermeable clays (Oaks and Coch, 1963, 1973; Oaks and others, 1974a; Levy, 1979). Thick peat deposits are characteristic and extensive. Elevations range from about 15 to 20 feet.

The Dismal Swamp together with the Everglades and the Okefenokee Swamp contain the largest peat and muck deposits on the Atlantic seaboard south of Maryland (Hunt, 1974). The Dismal Swamp is critical habitat for several vulnerable mammals, including the threatened Dismal Swamp subspecies of the southeastern shrew (Terwilliger and Tate, 1994). Soils are largely Histosols and formed under saturated or very poorly-drained conditions; they are derived from organic material and are very acidic. Surface water is also highly acidic, far more so than in surrounding ecoregions. The largest lake in Virginia, Lake Drummond, is located in Ecoregion 63c and has a pH of 4.0-5.0. Few fishes are adapted to this high level of acidity and, as a result, the Dismal Swamp (63c) is depauperate in fish species; some cutoff pools are ultra acidic and may not support fish life (Jenkins and Burkhead, 1993 (1994)).

The potential natural vegetation is Southern Floodplain Forest (Kuchler, 1964). Dominant trees included tupelo (*Nyssa aquatica*), bald cypress (*Taxodium distichum*), oak (*Quercus spp.*), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*). Numerous fires, repeated logging, and the construction of over 100 miles of drainage ditches with parallel roads have affected vegetation (Levy, 1979). Today, red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*) are by far the most common trees on organic soils. Mineral soils in contrast have lower densities of red maple (*Acer rubrum*) and black gum *(Nyssa sylvatica)* and greater species richness (Levy and Walker, 1979).

Ecoregion 63c's boundaries are shown on Figure 1. Ecoregion 63c includes peat deposits, swamp deposits, peaty soils, and marshland (US Geological Survey 1:250,000 scale topographic sheets; Mixon and others (1989); Natural Resources Conservation Service (no date). The western boundary is near the Suffolk Scarp.

63d. Barrier Islands-Coastal Marshes

Ecoregion 63d is composed of beaches, dunes, low terraces, beach ridges, and barrier islands that are fringed by lagoons, bays, tidal salt marshes, mudflats, anastomosing tidal channels, or ocean. An extensive barrier – back barrier system parallels much of the Atlantic shore (Owens and Denny, 1979). Elevations range from only 35 feet (11 m) to sea level.

The Barrier Islands - Coastal Marshes (63d) ecoregion is more exposed to the open ocean than other nearby regions and, resultantly, its landforms are more dynamic. Significant wave and wind action occurs and has affected both landforms and the position of the shoreline itself. In the last 10,000 years, the overall trend for the sandy coastline has been westward retreat; from the mid-1950s or mid-1960s to the early-1980s, net erosion averaged five feet (1.5 m) per year (Bloom, 1983b). The barrier islands, in particular, have been heavily affected by hurricanes while protecting the mainland from erosion (Brown, 1997).

Ecoregion 63d is underlain by Quaternary unconsolidated sand, silt, and clay that were laid down as beach, dune, barrier beach, saline marsh, terrace, and nearshore marine deposits. Soils are mostly Entisols, Ultisols, and Inceptisols.

The potential natural vegetation of Ecoregion 63d is mapped as mostly Northern Cordgrass Prairie and contrasts with the natural hardwood vegetation of the Delmarva Uplands (63f) (Kuchler, 1964). The dunes and strand support only a few species of xerophilous herbaceous plants and are characteristically unwooded. Oak-Hickory-Pine Forest occurs in better drained, higher areas; dominants are hickory *(Carya* spp.), shortleaf pine *(Pinus echinata)*, loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)*, and post oak *(Quercus stella)* (Kuchler, 1964).

Ecoregion 63d and, particularly, its barrier islands contain many unique habitats for wildlife; large areas have been set aside as state parks, wildlife refuges, and national seashore. Several of Virginia's rarest birds, including the piping plover, Wilson's plover, and the gull billed tern nest in the sand of the Barrier Islands - Coastal Marshes (63d). In addition, loggerhead turtles use its barrier island beaches as nest sites (Terwilliger and Tate, 1994).

Ecoregion 63d's boundaries are shown on Figure 1. The Barrier Islands - Coastal Marshes (63d) is found adjacent to the ocean and includes beaches, dunes, low terraces, beach ridges, and barrier islands. Its western boundary with the Delmarva Uplands (63f) generally follows a long, often poorly defined, east-facing scarp that parallels the present shoreline at about 20 feet (6 m) above sea level (Owens and Denny, 1969). As such it includes upper Pleistocene and younger deposits (Mixon and others, 1989).

63e. Mid-Atlantic Flatwoods

Ecoregion 63e is a broad plain composed of middle-elevation terraces, sandy ridges, and broad, shallow valleys. Evergreen shrub bogs or "pocosins" are characteristic and are found on flat, poorly-drained uplands between major streams. Elevations range from 0 to 100 feet (0-30 m) and local relief is less than 30 feet (9 m). Dissection and elevation are generally less than ecoregions to the west and many streams meander widely. Drainage is often restricted and Aquults are the most extensive soils; they are a contrast to the better drained Udults that are common on the Rolling Coastal Plain (65m) (Buol, 1973, U.S. Soil Conservation Service, 1981b). Streams have high values of dissolved organic carbon and are more acidic than those of the Piedmont (45) and the Southeastern Plains (65) especially during low flow events (Markewich and others, 1990).

The potential natural vegetation is mapped as Oak-Hickory-Pine Forest on the uplands and Southern Floodplain Forest in the valleys (Kuchler, 1964). Upland dominants are hickory *(Carya s*pp.), shortleaf pine *(Pinus echinata)*, loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)*, and post oak *(Quercus stella)*. Valley dominants are tupelo *(Nyssa aquatica)*, oak *(Quercus* spp.), and bald cypress *(Taxodium distichum)*.

Today, the ecoregion is a mixture of woodland and agricultural land. Corn, soybean, pasture crops, and peanuts are often grown where drainage permits. Poultry, livestock, and dairy cattle farms also occur. On the wooded uplands, loblolly pine (*Pinus taeda*) and upland oaks are dominant whilst on bottomlands, water tupelo, swamp blackgum, sweetgum, and oaks are common. Pocosins have a dense, fire adapted, shrub layer and an open overstory of pond pine (*Pinus serotina)*; the endangered canebrake rattlesnake occurs here (Terwilliger and Tate, 1994). Longleaf pine (*P. palustris*) was once abundant on the low nutrient, well-drained sandy uplands of Ecoregion 63e even though it was near the northernmost limit of its range; subsequent logging, grazing, and fire suppression have caused longleaf pine to decline and it is now officially listed as a species of special concern in Virginia (Terwilliger and Tate, 1994; Williams, 1990).

Ecoregion 63e includes the middle-elevation terraces between the Surry Scarp on the west and the Suffolk Scarp on the east (Levy, 1991; Coch, 1965; Oaks and Coch, 1973) (Figure 1). Its northern boundary is at the James River and is near the mapped northern extent of the Southeastern Evergreen Forest Region of Braun (1950) that is dominated by evergreens, particularly longleaf pine.

63f. Delmarva Uplands

Ecoregion 63f encompasses the nearly level to gently rolling, uplands of the Delmarva Peninsula. It includes sandy ridges, swales, low paleodunes, and the central ridge of the peninsula. Marshes and swamps are far less extensive than in ecoregions 63a, 63b, and 63d but, nevertheless, do occur and include the Great Cypress Swamp of southern Delaware. Elevations range from about 20 to less than 100 feet (6-30 m) and local relief is less than 50 feet (15m); maximum elevations and local relief are greater than in the neighboring Delaware River Terraces and Uplands (63a), the Chesapeake-Albemarle Silty Lowlands and Tidal Marshes (63b), and the Barrier Islands - Coastal Marshes (63d). Many wet, shallow elliptical depressions (i.e. Carolina Bays or Delmarva Bays) occur and have high, droughty, sandy rims (Pettry and others, 1979; Prouty, 1952); they are conspicuously absent from the Barrier Islands-Coastal Marshes (63d) and the Delaware River Terraces and Uplands (63a). Flat interfluves occur on the central ridge and are often poorly drained.

Ecoregion 63f is underlain by unconsolidated Quaternary sands, silts, clays, shells, and gravels (Cleaves and others, 1968; Spoljaric and Jordon, 1966;Virginia Division of Mineral Resources, 1993). Parsonsburg Sand mantles broad areas; its surface consists of sinuous, low sand ridges and broad, seasonally-wet, swales (Delcourt and Delcourt, 1986, Denny and others, 1979). Gravelly sediments are found on the upland surface from near the head of Chesapeake Bay south to an irregular line connecting Milford, Delaware and Cambridge, Maryland (Owens and Denny, 1979).

Ultisols are common and have developed from residuum under a temperate climate. They originally supported a potential natural vegetation of mostly Oak-Hickory Pine Forest (Kuchler, 1964); pine-birch barrens may have occurred on paleodunes (Denny and others, 1979). The growing season is long, 175 to 225 days, and rainfall is both well-distributed and adequate (Mathews, 1964, p. 4). Ecoregion 63f is home to the most intensive row crop agriculture on the Delmarva Peninsula (White, 1997). It produces corn, soybean, small fruit, and truck crops. In addition, poultry, livestock, and dairy farms are widespread and are economically important (Bureau of the Census, 1995; U.S. Soil Conservation Service, various dates). Commercial woodland also occurs. Sandy soils are nutrient poor and have a limited water holding capacity (White, 1997). Other less permeable soils require artificial drainage to be farmed (U.S. National Oceanic and Atmospheric Administration, 1974, Mathews, 1964, p. 4).

Streams and rivers are often flanked by riparian woodland. They are generally low in gradient, often tidally influenced, and have wide valleys. Many streams in Ecoregion 63f have been straightened and deepened to improve drainage and interbasin connections in headwater areas are not uncommon (Cushing and others, 1973). Streams on the well-drained uplands have riffle sections with gravelly bottoms; they are incised but not as much as on the Southeastern Plains (65) (White, 1997).

Ecoregion 63f's boundaries are shown on Figure 1. Ecoregion 63f's border with the Chesapeake Rolling Coastal Plain (65n) follows physiography; ecoregion 65n has more relief than Ecoregion 63f. Ecoregion 63f's boundary with the Piedmont Uplands (64c) occurs at the Fall Line where sedimentary rocks interfinger with the older, metamorphic rocks of the Piedmont. Many of its other boundaries conform to scarps and, thus, to particular Quaternary deposits that occur within a particular elevational band. Its western boundary with the Chesapeake-Albemarle Silty Lowlands and Tidal Marshes (63b) roughly follows the inner limit of the STATSGO MDOO5 (silty Othello, Elkton, and Mattapex soils (Natural Resources Conservation Service, no date, State Soil Geographic Data Base) and is near the aeb limit (alluvial and estuarine sand and silt) on Richmond and others (1987). The Delmarva Uplands (63f)'s eastern boundary roughly follows the innermost limit of the hps (saline marsh deposits), bmb (beach and nearshore marine sand) or mlb (marine sand, silt, and clay) polygons on Richmond and others (1987) and the mapped Central Uplands of Mixon (1985); barrier beaches, marshes, and open ocean characteristics typify the Barrier Islands - Coastal Marshes (63d) but not Ecoregion 63f.

64. Northern Piedmont

Ecoregion 64 consists of low rounded hills, irregular plains, and open valleys and is underlain by metamorphic, igneous, and sedimentary rocks. Crestal elevations typically range from about 325 feet (99 m) on limestone to 1,300 feet (396 m) on more resistant metamorphic rock. Isolated, higher, rocky hills and ridges occur and were formed by diabase intrusions. The climate is humid continental, with cold winters, hot summers, and an average of 170-210 days without killing frost. The natural vegetation was mostly Appalachian Oak Forest (dominated by white and red oaks). Some Oak-Hickory-Pine Forest occurred along the Susquehanna River and was dominated by hickory (*Carya* spp.), Virginia pine (*Pinus virginiana*), pitch pine (*Pinus rigida),* chestnut oak (*Quercus prinus*), white oak (*Quercus alba),* and black oak (*Quercus velutina)* (Cuff and others, 1989, p. 52). There are scattered serpentine barrens in Chester, Delaware, and Lancaster counties of Pennsylvania.

Soils within the Northern Piedmont (64) are generally deep, well-developed Alfisols and Ultisols of moderate to excellent fertility. Those derived from the carbonate bedrock in the York and Lancaster valleys are exceptionally fertile. Land use and land cover is a complex mix of small farms interspersed with residential, commercial, and industrial development and scattered woodland.

The boundary with the Middle Atlantic Coastal Plain (63) occurs at the Fall Line. The border with the Ridge and Valley (67) is based on topography, lithology, and geological structure. The boundary with the Piedmont (45) is based on potential natural vegetation; the dominantly Appalachian Oak Forest of the Northern Piedmont (64) contrasts with the Oak-Hickory-Pine Forest of Ecoregion 45 to the south.

On the ecoregion map (Figure 1), the Northern Piedmont (64) is composed of four level IV ecoregions: the Triassic Lowlands (64a), the Diabase and Conglomerate Uplands (64b), the Piedmont Uplands (64c), and the Piedmont Limestone/Dolomite Lowlands (64d). Descriptions of the individual characteristics of these four ecoregions follow.

64a. Triassic Lowlands

Ecoregion 64a is a plain underlain and delineated by sedimentary rock and characterized by wide undulating ridges, broad nearly level valleys, limited local relief, and a mosaic of farms and houses. Typical hilltop elevations generally rise westward from 175 to 600 feet (53-183 m) and local relief is only 30-200 feet (9-61 m). Ecoregion 64a is higher than the Piedmont Limestone/Dolomite Lowlands (64d), but lower than either the Piedmont Uplands (64c) or the Diabase and Conglomerate Uplands (64b); it is not as deeply dissected as Ecoregion 64c. Springs are rather uncommon because the comparatively flat and undissected relief offers little means for the ground water to flow to the surface (Petro and others, 1956).

The soils of Ecoregion 64a were derived from Triassic sandstone, shale, siltstone, and argillite of the Brunswick, Stockton, Lockatong, Gettysburg, and New Oxford formations; lithology is distinct from the metamorphic rocks of the surrounding portions of the Piedmont. The soils were derived from residuum and are mostly Alfisols containing a moderate to high level of subsoil base saturation. They are less fertile than the Alfisols of Ecoregion 64d, which were derived from carbonates, but are slightly more fertile than the Ultisols and Inceptisols of Ecoregion 64c, which were derived from metamorphic rock (Ciolkosz and Dobos, 1989, p. 295; Kuhl and others, 1984, p. 29).. They supported a potential natural vegetation of Appalachian Oak Forest (dominated by white and red oaks) (Kuchler, 1964).

Today, the native Appalachian oak forest has been replaced by a mosaic of farms, houses, and woodland. Agriculture is favored by nearness to market, fairly fertile soils, and a long growing season of 170-183 days. Dairy farming is the main source of farm income; beef cattle, poultry, fruit, vegetables, and grain are also important. Suburbanization increases near Philadelphia. Despite their soils differences, ecoregions 64a and 64c have similar land uses. Hickory (*Carya* spp.) is more abundant than elsewhere in the Piedmont because the soils of Ecoregion 64a are less acidic and more calcium- and magnesium-rich than those derived from nonsedimentary rocks (Farrell and Ware, 1991). Red maple (*Acer rubrum*) and black tupelo (*Nyssa sylvatica*) are less abundant on soils derived from Triassic sediments than on the low calcium, low magnesium, and more acidic soils found elsewhere in the Piedmont over metamorphic rocks (Farrell and Ware, 1991).

Streams, wetlands, and a few ponds occur in Ecoregion 64a. In the Schuylkill River system of northern Montgomery and Chester counties, mallards (*Ánas platyrhynchos*), Canada geese (*Branta canadensis*), wood ducks (*Aix sponsa*), and black ducks (*Ánas rúbripes*) are common and the water is warm enough for many species of fish, including bass, bluegill, and carp (Smith and others, 1967). Wetlands are becoming rarer, especially in the Philadelphia area, but they still support populations of the New Jersey chorus frog (*Pseudacris triseriata kalmi*) and the bog turtle (*Clemmys muhlenbergii),* both endangered in Pennsylvania (McCoy, 1985, pp. 261, 270).

The boundaries of Ecoregion 64a generally occur at the limit of nonresistant Triassic deposits. Changes in topography and soils often coincide with these boundaries.

64b. Diabase and Conglomerate Uplands

Ecoregion 64b is characterized by wooded, stony, hills and steep ridges that are composed of highly resistant igneous (diabase), heat-altered sedimentary rock, or sedimentary rock. Crestal elevations are typically 300-1,150 feet (91-351 m), but in the Conewago Mountains, they rise to about 1,300 feet (396 m). Local relief varies substantially from a minimum of about 50 feet to a maximum of 650 feet (15-198 m).

Ecoregion 64b is underlain mostly by Triassic conglomerates and reddish sandstones that were intruded by Triassic and Jurassic diabase along a series of linear sills and dikes. These intrusions in turn heated nearby sediments and altered them into harder, denser, and less porous material (Geyer and Bolles, 1979, p. 408). The primary ridge formers are the Gettysburg and Hammer Creek conglomerates and, most commonly, diabase (trap rock). A famous example of the latter is Gettysburg's Cemetery Ridge. Triassic diabase has more open joints than sandstone or shale and yields more water; the ground water from diabase is softer than the harder water from wells in shale or sandstone (Petro and others, 1956).

Thin, fine-textured clayey soils have commonly developed over diabase and are non-acidic and shallow. They are hard to till and best suited for forest or pasture. Saprolite is thin to nonexistent unlike elsewhere in the Northern Piedmont (64). Soils are mostly Alfisols and originally supported Appalachian Oak Forest (dominated by white and red oaks)) (Cuff and others, 1989, p. 52). The flora on soils derived from the diabase intrusions which are basic in character are distinctive; acid loving plants are absent from diabase areas (Allard and Leonard, 1962).

Today, woodland is still common in Ecoregion 64b, especially where the surface is steep or covered in rocks or boulders. In other areas, the land is more suitable to agriculture. Here general farms occur, typically scattered among woodland and idle land. Camps and resort cottages are locally common, for example, in eastern Montgomery County (Smith and others, 1967, p. 9).

Lithology, woodland density, elevation, and topography differentiate Ecoregion 64b from the other ecoregions of the Northern Piedmont (64). Ecoregion 64b alone is a wooded upland composed of resistant Jurassic and Triassic diabase and Triassic conglomerate.

64c. Piedmont Uplands

Ecoregion 64c is characterized by rounded hills, low ridges, relative high relief, and narrow valleys and is underlain by metamorphic rock. Irregular plains and narrow valleys typically have elevations that often range from about 450 feet to 1,000 feet (137-304 m) and a local relief that is often 130 feet to 330 feet (40 to 101 m). Ruggedness increases toward the southwest and local relief can be as much as 590 feet (180 m) adjacent to the incised Susquehanna River. Here gorges containing high-gradient streams and waterfalls occur, including Otter Creek, Tucquan Glen, Wildcat Run, Counselman Run, Kelly Run, Ferncliff Run, and Oakland Run (Geyer and Bolles, 1979, pp. 442-465; Guilday, 1985, p. 19). The Piedmont Uplands (64c) has substantially higher relief than the Triassic Lowlands (64a), Piedmont Limestone/Dolomite Lowlands (64d), or the Outer Piedmont (45f). Channel gradient is generally moderate and is greater than that of neighboring ecoregions with less relief; Piedmont fish habitats vary in relation to gradient (Jenkins and Burkhead, 1993 (1994)).

The Fall Zone occurs near the eastern edge of Ecoregion 64c and is characterized by areas of high stream gradient, exposed bedrock, islands, falls, and a mixture of metamorphic and sedimentary rock. Parts are suited to many upper Piedmont and montane fishes. The Fall Zone is an ecologic barriers to lowland, calm-water species. The Great Falls of the Potomac is the largest physical river barrier of natural origin in Virginia and is insurmountable to fishes at low and normal river levels; it has barred anadromous fishes from potential spawning grounds and may have curtailed the upstream distribution of Coastal Plain fish species (Jenkins and Burkhead, 1993 (1994)).

Metamorphic rocks of Lower Paleozoic and Precambrian age underlie the ecoregion and are folded and faulted; lithology is distinct from the sedimentary rocks of the neighboring Southeastern Plains (65). Schists of the Wissahickon and Peters Creek formations predominate and Precambrian gneisses are common in the east. Very resistant quartzite and phyllite of the Chickies, Antietam, and Harpers formations form the highest areas, the Pigeon Hills and Hellam Hills. Scattered outcrops of very basic serpentinite also occur.

Deep Ultisols and Inceptisols are common and have developed from residuum. Chester and Glenelg soils are common. These Ultisols are capable of supporting highly diversified farms, even though they are less fertile than the soils of Ecoregion 64d. Soils derived from quartzite are commonly stony and are often forested. Chrome soils from serpentinite occur locally and are low in calcium and high in magnesium, chromium, and nickel.

Scattered serpentine barrens occur on chrome soils and support a specialized vegetation composed of dry oak/pine forests (e.g., *Quercus marilandica, Q. stellata, Q. velutina, Pinus virginiana*), greenbrier (*Smilax rotundifolia*), prairie grasses (e.g., *Schizachyrium scoparius, Sporobolus heterolepis*), and herbs (e.g., *Aster depauperatus, Cerastium arvense var. villossissimum, Talinum teretifolium*) (Cuff and others, 1989, p. 56). Most of these are rare in Pennsylvania and some are threatened, including the prairie dropseed (*Sporobolus heterolepis*) (Wiegman, 1985, p. 57). In addition, the buckmoth (*Hemileuca maia)* occurs only in the serpentine barrens and is threatened in Pennsylvania (Opler, 1985, p. 88). Pitch pine (*Pinus rigida*) is a co-dominant in serpentine barren woodlands and an important component of bluestem-dropseed savannas; it is found at seven serpentine barren sites in Chester, Delaware, and Lancaster counties. Those at Nottingham County Park and at Goat Hill State Forest Natural Area are among the largest remaining barrens in the eastern United States (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995). Grazing, quarrying, and suburban development continue to threaten the remaining barrens (Wiegman, 1985, p. 57) and The Nature Conservancy has given them second-highest priority on their state biodiversity conservation agenda (Roger Latham, Department of Geology, University of Pennsylvania, written communication, 1995).

The potential natural vegetation is mapped as Appalachian Oak Forest (dominated by white and red oaks); it distinct from the Oak-Hickory-Pine of the Inner Piedmont (45e) (Kuchler, 1964). Some Mixed Mesophytic Forest also occurred. Remnants of the original vegetation can be found in the cool, very rugged Otter Creek gorge, where virgin chestnut oak (*Quercus prinus),* hemlock (*Tsuga canadensis*), beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and basswood (*Tilia heterophylla*) still grow (Erdman and Wiegman, 1974, p. 98).

Today, forests are less extensive than they were originally and there is more agriculture than in the Inner Piedmont (45e). Extensive urban, commercial, and industrial development occurs in the Philadelphia area. Suburban development is common, especially near Philadelphia, Wilmington, and the major transportation corridors. Farms become progressively more common with distance from the cities. Grain, potatoes, and hay are produced and many of the farms have pastures for dairy and beef cattle or ranges for poultry. Farming is favored by nearness to market, rather fertile soils, and Pennsylvania's longest growing season, up to 200 days. Agricultural erosion has been a serious problem in many places (Kunkle, 1963).

The boundary of Ecoregion 64c follows the limit of the Lower Paleozoic and Precambrian metamorphic rocks; they are distinct from the largely sedimentary rock of the surrounding ecoregions. The Northern Piedmont (64) is divided from the Middle Atlantic Coastal Plain (63) by the Fall Line. The southern boundary is close to Braun’s (1950) natural vegetation line. The western boundary with the high, rugged, forested Blue Ridge Mountains (66) is based on topography and vegetation density.

64d. Piedmont Limestone/Dolomite Lowlands

Ecoregion 64d is a very fertile and intensively farmed area underlain mostly by limestone and dolomite. These carbonates have been weathered to form a nearly level to undulating terrain that contains sinkholes, caverns, and disappearing streams. Ecoregion 64d is lithologically distinct from the metamorphic rock of the neighboring Piedmont Uplands (64c). Elevations are lower than adjacent ecoregions, typically 250-525 feet (76-160 m). In the York Valley, however, they rise to about 675 feet (206 m). There is little dissection and local relief is typically only 30-125 feet (9-38 m).

Ordovician limestone predominates. It is a high yielding aquifer riddled with solution channels that reduce water filtration; as a result, groundwater is sometimes contaminated. Other Ordovician and Cambrian formations occur and contain limestone, dolomite, and shale.

The soils, unlike those of surrounding ecoregions, are derived largely from carbonate rock and are very fertile. The Duffield and Hagerstown soils are common and, with the exception of sinkholes, pose no limitations for agriculture. These base-rich Alfisols (Hapludalfs) developed under a humid and mild climate. They supported a potential natural vegetation of mostly Appalachian Oak Forest (dominated by white and red oaks) (Kuchler, 1964), but along the Susquehanna River, Oak-Hickory-Pine Forest also grew (Cuff and others, 1989, p. 52).

Today, virtually all of the forest has been replaced by agriculture although a few wetlands still occur, including Gleisner's Swamp near Quarryville, the type locality of the bog turtle (*Clemmys muhlenbergii*), which is endangered in Pennsylvania (Erdman and Wiegman, 1974, p. 96). The Piedmont Limestone/Dolomite Lowlands (64d) has a very favorable natural environment for agriculture; its topography, climate/growing season, and market proximity are conducive to commercial agriculture, and its soils are among the best in the eastern United States (Cuff and others, 1989, p. 20). It is one of the most productive agricultural areas in eastern United States and is dominated by general farming. Land use is similar in both the carbonate and the shale areas of Ecoregion 64d; corn, hay, soybeans, and wheat are commonly produced. Dairy farming also occurs, but is not dominant as in neighboring ecoregions. In addition, tobacco is an economically important specialty crop in Lancaster County, where it is typically grown on small, rotating plots to reduce soil depletion (Pennsylvania Agricultural Statistics Service, 1990-1991). Rocky land is mostly used for pasture. Residential and industrial developments occur and are expanding, especially in Montgomery County and in the Lancaster area. Present day flora and vegetation on basic soils in the Culpeper Basin are distinct from that occurring on more acid, less fertile soils of the neighboring Piedmont Uplands (64c) that are underlain by Paleozoic and Precambrian metamorphic rock.

The boundary of Ecoregion 64d generally follows the limit of Ordovician-Cambrian carbonate rocks and the karst, agricultural lowland. However, in the Conestoga Valley, shales of the Cocalico Formation also occur.

65. Southeastern Plains

Ecoregion 65 is composed of irregular plains that are covered by a mosaic of cropland, pasture, woodland, and forest. The Cretaceous or Cenozoic-age sands, silts, and clays of the region contrast geologically with the older igneous and metamorphic rocks of the Piedmont. Elevations range from sea level to about 300 feet (91 m); relief and maximum elevations are less than in the neighboring Piedmont. Stream channels are relatively low in gradient and are sandy-bottomed. The most common soils are Ultisols. They support a potential natural vegetation of mostly Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) and, in northeast, Appalachian Oak Forest (dominated by white and red oaks) (Kuchler, 1964).

The boundary between the Southeastern Plains (65) and ecoregions 45 and 64 occurs at the Fall Line where the metamorphic rocks of the Piedmont and the sedimentary rocks of the Coastal Plain interfinger. Ecoregion 65's border with the Middle Atlantic Coastal Plain (63) is based on elevation, topography, and drainage; Ecoregion 65 is typically higher, not as level, better drained, and less marshy than Ecoregion 63. In addition, although both ecoregions 63 and 65 are underlain by unconsolidated sediments, Holocene-age deposits are restricted to the Middle Atlantic Coastal Plain (63).

On the ecoregion map (Figure 1), the Southeastern Plains (65) is composed of two level IV ecoregions: the Rolling Coastal Plain (65m) and Chesapeake Rolling Coastal Plain (65n). Descriptions of the individual characteristics of these two ecoregions follow.

65m. Rolling Coastal Plain

Ecoregion 65m is a rolling, hilly, dissected portion of the Inner Coastal Plain that is made up of sedimentary material. Lithology is distinct from the adjacent Northern Outer Piedmont (45f) that is composed of metamorphic rocks. The terrain is hillier than the Chesapeake-Albemarle Silty Lowlands and Tidal Marshes (63b). Elevations typically range from 30 to 250 feet and local relief is 25 to 175 feet (7.6-53 m). Relief, elevation, and channel gradients are generally greater than in the Middle Atlantic Coastal Plain (63); correspondingly, drainage also tends to be better. Stream margins can be swampy and stained water can occur. Parts of the Fall Zone are included in the westernmost portion of the Rolling Coastal Plain (65m); here aquatic habitats vary between the islands, pools, swampy streams, and cascades of the zone.

The Rolling Coastal Plain (65m) is mostly underlain by unconsolidated Tertiary sand, silt, clay, and gravels of the Bacons Castle Formation and the Chesapeake Group (Virginia Division of Mineral Resources, 1993); Holocene-age deposits and metamorphic rocks are typically absent. Ultisols are common and have a thermic temperature regime (Buol, 1974); they are better drained than the Aquults of the Middle Atlantic Coastal Plain (63) and are warmer than the soils of the Chesapeake Rolling Coastal Plain (65n). The soils support a potential natural vegetation of Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) (Kuchler, 1964).

Today, Ecoregion 65m is a mosaic of woodland and farmland (U.S. Soil Conservation Service, various dates). Common crops are corn, soybeans, and, in the south, peanuts (Bureau of the Census, 1995). Hardwoods are now more common than at the time of settlement because of frequent fires and the repeated preferential cutting of pine. Woodlands are more extensive than in the Northern Rolling Inner Coastal Plain (65n) to the north of the Potomac River.

Ecoregion 65m's boundaries are shown on Figure 1. The Fall Line acts as the western border and separates Ecoregion 65m from the higher and lithologically distinct Northern Outer Piedmont (45f). Its eastern limit is the

Suffolk and Harpersville scarps which separate it from the low, flat terraces of Ecoregion 63b. Its southeastern boundary is the Surry Scarp that divides it from the middle-elevation terraces of Ecoregion 63e. Ecoregion 65m's northern border with the Chesapeake Rolling Coastal Plain (65n) is the Potomac River where forest density and soil temperature regimes change.

65n. Chesapeake Rolling Coastal Plain

Ecoregion 65n is a hilly upland with narrow stream divides, incised streams, and well-drained loamy soils. It is hillier, more dissected, and better drained than the Middle Atlantic Coastal Plain (63) and its underlying sedimentary rocks are distinct from the older, metamorphic rocks of the Piedmont. Elevations are under 400 feet (122 m) and local relief ranges from 25 to 225 feet (7.6-69 m); maximum elevation and relief are in between those of the higher Piedmont and the lower Middle Atlantic Coastal Plain (63). In addition, channel gradients are in between those of the Piedmont and the Middle Atlantic Coastal Plain (63) (White, 1997). Stream margins can be swampy and stained water commonly occurs.

Soils are naturally low in nutrients and require liming and fertilizing to be productive for agricultural crops (White, 1997); they have a mesic temperature regime and are colder than the thermic soils of the Rolling, Inner Coastal Plain (65m). These Ultisols support a potential natural vegetation of mostly Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak); in the northeast, Appalachian Oak Forest (dominants: white and red oaks) also occurs (Kuchler, 1964).

Today, urbanization and residential development are extensive within commuting distance to Baltimore, Washington, Wilmington, or Annapolis. Elsewhere, less intensive agriculture, general farming, or part time agriculture occurs; the landuse mosaic is distinct from the more forested Rolling, Inner Coastal Plain (65m). The average annual growing season varies according to latitude and proximity to water bodies and ranges from 160 to 225 days (U.S. National Oceanic and Atmospheric Administration, 1974).

The boundaries of Ecoregion 65n are shown on Figure 1. The Fall Line acts as the western border and separates Ecoregion 65n from the higher and lithologically distinct ecoregions of the Piedmont. Ecoregion 65n's southern border with the Rolling Coastal Plain (65m) is the Potomac River; the river divides the mesic soils of the north from thermic soils of the more forested south. Ecoregion 65n's eastern boundary with the Middle Atlantic Coastal Plain (63) is primarily based on physiography; Ecoregion 63 is generally flatter than Ecoregion 65.

66. Blue Ridge Mountains

Ecoregion 66 is a narrow strip of mountainous ridges that are forested and well dissected. Crestal elevations range from about 1,000 feet to over 5,700 feet (305-1,737 m) on Mt. Rogers and tend to rise southward. Local relief is high and both the side slopes and the channel gradients are steep. Streams are cool and clear and have many riffle sections; they support a different, less diverse fish assemblage than the streams of the valleys below, which are warmer, lower in gradient, and more turbid.

The Blue Ridge Mountains (66) are underlain by resistant and deformed metavolcanic, igneous, sedimentary, and metasedimentary rock. Inceptisols, Ultisols, and Alfisols have developed on the Cambrian, Paleozoic, and Precambrian rock.

The Blue Ridge Mountains (66) can be divided into northern (ecoregions 66a and 66b) and southern parts (ecoregions 66c, 66d, 66e) at the Roanoke River (Hack, 1982). North of the river, just three different rock types form the crest and the effects of differential erosion partially determine their local altitude. South of the Roanoke River, the Blue Ridge Mountains become higher and lithologically complex.

Climate varies significantly. Generally, both growing season and precipitation increase southward. The frost-free period varies from less than 150 days to more than 175 days, and the precipitation varies from 39 to 49 inches (99-124 cm). Locally, however, relief and topographic position have significant effects on the microclimate.

The natural vegetation varied from north to south. North of a transitional area near the Roanoke River, it was predominantly Appalachian Oak Forest (dominated by white and red oaks). South of the transitional area, grew a mix of Appalachian Oak Forest, Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak), and, in higher areas, Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Kuchler, 1964). On the foothills, a mix of loblolly and shortleaf pines occurred and were mixed with Appalachian Oak Forest.

On the ecoregion map (Figure 1), the Blue Ridge Mountains ecoregion (66) is composed of five level IV ecoregions: the Northern Igneous Ridges (66a), the Northern Sedimentary and Metasedimentary Ridges (66b), the Interior Plateau (66c), the Southern Igneous Ridges and Mountains (66d), and the Southern Sedimentary Ridges (66e). Each is a highland that is typically wooded and often composed of crystalline rock; each is distinct from the adjacent, agricultural lowlands of the Northern Limestone/Dolomite Valleys (67a), the Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f), the Southern Shale Valleys (67g), and the Triassic Lowlands (64a).

66a. Northern Igneous Ridges

Ecoregion 66a extends southwestward from South Mountain, Pennsylvania, to near the Roanoke River. It consists of pronounced ridges separated by high gaps and coves. Mountain flanks are steep and well dissected. Crestal elevations tend to rise southward, from 1,000 to 1,575 feet (305-480 m) in Pennsylvania, to a maximum of over 3,750 feet (1,143 m). Local relief also increases southward to a maximum of about 1,300 feet (396 m).

Precambrian and Paleozoic metavolcanic and igneous rock underlie Ecoregion 66a. Typically occurring in Virginia are basalt and metabasalt of the Catoctin Formation, granite and granodiorite of the Virginia Blue Ridge Complex, and andesite, tuft, and greenstone of the Swift Run Formation. Metarhyolite and metabasalt occur in Pennsylvania; diabase, metabasalt, and metarhyolite are found in Maryland. Inceptisols, Alfisols, and Ultisols have commonly developed from the bedrock. Catoctin, Myersville, and Hayesville soils are widespread. Low fertility, acidity, stoniness, and steepness are characteristics of these soils.

The natural vegetation was Appalachian Oak Forest (dominants: white and red oaks) (Kuchler, 1964). Today, the Northern Igneous Ridges (66a) remain extensively forested. On South Mountain, however, localized dairy farming and poultry raising occur; in addition, orchards are found on Arendtsville soils.

The boundary between Ecoregion 66a and the Northern Sedimentary and Metasedimentary Ridges (66b) is shown in Figure 1; it follows the contact between igneous-metavolcanic rocks and sedimentary-metasedimentary rocks.

66b. Northern Sedimentary and Metasedimentary Ridges

Ecoregion 66b extends from South Mountain, Pennsylvania, to the Roanoke River area. It is composed of high, steeply sloping ridges and deep, narrow valleys. Crestal elevations typically rise southward, from about 1,300 to 2,000 feet (396-610 m) in Pennsylvania, to a maximum of over 3,500 feet (1,067 m). Local relief also increases southward and reaches a maximum of about 1,000 feet (305 m).

Erosion resistant sedimentary and metasedimentary rock of Cambrian age underlies Ecoregion 66b. The Weverton-Loudon, Antietam (Erwin in Virginia), and Harpers (Hampton in Virginia) formations are common. Typically, Inceptisols, Ultisols, and Alfisols developed from the bedrock. Laidig, Wallen, Dekalb, Lily, Berks, and Weikert soils are widespread. Stoniness, steepness, low fertility, and acidity are characteristics of these soils. Streams do not have much buffering capacity and are subject to acidification.

The natural vegetation was Appalachian Oak Forest (dominants: white and red oaks) (Kuchler, 1964). Today, the Northern Sedimentary and Metasedimentary Ridges (66b) remain extensively forested.

The boundary between Ecoregion 66b and the Northern Igneous Ridges (66a) is shown in Figure 1; it follows the contact between igneous-metavolcanic rocks and sedimentary-metasedimentary rocks.

66c. Interior Plateau

Ecoregion 66c is a high, hilly plateau punctuated by scattered isolated knobs (monadnocks). The Interior Plateau (66c) is more than 1,000 feet (304 m) higher than the nearby Piedmont; crestal elevations are approximately 2,600 to 4,500 feet (792-1,372 m). Local relief is often under 200 feet (61 m).

Ecoregion 66c is underlain by Precambrian metamorphic rock, including quartzite, graywacke, and conglomerate of the Lynchburg Formation. Gneiss and schist also outcrop. Inceptisols, Alfisols, and Ultisols occur and Chester, Hayesville, Glenelg, Manor, and Myersville soils are common. Stoniness and limited depth to bedrock are characteristics of these soils.

The natural vegetation was Appalachian Oak Forest (dominated by white and red oaks) and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) (Kuchler, 1964). Today, the Interior Plateau (66c) has woodlots interspersed with pastures. Dairy and livestock farms are common and some apple orchards also occur. Woodland remains on steeper slopes.

Ecoregion 66c's boundary is shown in Figure 1; its muted relief, lower elevations, and lower woodland density are a marked contrast to those of the Southern Igneous Ridges and Mountains (66d) and Southern Sedimentary Ridges (66e) which are adjacent.

66d. Southern Igneous Ridges and Mountains

Ecoregion 66d extends from near the Roanoke River into Tennessee and North Carolina border. It consists of pronounced ridges and mountain masses separated by high gaps and coves. Mountain flanks are steep and well dissected. Crestal elevations range from about 2,600 to 5,728 feet (792-1,746 m) on Mt. Rogers. Local relief varies from about 1,150 to 1,500 feet (351-457 m).

Precambrian and Paleozoic rock underlies Ecoregion 66d. The Mt. Rogers Volcanic Group, the Virginia Blue Ridge Complex, and the Lynchburg Formation are commonly exposed. Typically, Inceptisols (Dystrochrepts) and Ultisols (Hapludults) developed from the bedrock. The Hayesville and Grimsley, Porters soils are widespread and are characterized by stoniness and steepness.

The natural vegetation was Appalachian Oak Forest (dominants: white and red oaks) or, at higher elevations, Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Kuchler, 1964). Today, the Southern Igneous Ridges and Mountains ecoregion (66d) remains extensively forested.

The boundary between ecoregion 66d and the Southern Sedimentary Ridges (66e) is shown in Figure 1; it follows the contact between igneous-metamorphic and sedimentary-metasedimentary rocks.

66e. Southern Sedimentary Ridges

Ecoregion 66e extends from the Roanoke River into Tennessee. It is composed of high, steeply sloping ridges and deep, narrow valleys. Crestal elevations range from about 2,600 to 4,425 feet (792-1,349 m) and are often higher than those of the Northern Sedimentary and Metasedimentary Ridges ecoregion (66b). Local relief ranges from about 500 to 1,150 feet (152-351 m).

Cambrian sedimentary and metasedimentary rocks, including sandstone and quartzite of the Chilowee Group, underlie Ecoregion 66e. Ridge crests are underlain by resistant sandstone and quartzite, while side slopes are made up of phyllite, shale, siltstone, and sandstone. Typically, Inceptisols (Dystrochrepts) developed from the bedrock. The Berks, Weikert, Dekalb, and Wallen soils are common.

The natural vegetation was Appalachian Oak Forest (dominants: white and red oaks) or, at higher elevations, Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Kuchler, 1964). Today, the Southern Sedimentary Ridges ecoregion (66e) remains extensively forested.

The boundary between Ecoregion 66e and the Southern Igneous Ridges and Mountains (66d) is shown in Figure 1; it follows the contact between igneous-metamorphic and sedimentary-metasedimentary rocks.

66f. Limestone Valleys and Coves

Ecoregion 66f is a small but distinct area of narrow valleys and coves in the Blue Ridge Mountains (66) that are bordered by comparatively high mountains. It is underlain by interbedded sedimentary rock that can be dominated by carbonates; limestone sinks occur in the valleys. Here, along the southern border of Virginia, the Blue Ridge overthrust belt forced rocks to the east up and over younger rocks to the west; the area is underlain by the Cambrian Rome Formation that is composed of shale, limestone, siltstone, and dolomite (Virginia Division of Mineral Resources, 1993). Soils are typically Alfisols, Ultisols, and Inceptisols and developed from residuum. Elevations are 2500 to 3000 feet. The frost-free period is 165 to170 days and average annual precipitation ranges from 40-45 inches.

Most of the valleys and coves were originally forested but have now been cleared for agriculture. Pastures and field crops are common; corn, hay, tobacco, and some wheat farming occur. Knolls and slopes are covered by oaks, hickory, black locust, and tulip trees.

Ecoregion 66f becomes much more extensive to the south in Tennessee (Griffith and others, 1997, 1998). Shady Valley in northeastern Tennessee historically had extensive wetlands, and its soils still have a residual histic component (Milo Pyne, The Nature Conservancy, personal communication to Glenn Griffith). Vegetation changes for Shady Valley and Johnson County have been described by Barclay (1957).

67. Ridge and Valley

Ecoregion 67 extends from Wayne County, Pennsylvania, through Virginia along a southwesterly axis. It is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. Elevations range from about 500 to 4,300 feet (152-1,311 m). Local relief varies widely from approximately 50 to 1,500 feet (15-457 m). The Ridge and Valley (67) narrows toward the south and is generally bordered by the higher Blue Ridge Mountains and the higher and less deformed Allegheny and Cumberland plateaus.

Underlying Ecoregion 67 are largely Paleozoic sedimentary rocks that have been folded and faulted. Sandstone, shale, limestone, and dolomite are the predominant rock types. Lithological characteristics often determine surface morphology. Many ridges are formed on well-cemented, relatively resistant material such as sandstone or conglomerate; they are often rather parallel and alternate with valleys but, in central Pennsylvania, they zigzag because resistant strata were compressed into plunging folds during orogeny and later eroded. Valleys tend to be created on weaker strata, including limestone and shale. Inceptisols and Ultisols are common and were developed on noncarbonate rock. Alfisols and Ultisols are found in the limestone valleys.

The valleys vary in microtopography and agricultural potential. Valleys derived from limestone and dolomite are smoother in form and have a lower drainage density than those developed in shale. Shale valleys often display a distinctive rolling topography. Soils derived from limestone are fertile and well suited to agriculture, while those derived from shale have a much lower agricultural potential unless they are calcareous. Poultry operations are locally common and economically important.

Many of the streams networks are trellised; topography dictates that the swift, actively down-cutting streams which run off steep ridges must join the gentle valleys perpendicularly. Other larger rivers such as the Susquehanna River cross structure, cutting deep gorges through ridges in the process. High-gradient streams are common in watergaps and on ridge slopes; elsewhere, gentler gradient, warmer, more meandering streams are common. Partially as a result, the latitudinally extensive Ridge and Valley (67) has good aquatic habitat diversity.

The natural vegetation varied from north to south. From northeastern Pennsylvania to near its border with Maryland, the Ridge and Valley (67) was dominated by Appalachian Oak Forest. Southward, Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) was common to about the James River, whereupon the Appalachian Oak Forest returned (Kuchler, 1964). Hemlock *(Tsuga canadensis),* along with a mixture of white pine *(Pinus strobus),* beech *(Fagus grandifolia),* and other hardwoods also occurred locally (Brenner, 1985, p. 13).

Climate varies significantly in the Ridge and Valley (67). Generally, both growing season and precipitation increase southward. The frost-free period varies from less than 120 days to more than 180 days and the precipitation varies from 36 to 50 inches (91-127 cm). Locally, however, relief and topographic position have significant effects on the microclimate. The Ridge and Valley (67) is significantly lower than the Central Appalachians (69). As a result, it has less severe winters, considerably warmer summer temperatures, and lower annual precipitation due to a rain shadow effect.

On the ecoregion map (Figure 1), the Ridge and Valley (67) is composed of 10 level IV ecoregions: the Northern Limestone/Dolomite Valleys (67a), the Northern Shale Valleys (67b), the Northern Sandstone Ridges (67c), the Northern Dissected Ridges (67d), the Anthracite (67e), the Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f), the Southern Shale Valleys (67g), the Southern Sandstone Ridges (67h), and the Southern Dissected Ridges and Knobs (67i). Each is underlain by folded and faulted sedimentary rock which is distinctive of the ecoregion. The division between ecoregions 67a, 67b, 67c, and 67d and ecoregions 67f, 67g, 67h, and 67i occurs in a broad zone near the James River.

67a. Northern Limestone/Dolomite Valleys

Ecoregion 67a is a lowland characterized by broad, level to undulating, fertile valleys that are extensively farmed. The Great Valley, the Shenandoah Valley, and the Nittany Valley all occur in Ecoregion 67a. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolomite, and as a result, the drainage density is low. Where streams occur, they tend to have gentle gradients, plentiful year around flow, and distinctive fish assemblages. Local relief typically ranges from 50 to 500 feet (15-152 m).

Silurian, Ordovician, and Cambrian limestone and dolomite commonly underlie Ecoregion 67a. Interbedded with the carbonates are other rocks, including shale, which give the ecoregion topographic and soil diversity. Mesic Alfisols (Hapludalfs, Fragiudalfs, Paleudalfs) and Ultisols (Hapludults, Paleudults) have developed from the rock. Hagerstown soils are common locally and are very productive. They are also found on the Lancaster Plain and York Valley of the Piedmont Limestone/Dolomite Lowlands (64d).

The climate of Ecoregion 67a varies significantly because of the ecoregion's elevational and latitudinal range. The growing season varies from 145 to 180 days and is sufficient for agriculture. Farming predominates, with scattered woodlands occurring in steeper areas. Kuchler (1964) mapped the natural vegetation as mostly Appalachian Oak Forest (dominated by white and red oaks) in the north and Oak/Hickory/Pine Forest in the south; bottomland forests also occurred.

Figure 1 shows the boundaries of Northern Limestone/Dolomite Valleys (67a); base-rich soil, muted terrain, low drainage density, and limestone, dolomite, and calcareous shale bedrock are characteristic.

67b. Northern Shale Valleys

Ecoregion 67b extends over a large area from northeastern Pennsylvania to near the James River in Virginia. It is characterized by rolling valleys and low hills and is underlain mostly by shale, siltstone, and fine-grained sandstone. Local relief varies from about 50 feet to 500 feet (15-152 m).

The Hamilton, Hampshire, Chemung, and Brallier formations and, in Maryland, the Chemung Group underlie Ecoregion 67b. They are folded and faulted and are of Devonian age. The underlying rocks are not as permeable as the limestone of Ecoregion 67, so surface streams are larger and drainage density is higher than in limestone areas. There is more soil erosion in Ecoregion 67b than in the Northern Limestone/Dolomite Valleys (67a) (Cuff and others, 1989, p. 21). As a result, the stream turbidity can be comparatively high and the stream habitat relatively impaired.

Inceptisols (Dystrochrepts) have developed from residuum, and Berks, Weikert, and Lehew soils are common. Soils derived from acid shale are poorer than the soils of Ecoregion 67a, which were derived from limestone (Cuff and others, 1989, p. 21). Within Ecoregion 67b, however, there is considerable soil variability, and some soils are more calcareous than others. Kuchler (1964) mapped the natural vegetation as mostly Appalachian Oak Forest (dominants: white and red oaks) in the north and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) in the south; bottomland forests also occurred. Today, farming predominates, with woodland occurring on steeper sites. Scattered shale barrens occur on steep west and south facing slopes; it is one of rarest types of habitat in Pennsylvania and occurs in Huntingdon, Fulton, and Bedford counties (Cuff and others, 1989, p. 56; Erdman and Wiegman, 1974, pp. 71-74).

The boundaries of Ecoregion 67b are shown in Figure 1; they encompass acidic to neutral, valley and low hill soils that developed on shales and siltstones.

67c. Northern Sandstone Ridges

Ecoregion 67c is characterized by high, steep, forested ridges with narrow crests. Crestal elevations range from about 1,000 feet to 4,300 feet (305-1,311 m) and local relief typically ranges from 500 to 1,500 feet (152-457 m). Most of the major ridges in Ecoregion 67 are found in Ecoregion 67c or in the Southern Sandstone Ridges (67h). High-gradient streams flow off the ridges into narrow valleys. Streams do not have as much buffering capacity as ecoregions 67d or 67i and are subject to acidification. The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate. The Tuscarora Formation, Pocono Formation, Bald Eagle Formation, and Clinton Group predominate. Other less resistant rocks, such as shale and siltstone, may form the side slopes.

Inceptisols (Dystrochrepts) and Ultisols (Fragiudults) have commonly developed in the residuum; they vary significantly within a short distance as do rock type and elevation. Typically, however, the soils are poor and sandy (Cuff and others, 1989, p. 21). Dekalb, Laidig, Berks, Weikert, and Lehew soils are all common and slope angle, fertility, and stoniness are limitations.

Kuchler (1964) mapped the natural vegetation as mostly Appalachian Oak Forest (dominants: white and red oaks) in the north and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) in the south. Today, extensive forest covers this ecoregion.

Figure 1 shows the location of the sharp, wooded ridges and narrow, minor valleys of Ecoregion 67c. Ridge contour lines are straight and parallel, not crenulated like those of the Northern Dissected Ridges (67d).

67d. Northern Dissected Ridges

Ecoregion 67d is composed of broken, dissected, almost hummocky ridges. It is underlain by interbedded sedimentary rocks including siltstones.

Crestal elevations range from approximately 800 feet to 4,150 feet (244-1,265 m), and local relief varies from about 200 feet to 1,150 feet (61-351 m). Streams tend to be less acidic than those of Ecoregion 67c and to have storm hydrographs with more peaks.

Ecoregion 67d is often underlain by the Brallier, Hampshire, Lock Haven, Chemung, and Trimmers Rock formations and, in Maryland, the Chemung Group. They are Devonian in age and folded. The soils developed from this interbedded rock are mostly Inceptisols (Dystrochrepts). Dekalb, Berks, Weikert, and Lehew soils are common.

Kuchler (1964) mapped the natural vegetation as mostly Appalachian Oak Forest (dominants: white and red oaks) in the north and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) in the south. Today, forest covers most of this ecoregion, but there are also some pastures. Shale barrens occur on steep west and south facing slopes; they consist of stunted trees (including eastern red cedar (*Juniperus virginiana*), Virginia pine (*Pinus virginiana*), and chestnut oak (*Quercus prinus*)), thickets of shrubs (including hawthorn (*Crataegus uniflora*), Allegheny plum (*Prunus alleghaniensis*), huckleberry (*Gaylussacia baccata*)), and herbaceous vegetation (including mountain parsley (*Taenidia montana)*, moss pink (*Phlox subulata*), barrens ragwort (*Senecio antennariifolius*), birdfoot violet (*Viola pedata*) and Kate's mountain clover (*Trifolium virginicum*) (Cuff and others, 1989, p. 56; Erdman and Wiegman, 1974, pp. 71-74). The shale barren habitat type is one of the rarest in Pennsylvania and is found in Huntingdon, Fulton, and Bedford counties.

Figure 1 shows the location of the broken, dissected wooded ridges, knobs, and minor valleys of Ecoregion 67d. They are morphologically distinct from the sharp ridges and narrow valleys of the Northern Sandstone Ridges (67c).

67e. Anthracite

Ecoregion 67e in eastern Pennsylvania comprises an area that has been extensively disturbed by anthracite coal mining and urban-industrial development. Landforms, soils, and vegetation have all been indirectly or directly affected by mining operations and subsequent runoff. Streams tend to be very acidic and to have high amounts of turbidity (Biesecker and George, 1966, Plate 1; Kinney, 1964, p. 16; Dyer, 1982a; Herlihy and others, 1990, Table IV). Associated habitat destruction has occurred. Crestal elevations range from about 1,000 to 1,650 feet (305-503 m) and local relief ranges up to 600 feet (183 m).

Pennsylvanian sandstone, shale, siltstone, conglomerate, and anthracite coal underlie Ecoregion 67e. The Llewellyn Formation and the Pottsville Group are exposed. The soils are typically Entisols (Udorthents), Inceptisols (Dystrochrepts), and Ultisols (Fragiudults).

The natural forest was Appalachian Oak Forest (dominants: white and red oaks) with some Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock). Today cherry and birch are recolonizing some of the mined areas.

The boundaries of the Anthracite (67e) are shown in Figure 1 and enclose areas underlain by anthracite-bearing strata, Udorthents, and low woodland density.

67f. Southern Limestone/Dolomite Valleys and Low Rolling Hills

Ecoregion 67f is a lowland characterized by broad, undulating, fertile valleys that are extensively farmed. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolomite, and as a result, the drainage density is low. Where streams occur, they tend to have gentle gradients, plentiful year around flow, and distinctive fish assemblages. Crestal elevations vary from 1,640 to 3,200 feet (500-975 m). Local relief typically ranges from 150 to 500 feet (46-152 m).

Ordovician and Cambrian limestone and dolomite commonly underlie Ecoregion 67f. Interbedded with the carbonates are other rocks, including shale, which gives the ecoregion topographic and soil diversity. Mesic Alfisols and Ultisols have developed from the rock.

The climate of Ecoregion 67f is warmer than much of Ecoregion 67a which lies to the north and its growing season of 175 to 180 days is well suited for agriculture. Farming predominates, with scattered woodland occurring in steeper areas.

Figure 1 shows the boundaries of the Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f); base-rich soil, muted terrain, low drainage density, and limestone, dolomite, and calcareous shale bedrock are characteristic. Kuchler (1964) mapped a natural vegetation break near the boundary between ecoregions 67f and 67a; to the north in Ecoregion 67a grew Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) while to the south Appalachian Oak Forest was found.

67g. Southern Shale Valleys

Ecoregion 67g extends from the James River into Tennessee. It is characterized by rolling valleys and low hills and is underlain mostly by fine grained rock. Local relief varies from about 125 feet to 650 feet (38-198 m). The terrain is often more rugged than that of Ecoregion 67b. Woodland occurs on steeper sites and farming is common elsewhere.

The Brallier, Rome, Elbrook, Chemung, and Clinton formations commonly underlie Ecoregion 67g. They are folded and faulted, and are of Paleozoic age. The underlying rock is not as permeable as the limestone of Ecoregion 67, so surface streams are larger and drainage density is higher than in limestone areas. There is more soil erosion in Ecoregion 67g than in the Southern Limestone/ Dolomite Valleys and Low Rolling Hills (67f); stream turbidity can, therefore, be comparatively high and the riverine habitat relatively impaired.

Inceptisols and Ultisols have developed from residuum. Soils derived from acid shale commonly occur in Ecoregion 67g and are poorer than the soils of Ecoregion 67f, which were derived from limestone. However, within Ecoregion 67g there is considerable soil variability, and some soils are more calcareous than others.

Figure 1 shows the boundaries of the Southern Shale Valleys (67g); they enclose acidic to neutral valley and low hill soils that developed primarily on interbedded shales and siltstones. To the north, in Ecoregion 67b, grew Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) while, in Ecoregion 67g, Appalachian Oak Forest grew; bottomland forests also occurred.

67h. Southern Sandstone Ridges

Ecoregion 67h is composed of high, steep, forested ridges with narrow crests. Crestal elevations range from about 2,300 feet to 3,450 feet (701-1,052 m), and local relief ranges from approximately 500 to 1,500 feet (152-457 m). Most of the major ridges in Ecoregion 67 are found in ecoregions 67c and 67h. The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate. Other less resistant rocks, such as shale and siltstone, form the side slopes.

Inceptisols (Dystrochrepts) and Ultisols (Fragiudults) have commonly developed in the residuum; they vary significantly within a short distance, as do rock type and elevation. However, the soils are typically steep, stony, sandy, and low in fertility.

Kuchler (1964) mapped a natural vegetation break near the boundary between ecoregions 67h and 67c. To the north grew Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) and to the south, in Ecoregion 67h, grew Appalachian Oak Forest. Today, extensive forest covers Ecoregion 67h.

Figure 1 shows the location of the sharp, wooded ridges and narrow, minor valleys of Ecoregion 67h. Ridge contour lines are straight and parallel, not crenulated like those of the Southern Dissected Ridges and Knobs

(67i). Appalachian Oak Forest was characteristic of the ecoregion and was distinct from the Oak-Hickory-Pine Forest of the southern part of Ecoregion 67c.

67i. Southern Dissected Ridges and Knobs

Ecoregion 67i is composed of broken, dissected, almost hummocky ridges. It is morphologically distinct from the sharp ridges and narrow valleys of Ecoregion 67h and underlain by interbedded sedimentary rocks including siltstones. Crestal elevation ranges from approximately 2,100 feet to 4,150 feet (640-1,265 m), and local relief varies from about 150 feet to 800 feet (46-244 m). Streams tend to be less acidic than those of Ecoregion 67h and to have storm hydrographs with higher peaks.

Ecoregion 67i is often underlain by folded, mostly Devonian age sedimentary rocks; the Chemung Group and the Brallier Formation are common. The soils developed from this interbedded rock are mostly Inceptisols (Dystrochrepts) and Ultisols (Fragiudults); Berks, Laidig, and Wallen soils are common.

Figure 1 shows the location of the broken, dissected wooded ridges, knobs, and minor valleys of Ecoregion 67i. They are morphologically distinct from the sharp ridges and narrow valleys of the Southern Sandstone Ridges (67h). Appalachian Oak Forest (dominants: white and red oaks) was characteristic of the ecoregion and distinguish it from the southern part of Ecoregion 67d which was dominated by Oak-Hickory-Pine Forest (Kuchler, 1964). Today, forest covers most of this ecoregion, but there are also pastures.

69. Central Appalachians

Ecoregion 69 includes parts of south central Pennsylvania, eastern West Virginia, western Maryland, and southwestern Virginia. It is a high, dissected, and rugged plateau made up of sandstone, shale, conglomerate, and coal of Pennsylvanian and Mississippian age. The plateau is locally punctuated by a limestone valley and a few anticlinal ridges. Its soils have developed from residuum and are mostly frigid and mesic Ultisols and Inceptisols. Local relief varies from less than 50 feet (15 m) in mountain glades to over 1,950 feet (594 m) in watergaps where high-gradient streams are common. Crestal elevations generally increase towards the east and range from about 1,200 feet to 4,600 feet (366-1,402 m). Elevations can be high enough to insure a short growing season, a great amount of rainfall, and extensive forest cover. In lower, less rugged areas, more dairy and livestock farms occur, but they are still interspersed with woodland. The limestone of the Greenbrier River Valley supports permanent bluegrass pasture. Bituminous coal mines are common and associated stream siltation and acidification have occurred (Biesecker and George, 1966, Plate 1; Herlihy and others, 1990, Table IV; Kinney, 1964, pp. 15, 16, 24).

The boundaries of Ecoregion 69 are shown on Figure 1. Its eastern boundary with the folded and faulted strata of the Ridge and Valley (67) occurs along the sandstone escarpment known as the Allegheny Front or near the Greenbrier River or around the perimeter of Broad Top Mountain. Its western boundary with Ecoregion 70 occurs at the elevation and forest density break; the more densely forested Ecoregion 69 is higher, cooler, and steeper than the Western Allegheny Plateau (70) and is underlain by more resistant rock. Its northern border with the North Central Appalachians (62) is based on climate, forest density and land use; Ecoregion 69 has a less severe climate, less forest density, and a much lower oil well density than Ecoregion 62.

On the ecoregion map (Figure 1), the Central Appalachians (69) is composed of four level IV ecoregions: the Forested Hills and Mountains (69a), the Uplands and Valleys of Mixed Land Use (69b), the Greenbrier Karst (69c), and the Cumberland Mountains (69d). Descriptions of the individual characteristics of these four ecoregions follow.

69a. Forested Hills and Mountains

Ecoregion 69a occupies the highest and most rugged parts of Ecoregion 69 and is extensively forested. Its highly dissected hills, mountains, and ridges are steep sided and have narrow valleys. Crestal elevations are often 1,800 to 2,600 feet (549-793 m) and reach their maximum, about 4,600 feet (1,402 m), in West Virginia. Resistant sandstone and conglomerate of the Pennsylvanian Pottsville Group, sandstone of the Mississippian Pocono Formation, and sedimentary rocks of the Mississippian Mauch Chunk formations are commonly exposed at the surface and typically have a gentle dip. In some places, however, the strata have been gently folded into a series of northeasterly trending ridges that reach an elevation of 3,200 feet (975 m). These anticlinal ridges, Chestnut Ridge, Laurel Mountain, and Negro Mountain, form a transition between the relatively undeformed Western Allegheny Plateau (70) and the folded and faulted Ridge and Valley (67) (Ciolkosz and others, 1984, p. 9). Broad Top

Mountain, Pennsylvania is an outlier of the Forested Hills and Mountains (69a) that is surrounded by Ecoregion 67; its lithology and surface topography resemble Ecoregion 69a despite its geographical position (Guilday, 1985, p. 23). Local relief varies widely; on mountain bogs (glades), topography can be almost flat, whereas adjacent to watergaps, such as the Conemaugh River Gorge, local relief can exceed 1,300 feet (396 m). The eastern woodrat *(Neotoma flo*ridana), found on the cliff faces and boulder piles of water gaps, has been classified as threatened in Pennsylvania (Genoways, 1985, p. 362). Cool water, steep-gradient streams and waterfalls occur and have a less diverse fish population than those nearer the Ohio River. Characteristically, the streams of Ecoregion 69a do not have much buffering capacity and many reaches, including some not affected by mine drainage, are too acidic to support fish (R. Webb, Department of Environmental Sciences, University of Virginia, written communication, 1995).

Mean annual precipitation varies from about 38 to 60 inches (96-152 cm), while the average growing season is only 135-155 days (U.S. Department of Agriculture, 1972). The high, rugged topography has a heavy impact on the climate. The average annual temperatures of Ecoregion 69a can be more than 10°F (5°C) lower and the average rainfall can be from 20% to 100% higher than in the adjacent Ridge and Valley (67) (Williams and Fridley, 1938). Higher elevations get more precipitation and have a shorter growing season than lower elevations. Prevailing westerly winds bring substantial precipitation to the windward side of the mountains.

Most of the soils are frigid and mesic Ultisols (Hapludults, Fragiudults) and Inceptisols (Dystrochrepts, Fragiochrepts, Haplaquepts) that are acidic, steep, often stony, and low in nutrients. The relatively infertile soils, cool climate, short growing season, and ruggedness of Ecoregion 69a make the area particularly unsuited to agriculture. The original vegetation was mostly Appalachian Oak Forest (dominants: white and red oaks), Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock), and Mixed Mesophytic Forest. Scattered areas of northeastern spruce/fir forest occurred at especially high elevations (Cuff and others, 1989, p. 52; Kuchler, 1964). Today, extensive forests of hard maple, black cherry, birch, and red oak dominate many areas. Conifer belts can be found in the high and cool localities and are dominated by red spruce *(Picea rubens)* and hemlock *(Tsuga canadensis)* (Williams and Fridley, 1938). The white monkshood *(Aconitum reclinatum)* is found in moist mountain woods and adjacent floodplains of Somerset County, Pennsylvania, and is endangered in the state (Wiegman, 1985, p. 57). Glades, including Cranberry Glades northwest of Hillsboro, West Virginia, occur in highland bowls that trap cold air and have restricted water drainage; sphagnum moss, black spruce *(Picea mariana),* and tamarack *(Larix laricina)* grow here (Raitz and others, 1984, p. 70).

Gas wells and bituminous coal mines are locally common, and associated stream and land degradation occurs. Agriculture is usually restricted to livestock or dairy farming, but many fields are reverting to woodland or have been planted with Christmas trees.

The boundary between Ecoregion 69a and the Pittsburgh Low Plateau (70c) is determined primarily by land use, geology, and elevation and is shown on Figure 1; the more densely forested Ecoregion 69a is higher and steeper than Ecoregion 70c and is underlain by different, more resistant rock strata. Land use and rock type differentiate Ecoregion 69a from the Uplands and Valleys of Mixed Land Use (69b); the more densely forested Ecoregion 69a is underlain by sandstone and conglomerate of the Pennsylvanian Pottsville Group, sandstone of the Mississippian Pocono Formation, and sedimentary rocks of the Mississippian Mauch Chunk formations whereas Ecoregion 69b is composed of shale, siltstone, and sandstone of the Conemaugh Group. Land form and rock type separates Ecoregion 69a from the folded and faulted Ridge and Valley (67); often, the boundary follows the high sandstone escarpment of the Allegheny Front.

69b. Uplands and Valleys of Mixed Land Use

Ecoregion 69b is a dissected upland plateau characterized by a mosaic of woodland and agriculture; it includes a small outlier on Broad Top Mountain, Pennsylvania. Bituminous coal mines are numerous. The rounded hills and low ridges attain elevations of 1,375-2,800 feet (419-853 m), high enough to produce a rather short growing season of 135-165 days. Local relief ranges from less than 50 feet (15 m) in glades to about 1,000 feet (305 m).

Pennsylvanian shales, siltstones, sandstones, and coals of the Allegheny Group, and especially the Conemaugh Group, are extensively exposed and nearly horizontal. Soils of low to moderate fertility have weathered from this rock and are mostly mesic Ultisols (Hapludults, Fragiudults) and Inceptisols (Dystrochrepts).

The natural vegetation was primarily Appalachian Oak Forest (dominants: white and red oaks) and Mixed Mesophytic Forest (Cuff and others, 1989, p. 52; Kuchler, 1964). Scattered glades composed of sphagnum moss, black spruce *(Picea mariana),* and tamarack *(Larix laricina)* also occurred. Isolated remnants of the original vegetation can still be found and Markelysburg Bog, near Farmington, Pennsylvania, is the type locality of the

Allegheny glade gentian *(Gentian saponaris* var. *Allegheniensis)* (Erdman and Wiegman, 1974, pp. 25, 32). Today, about 60-70% of Ecoregion 69b is forested, in Christmas tree plantations or reverting to woodland. Dairy farming and livestock raising are the main agricultural pursuits.

Bituminous coal mines are common, and in some areas, such as Clearfield County, Pennsylvania, they affect more than 10% of the land surface (Hallowich, 1988). Associated stream siltation and acidification have occurred (Biesecker and George, 1966, Plate 1; Dyer, 1982b; Herlihy and others 1990, Table IV)

The boundary between ecoregions 69b and 70c is determined primarily by land use, geology, and elevation and is shown in Figure 1; the more densely forested Ecoregion 69b is higher, cooler, and steeper than Ecoregion 70c and is underlain by more resistant rock. Land use, elevation, and rock type differentiate ecoregions 69b from 69a; Ecoregion 69b, largely underlain by the Conemaugh Group, is lower and often less forested than Ecoregion 69a, which is underlain largely by the sandstone and conglomerate of the Pennsylvanian Pottsville Group, sandstone of the Mississippian Pocono Formation, and sedimentary rock of the Mississippian Mauch Chunk formations. The border between ecoregions 62d and 69b is based on forest density and land use; Ecoregion 69b has a lower forest density and a much lower oil well density than Ecoregion 62d.

69c. Greenbrier Karst

Ecoregion 69c is a rolling, agricultural lowland punctuated by isolated hills. Karst landscape is common, such as at Little Levels, and developed on limestone. Saucer-shaped sinkholes and underground solution channels occur; stream density therefore is low. Resultant subsurface drainage feeds the Greenbrier River, which has large amounts of year around, high-quality flow. Crestal elevations range from about 1,800 to 2,900 feet (549-884 m). Lower areas have an adequate growing season (up to 165 days) for pasture, small grain, and corn (Gorman, 1972). Valley bottoms are typically 150 to 650 feet (46-198 m) below hilltops. Where river incision occurs, however, local relief sometimes reaches 1,000 feet (305 m).

Ecoregion 69c is underlain mostly by limestones of the Greenbrier Formation. Other Mississippian strata also occur, however, including the Bluefield and Maccrady formations, and are composed primarily of limestone and shale. Deep, gently sloping and well-drained soils, which are moderately fertile to fertile, developed on the sedimentary rock. The soils are mostly Ultisols (Hapludults, Paleudults), Alfisols (Hapludalfs), and Inceptisols (Dystrochrepts). Frederick, Frankstown, Westmoreland, Litz, Gilpin, Calvin (often high-base substratum) soils are locally common.

Oak/hickory forest was originally common in Greenbrier Karst (69c) whereas Mixed Mesophytic Forest occurred in adjacent ecoregions (Raitz and others, 1984, p. 70). By 1938, only scattered woodland remained. Stands dominated by white oak *(Quercus alba),* red oak *(Quercus rubra),* and sugar maple *(Acer saccharum)* occurred only on the limestone soils of steeper slopes (Williams and Fridley, 1938). Elsewhere, such as on the Big Levels and the Little Levels, bluegrass pasture and hay crops predominate. These permanent pastures have remained excellent since they were cleared in the late-18th century and support beef cattle, sheep, poultry, and dairy farming. The Greenbrier Karst (69c) is among West Virginia's principal livestock producing areas (Raitz and others, 1984, p. 70).

The ecoregion boundary follows the break in topography, geology, land use, natural vegetation, and soil; karst topography, limestone bedrock, permanent pastures, original oak/hickory forest, and fertile, high base soils are characteristic of Ecoregion 69c and are absent from adjacent ecoregions (Figure 1).

69d. Cumberland Mountains

The Cumberland Mountains (69d) is a strongly dissected region with steep slopes, very narrow ridgetops, and extensive forests. It is primarily underlain by flat-lying Pennsylvanian sandstone, siltstone, shale, and coal of the Pottsville Group. Typically, crests range in elevation from 1,200 feet to about 3,600 feet (366-1,097 m) and are from 350 to 550 feet (107-168 m) above the narrow valleys. Well-drained soils of low to moderate fertility have developed on the sedimentary rocks. Clymer, Dekalb, and Jefferson soils are common and are Ultisols (Hapludults) and Inceptisols (Dystrochrepts) (Cunningham and Ciolkosz, 1984; U.S. Department of Agriculture, 1979). They originally supported mostly Mixed Mesophytic Forest (Kuchler, 1964). Today, commercial woodland is common in Ecoregion 69d and approximately 90% of the rugged ecoregion is forested or reverting to it (U.S. Department of Agriculture, 1979). Much of the remainder is mined for coal, and stream degradation has occurred (Dyer, 1982b; Herlihy and others, 1990, Table IV; Kinney, 1964, p. 24). In wider valleys, scattered towns and small-scale livestock farms are found.

The boundary between Ecoregion 69d and the Forested Hills and Mountains (69a) divides different fish assemblages and approximates the border between Land Resource Associations 125 and 127 (U.S. Department of Agriculture, 1979); it generally follows a topographic and elevational break with Ecoregion 69d more highly dissected and slightly lower than Ecoregion 69a. The boundary between Ecoregion 69d and the Ridge and Valley (67) approximates a major structural topographical, lithological, elevational, and land use break.

70. Western Allegheny Plateau

Ecoregion 70 is a mostly unglaciated, dissected plateau with 200 to 750 feet (61-229 m) of local relief and crestal elevations of less than 2,000 feet (610 m). The Western Allegheny Plateau (70) is composed of horizontally bedded sedimentary rock. Soils have developed from residuum and support a potential natural vegetation of Appalachian Oak Forest (dominants: white and red oaks) and, especially in the south, Mixed Mesophytic Forest (Kuchler, 1964).

The land use and land cover is a mosaic of forests, urban-suburban-industrial activity, general farms, dairy and livestock farms, pastures, coal mines, and oil-gas fields. Urban and industrial activity is common in valleys along the major rivers. Bituminous coal mining is widespread and has diminished water quality and reduced fish diversity; recent stream quality improvements have occurred in some rivers including the Allegheny, Monongahela, Youghiogheny, and Ohio (Cooper, 1985, p. 170).

The boundary of Ecoregion 70 with the less rugged, more agricultural Erie/Ontario Hills and Lake Plain (61) approximates the Wisconsinan till limit. Its boundary with the North Central Appalachians (62) approximates breaks in land use/land cover and elevation; Ecoregion 70 is less forested, warmer, and lower than Ecoregion 62. Its border with the Central Appalachians (69) approximates the break in elevation and forest density that occurs near the limit of the Pennsylvanian Allegheny Group (Figure 1); Ecoregion 70 is lower, warmer, less steep, and less densely forested than Ecoregion 69 and is underlain by less resistant rock.

On the ecoregion map (Figure 1), the Western Allegheny Plateau (70) is composed of three level IV ecoregions: the Permian Hills (70a), the Monongahela Transition Zone (70b), and the Pittsburgh Low Plateau (70c). Each is unglaciated, underlain by horizontal sedimentary rock, and mined for coal. Descriptions of the individual characteristics of these three ecoregions follow.

70a. Permian Hills

Ecoregion 70a is hilly. Elevations range from 575 to 1,600 feet (175-488 m) and local relief is 200-750 feet (61-229 m). Few flat areas occur and the ecoregion is generally more rugged, more forested, and cooler than the neighboring Monongahela Transition Zone (70b).

Soils are mostly Alfisols and Ultisols; the mix of soils is distinct from the Ultisols and Inceptisols that dominate Ecoregion 70c. Dormont, Culleoka, Newark, Gilpin, Upshur, and Vandalia soil series are locally common and support a natural vegetation of Appalachian Oak Forest (dominants: white and red oaks) or Mixed Mesophytic Forest (Kuchler, 1964). Soils were derived from shale, siltstone, limestone, sandstone, and coal; flat-lying, Permian Greene and Washington formations are found in Pennsylvania and the Permian/Pennsylvanian Dunkard Group occurs in West Virginia.

Today, forests remain common and most of the acreage is too steep to be farmed or is reverting to woodland. Nevertheless, there are some farms growing corn and hay on the ridges and some pastures on the hillslopes. Grazing and cultivation has caused slope erosion and upland top soil is often thin or absent (Guilday, 1985, p. 24). Bituminous coal mining and oil and gas production also occur. Coal mining and its environmental impacts are much more common in Ecoregion 70b than in Ecoregion 70a.

The boundaries of Ecoregion 70a are shown on Figure 1. Its border with the Monongahela Transition Zone (70b) generally follows geology, potential natural vegetation, and landuse. The Monongahela Group and the Waynesboro Formation are limited to Ecoregion 70b whereas the Greene and Washington formations and the Dunkard Group underlie Ecoregion 70a; coal mining is more common in Ecoregion 70b than in Ecoregion 70a. Appalachian Oak Forest is mapped as dominating Ecoregion 70a whereas Mixed Mesophytic Forest is typical of most parts of Ecoregion 70b (Kuchler, 1964). The boundary or the Permian Hills (70a) with the Pittsburgh Low Plateau (70c) is based on soils; the Alfisols of Ecoregion 70b are distinct from the Ultisols and Inceptisols of Ecoregion 70c.

70b. Monongahela Transition Zone

The unglaciated hills, knobs, and ridges of the Monongahela Transition Zone (70b) are typically underlain by interbedded limestone, shale, sandstone, and coal of the Monongahela Group (Berg and others, 1980; Cardwell and others, 1968). Entrenched rivers, gently dipping strata, and land slips occur. Elevations range from 575 to 1900 feet (175-580 m) and local relief is 200-700 feet (61-213 m). Soils are derived from residuum and are typically Alfisols; they are similar to those of Ecoregion 70a and have a higher base saturation than the Ultisols and Inceptisols of Ecoregion 70c. Guernsey, Dormont, Culleoka, Westmoreland, Clarksburg, and Neward soil series are common. The potential natural vegetation is mapped as mostly Mixed Mesophytic Forest while that of Ecoregion 70a is primarily Appalachian Oak Forest (dominants: white and red oaks) (Kuchler, 1964).

Today, forests are extensive and urban, suburban, and industrial activity are found in the river valleys that also serve as transportation corridors. Bituminous coal mining is common and some oil production occurs. There is also some general farming although it is less prevalent than in Ecoregion 70c.

Acid mine drainage, siltation, and industrial pollution have degraded stream habitat in Ecoregion 70b and have affectied fish and invertebrates. As a result, the eastern sand darter (Ammocrypta pellucida) was extirpated from the Ohio River drainage of Pennsylvania (Cooper, 1983, p. 189) and the obscure clubtail dragonfly (Progomphus obscurus) disappeared from the Allegheny River system (Opler, 1985, p. 138). Subsequent improvement of water quality has occurred and some species have reappeared upstream from Pittsburgh, including the smallmouth buffalo (Ictiobus bubalus) (Cooper, 1985, pp. 177-183).

The boundary between ecoregions 70b and 70c generally follows the geologic division between the limestone-bearing Monongahela Group and the noncarbonate Conemaugh Group. This line conforms to the break between the Ultisols and Inceptisols of Ecoregion 70c meet the base-saturated Alfisols of Ecoregion 70b (Cunningham and Ciolkosz, 1984). The boundary between ecoregions 70b and 70a in Pennsylvania generally conforms to the junction between the Permian Washington Formation and the Permian and Pennsylvanian Waynesboro Formation (Berg and others, 1980); in West Virginia, it conforms to the junction between the Dunkard Group and the Monongahela Formation (Cardwell and others, 1968).

70c. Pittsburgh Low Plateau

Ecoregion 70c is unglaciated and has rounded hills, narrow valleys, fluvial terraces, entrenched rivers, general farming, land slides, and bituminous coal mining. Its well-dissected landscape has a maximum local relief of 550 feet (168 m); the Pittsburgh Low Plateau (70c) is more rugged than the Low Lime Drift Plain (61c) but lacks the folded ridges of the Forested Hills and Mountains (69a). Hilltop elevations commonly range from 1,100 to 1,400 feet (366-396 m). Generally, Ecoregion 70c is both lower and less forested than either the Unglaciated Allegheny High Plateau (62d), the Forested Hills and Mountains (69a), or the Uplands and Valleys of Mixed Land Use (69b). The average annual growing season varies inversely with elevation and ranges from about 170 days in the southwest to 120 days in the northeast. Base-poor Ultisols are common. Gilpin, Ernest, Wharton, Hazleton, Weikert, Cavode, and Rayne soils occur and are derived primarily from Pennsylvanian sandstone, shale, and coal of the Conemaugh and Allegheny Groups. Entisols (Udorthents) are locally common and are byproducts of bituminous coal mining. The potential natural vegetation of Ecoregion 70c is mapped as mostly Appalachian Oak Forest (dominants: white and red oaks); some Mixed Mesophytic Forest also occurs in the south (Kuchler, 1964). Today, farming is more common than woodland. General farming and dairy operations predominate but are often handicapped by sloping terrain, soil wetness, low soil fertility, and a short growing season. There are oil wells in the west and gas fields in the east. Industry and population are concentrated in the Beaver, lower Allegheny, and Ohio valleys. Widespread coal mining has left some land barren or reverting to woodland. Other areas have been reclaimed and releveled but their soils are not always satisfactory for cultivation (Zarichansky and others, 1964, p. 88). Extensive acidic mine drainage and industrial pollution have degraded stream habitat and caused the loss of at least 16 fish species from the Ohio River drainage (Cooper, 1983, p. 5).

Ecoregion 70c's boundaries are shown on the enclosed map. Its western border with Ecoregion 61c generally follows the Wisconsinan ice limit; here, terrain, surficial deposits, natural vegetation, soils, and land use change markedly. The northeastern boundary with Ecoregion 62d is drawn at the break in elevation, forest density, and soils; the warmer Pittsburgh Low Plateau (70c) has lower elevations, less woodland density, and more base-poor Gilpin soils. The eastern boundary divides Ecoregion 70c from the more densely forested, higher, cooler, and steeper Central Appalachians (69) ecoregion which is underlain by more resistant rock. In Pennsylvania, its border with Ecoregion 70b generally follows the contact between the noncarbonate Glenshaw and Casselman formations of the Conemaugh Group and the limestone-bearing Monongahela Group (Berg and others, 1980); it approximates the juncture of the Ultisols and Inceptisols of Ecoregion 70c and the base-saturated Alfisols of Ecoregion 70b (Cunningham and Ciolkosz, 1984). In West Virginia, the ecoregion 70b-70c boundary is near the limit of the undivided Conemaugh Group (Cardwell and others, 1968) and roughly follows the Ultisol-Alfisol transition.

83. Eastern Great Lakes and Hudson Lowlands

This glaciated region of irregular plains bordered by hills generally contains less surface irregularity and more agricultural activity and population density than the adjacent Northeastern Highlands and Northern Appalachian Plateau and Uplands ecoregions. Although orchards, vineyards, and vegetable farming are important locally, a large percentage of the agriculture is associated with dairy operations. The portion of this ecoregion that is in close proximity to the Great Lakes experiences an increased growing season, more winter cloudiness, and greater snowfall.

On the ecoregion map (Figure 1), the Eastern Great Lakes and Hudson Lowlands (83) is composed of one level IV ecoregion, the Erie Lake Plain (83a) . Descriptions of the individual characteristics of this ecoregion follows.

83a. Erie Lake Plain

The narrow Erie Lake Plain (83a) is characterized by nearly level terrain, lacustrine deposits, a lake-modified climate, and distinctive crops. Inland from the Lake Erie shoreline at about 570 feet (174 m) elevation are gravelly beach ridges that mark the former shorelines of glacial lakes Warren and Whittlesey. Lacustrine deposits end at the highest late-Quaternary shoreline, approximately 790 feet (241 m). Local relief is typically less than 50 feet (15 m), but can be up to 100 feet (31 m) in the few northwesterly trending, steep-sided valleys. This entrenchment accompanied lake level reductions that occurred during the late-Pleistocene (Van Diver, 1990, p. 99).

Increased winter cloudiness and delayed coastal freezing are characteristics of Ecoregion 83a. Here, the growing season averages 194 days (Taylor, 1960) which is 3-10 weeks longer than anywhere else in the adjacent Low Lime Drift Plain (61c). Lake Erie's effect on climate is especially pronounced within 5 to 6 miles (8-10 km) of the coast and disappears entirely 8 to 16 miles (13-26 km) from the shoreline (Taylor, 1960).

The agricultural crops grown on the Erie Lake Plain are distinctive to Ecoregion 83a and are adjusted to its favorable climate. Grapes are the most valuable agricultural product (Pennsylvania Agricultural Statistics Service, 1990-1991). Early maturing vegetables, including asparagus, and fruit trees, including peach, apple, and cherry, are grown both on sandy soils and on the gravelly soils of beach ridges. Small fruits, including strawberries, and vegetables planted late in the spring are grown on the low-lying silty and clayey soils of the swales (Taylor, 1960).

The natural vegetation was largely Beech-Maple Forest; some chestnut (*Castanea dentata)* grew on gravelly soils (Hicks, 1934). Shoreline vegetation also occurred and is best preserved on the sandy beaches, dunes, and flats of Presque Isle, which shelters Erie harbor. Here grows vegetation such as sea rocket *(Cakile edentula)*, beach grass *(Ammophilia breviligulata), bluestem (Andropogon gerardi),* and Virginia pine *(Pinus virginiana)* (Cuff and others, 1989, p. 56).

The Erie Lake Plain (83a) contains habitat that is rare or even unique in Pennsylvania. Presque Isle alone “has by far the largest concentration of periphery-of-range and disjunct populations ... in Pennsylvania (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995);" thirty-five state rare species occur here (Cuff and others, 1989, p. 56). In addition, its lake shore bluffs that are composed of "landslide-prone drift and lacustrine deposits have unusual flora (R. Latham, Department of Geology, University of Pennsylvania, written communication, 1995)." The threatened least bittern *(Ixobrychus exilis exilis)* and regal fritillary *(Speyeria idalia)* are found, respectively, in marshes and low wet meadows (Gill, 1985, p. 308; Opler, 1985, p. 85).

The boundary between Ecoregion 83a and the Low Lime Drift Plain (61c) follows the 790 foot contour, the highest late-Quaternary shoreline; to the north of this line, lacustrine deposits begin, natural vegetation changes, and the climate moderates.

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