AN OVERVIEW OF WETLANDS AND WATER RESOURCES OF MARYLAND

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prepared for

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Introduction

This document has been prepared by the Department of the Environment for the Maryland Wetland Conservation Plan Work Group. It is intended to provide a brief overview of wetlands in Maryland: their current acreage, characteristics, and how they differ across the State. The document contains a summary of wetlands distribution by county and major watershed, a general description of wetlands in various regions, and a discussion of related water resources that support wetlands. A briefing document on wetland function will be prepared for future discussion by the Work Group.

For more detailed information about, the publication Wetlands of Maryland (Tiner and Burke, 1995), was prepared by the U.S. Department of the Interior, Fish and Wildlife Service and the Maryland Department of Natural Resources. The publication provides a comprehensive summary of the current status of wetlands in Maryland, including detailed information regarding wetland classification, mapping, physical condition, values, and current protection and regulation of wetlands throughout the State.

General Description

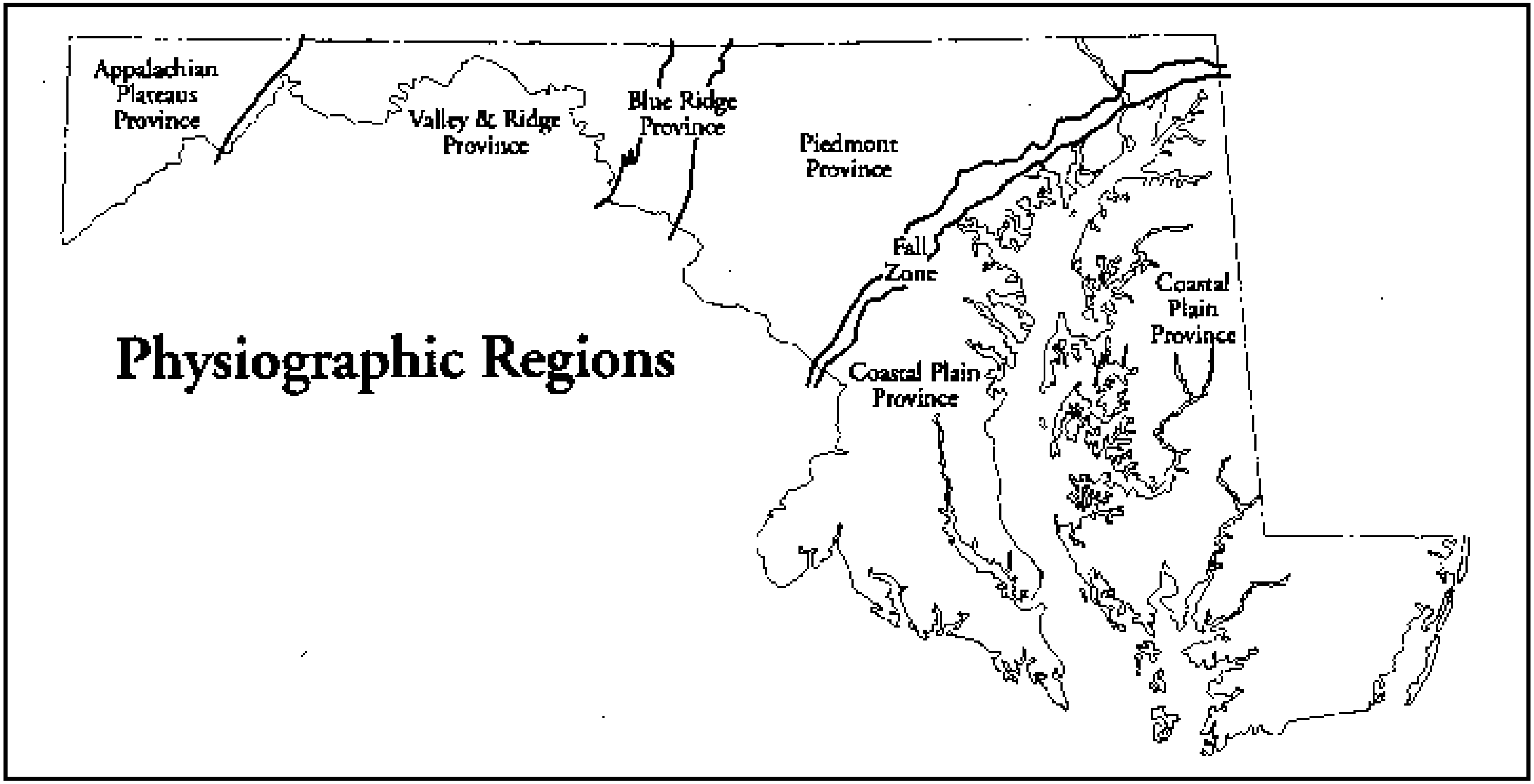
In total surface area, Maryland is the eighth smallest state in the nation. The State comprises 23 counties, the two largest being Frederick and Garrett Counties and the two smallest being Calvert and Howard Counties. Baltimore is an independent city occupying 80 square miles (Tiner and Burke, 1995). Maryland contains portions of two major U.S. ecoregions; the eastern portion of the state, roughly from Baltimore and Montgomery Counties east, falls within the Southeastern Mixed Forest, while the western section of the state is in the Appalachian Oak Forest (Bailey, 1978). Maryland also includes the majority of the Chesapeake Bay, which has a dominant influence on the region's climate, biological resources, and economy (Tiner and Burke, 1995).

The climate regime is quite variable throughout Maryland. The eastern part of the State is much warmer than the western part, with annual temperatures averaging around 56 degrees F in the east and 48 degrees F in Garrett County (Owenby et al., 1992). January is the coldest month and averages about 27 degrees F in Garrett County and 34 degrees F in the Bay area. July brings the warmest temperatures, averaging 77 degrees F in the east and 68 degrees F in Garrett County. Annual average precipitation ranges from a high of about 46 inches in the western part of Garrett County to a low of 38.5 inches in the eastern part of Garrett County and the western portion of Cumberland County. Annual precipitation in the Bay area averages about 44 inches. Monthly precipitation ranges from about 3 to 5 inches across the state. Eastern regions have highest precipitation in July and August, while western regions have highest precipitation during the period of May through August (Tiner and Burke, 1995).

Maryland's 9,837 square miles of land area lie in five distinct physiographic provinces, making it one of the most geologically and hydrologically diverse states in the northeastern United States. The five physiographic provinces, from east to west, include: the Coastal Plain, the Piedmont, the Blue Ridge, the Valley and Ridge and the Appalachian Plateau **(Figure 1)**.

The topography of Maryland is highly variable; the land surface elevation increases gradually from the Atlantic Ocean across the Coastal Plain, then increases rapidly over the Piedmont Province and the ridges of the Appalachian Plateau, culminating in the highlands of the Allegheny Plateau in Garret County. The boundary between the Piedmont and Coastal Plain Provinces is commonly known as the 'Fall Line', because of the dense concentration of falls throughout the area, and is characterized by rapid changes in geologic, topographic and hydrologic features.

Figure 1. Distribution of the five physiographic provinces of Maryland: Appalachian Plateau Province, Valley and Ridge Province, Blue Ridge Province, Piedmont Province and Coastal Plain Province. (from Tiner and Burke, 1995)



Wetlands of Maryland

Definition of Wetlands

As summarized in Wetlands of Maryland (Tiner and Burke, 1995), wetlands are areas that hold water for significant periods during the year and are characterized by anaerobic (low oxygen) conditions favoring the growth of specific plant species and the formation of specific soil types. The U.S. Fish and Wildlife Service developed a scientifically-based definition of the Nation's wetlands for resource management purposes and to help ensure accurate and consistent wetland determinations. This definition emphasizes three key attributes of wetlands: 1) hydrology – the degree of flooding or soil saturation, 2) wetland vegetation (hydrophytes), and 3) hydric soils. This further defines wetlands as all areas having enough water at some time during the year to stress plants and animals not adapted for life in water or saturated soils.

Wetlands may be permanently flooded by shallow water, permanently saturated by groundwater, or periodically inundated or saturated for varying periods during the growing season in most years. Many wetlands are the periodically flooded lands that occur between uplands and salt or fresh waterbodies (ie., lakes, rivers, streams and estuaries). Other wetlands may be isolated in areas with seasonally high water tables that are surrounded by upland or occur on slopes where they are associated with groundwater seepage areas or drainageways. Wetlands are important natural resources providing numerous values to society, including fish and wildlife habitat, flood protection, erosion control and water quality preservation. Wetlands comprise a range of environments within interior and coastal regions of Maryland **(Figure 2)**.

For more information about wetlands, follow these links to the EPA Wetlands website:

Wetland Types: **http://www.epa.gov/students/americas_wetlands.htm**

Wetlands in America: **http://www.epa.gov/students/americas_wetlands.htm**

Overview of Wetland Surveys

Several surveys of wetland acreage have been done in Maryland since the early 1900s. Survey methods and wetland definitions have varied over the years, making an estimate of wetland trends nearly impossible. The most recent statewide estimate is from the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI), using high altitude aerial photography. Wetland maps for Maryland were created during the early to mid 1980's at a scale of 1 inch = 2000 feet based on NWI data. According to the National Wetlands Inventory survey (1995), Maryland possesses roughly 600,000 acres of vegetated wetlands. About 9.5 percent of the state's land surface is covered by wetlands (NWI, 1995). Nearly 99.3% of the State's wetlands are two main types, estuarine and palustrine. The most abundant type is palustrine or freshwater wetlands, representing 57.3% of the State's total wetlands, equivalent to 342,626 acres. Palustrine wetlands may be either tidal or nontidal. Most palustrine wetlands - 88.7% - are nontidal wetlands. Estuarine wetlands (salt and brackish wetlands) represent 42 percent of the State's total wetlands, equivalent to 251,542 acres.

Digital orthophoto quarter quadrangle (DOQQ) maps (scale of 1 inch = 600 feet) are available for parts of the State and are produced by the Department of Natural Resources. DOQQ maps have been completed for Carroll, Frederick, St. Mary's, Queen Anne's, Worcester, Wicomico, and Somerset Counties. Portions of Prince George's, Charles, Anne Arundel, Calvert, Howard, and Harford Counties are also complete. Montgomery County mapping is in progress. DOQQ maps are generally more accurate than National Wetland Inventory (NWI) maps.

Vegetated tidal wetlands are also mapped by the State. State maps have been used since 1972 to identify the regulatory boundaries of wetlands under the jurisdiction of the Maryland Tidal Wetlands Act. Maps, at a scale of 1 inch =200 feet, are considered more accurate than both the State DOQQ maps and the NWI maps. According to the state maps, there are approximately 200,000 acres of vegetated tidal wetlands. Tidal wetlands include both fresh and brackish systems, with emergent, shrub, and forested vegetation. More recent aerial photographs, from the 1980's and 1990's, are used for guidance purposes.

Distribution of Wetlands by County

About 10 percent of the state is classified as wetland. Wetlands are most abundant on the Eastern Shore of the Coastal Plain, occupying 16 percent of the land area. **Figure 3** gives an overview of the distribution of Maryland's wetlands acreage by county and Table 1 summarizes the total acreage and percent acreage in each county, by wetland type. The counties with the most wetlands acreage in the State are Dorchester County, with 28.3 percent, and Somerset County, with 13.6 percent. Baltimore City, a substantially urbanized area, has the least wetland acreage with 0.04 percent. Of the coastal wetlands of Maryland, more than one third (36.4%) are located in Dorchester County and more than one quarter (26.0%) are located in Somerset County (McCormick and Somes, 1982).

Table 1. Wetland acreage for each county in Maryland as of 1981/1982, including wetland type, total wetland acreage and total percent of state. Totals have been rounded off to the nearest acre. (after Tiner and Burke, 1995)

Note: Acreages of palustrine wetlands may be conservative, especially for Eastern Shore Counties where temporarily flooded and seasonally saturated wetlands are difficult to identify.

County	Estuarine Wetland Acreage	Palustrine Wetland Acreage	Riverine, Lacustrine, Marine Wetland Acreage	1981-1982 Total Acreage	Total Percent of the State
Allegany	--	612	5	617	0.10
Anne Arundel	2,774	13,202	180	16,156	2.7
Baltimore City	64	155	31	250	0.04
Baltimore County	2,491	3,384	367	6,242	1.0
Calvert	3,630	7,077	--	10,707	1.8
Caroline	2,121	28,027	366	30,514	5.1
Carroll	--	4,229	562	4,791	0.80
Cecil	2,184	6,646	188	9,018	1.5
Charles	4,909	21,755	22	26,686	4.5
Dorchester	100,529	68,259	380	169,168	28.3
Frederick	--	7,243	82	7,325	1.2
Garrett	--	7,068	14	7,082	1.2
Harford	6,649	5,863	15	12,527	2.1
Howard	--	2,977	140	3,117	0.50
Kent	3,706	11,570	37	15,313	2.6
Montgomery	--	9,566	133	9,699	1.6
Prince Georges	2,019	17,309	188	19,516	3.3
Queen Annes	8,453	24,040	18	32,511	5.4
St. Mary’s	6,600	9,671	25	16,296	2.7
Somerset	62,408	19,155	--	81,563	13.6
Talbot	9,781	9,993	193	19,967	3.3
Washington	--	2,101	9	2,110	0.40
Wicomico	14,277	23,141	343	37,761	6.3
Worcester	18,954	39,603	929	59,486	9.9

Distribution of Wetlands by Watershed

As part of the National Wetland Inventory (NWI), U.S. Geological Survey hydrologic units (U.S.G.S, 1974) were used to determine the total acreage of wetlands throughout the State. This system defines 23 major watersheds in Maryland and names them based on the major rivers draining each geographical area (Tiner and Burke, 1995). This information is illustrated in **Figure 4** and total wetland acreage for each watershed is summarized in Table 2.

Table 2. Total wetland acreage in Maryland, by watershed, as defined by U.S. Geological Survey hydrologic units (U.S.G.S, 1974). Data presented are from National Wetland Inventory (NWI) maps and do not include acreage of the narrow streams and wetlands mapped as linear features or wetland and waterways too small to depict on NWI maps. (after Tiner and Burke, 1995)

U.S.G.S. Hydrologic Unit	Watershed	Total Wetland Acreage
2040205	Christina*	75
2050306	Susquehanna	1,079
2060001	Chesapeake Bay Shoreline	31,001
2060002	Chester, Sassafras, Elk,Wye and Miles	50,480
2060003	Patapsco, Gunpowder and Bush	20,593
2060004	Severn and Magothy	11,807
2060005	Choptank	85,655
2060006	Patuxent	33,972
2060007	Blackwater, Transquaking and Chicamacomico	118,537
2060008	Naticoke	46,651
2060009	Pocomoke	99,458
2060010	Chincoteague Bay	24,811
2070002		1,577

2070003	Savage, Wills and North Branch Potomac	206
2070004	Town Creek, North Branch Potomac, Fifteen Mile Creek, Cacapon and Sideling Hill Creek	1,875
2070008	Antietam, Conocoheague and Licking Creek	8,749
2070009	Catoctin and Seneca	8,390
2070010	Monocacy	7,032
5020006	Anacostia, Rock Creek, Mattawoman Creek, Piscataway Creek, Port Tobacco Creek, Pain Brush and Indian Creek	5,964
2070011	Youghiogheny and Casselman	40,134
	Wicomico, St. Mary’s and Lower Potomac	

* The majority of the Christina watershed lies in south-central Pennsylvania and only a small portion is located within the state of Maryland.

Based on the State designation, the twenty major watersheds of Maryland are illustrated in **Figure 5**. Many of these watersheds correspond with the U.S.G.S. hydrologic unit designations with a few exceptions where smaller watersheds have been combined. Like the U.S.G.S designations, the Maryland designations are named after the primary river drainage(s) within the geographical area.

Coastal-Tidal Wetlands

As shown in Table 3, 66.4 percent of the coastal wetlands in Maryland are located in the Pokomoke and Nanticoke River Basins (both part of the Lower Eastern Shore watershed) and the Choptank River Basin on the Eastern Shore.

Table 3. Total acreage and percent acreage of coastal wetlands in the major watersheds of Maryland. (after McCormick and Somes, 1982)

Sub-Basin Designation	Watershed	Acres	Percentage of Total Acreage
02-12-02	Lower Susquehanna River	841	0.3
02-13-01	Coastal Area	17,225	6.6
02-13-02	Pocomoke River	53,246	20.4
02-13-03	Nanticoke River	83,409	31.9
02-13-04	Choptank River	36,877	14.1
02-13-05	Chester River	16,204	6.2
02-13-06	Elk River	3,848	1.5
02-13-07	Bush River	5,992	2.3
02-13-08	Gunpowder River	2,599	1.0
02-13-09	Patapsco River	819	0.3
02-13-10	West Chesapeake River	3,419	1.3
02-13-11	Patuxent River	6,773	2.6
02-13-99	Chesapeake Bay	21,321	8.2
02-14-01	Lower Potomac River	8,438	3.2
02-14-02	Washington Metropolitan Area	298	0.1
	Total	**261,309**	**100.0**

Tidal wetlands are abundant on the lower Eastern Shore of the Coastal Plain and cover extensive areas **Figure 6**. Tidal wetlands are distinguished by their flood regime: wetlands flooded at least once per day are considered “low marsh” and those flooded less than once per day are considered “high marsh.” High marshes are typically flooded by high spring or storm tides. During the current post-glacial period, the gradual rise of sea level has resulted in the conversion of vegetated tidal wetlands to open water areas, and the conversion of forested nontidal wetlands to tidal marsh. Sea level rise has also inundated 16,721 acres of estuarine forested wetlands, equivalent to 6.7 percent of Maryland’s total estuarine wetlands acreage.

Eighty-two percent, 205,815 acres, of estuarine wetlands are emergent, thus making it the most common estuarine wetland type. Non-vegetated estuarine wetlands include 10.5 percent of the total acreage of estuarine wetlands. These coastal wetlands are extremely important to the Chesapeake Bay ecosystem and the economy of Maryland **(Figure 7)**.

The following is a summary the predominant type(s) of wetland in each watershed. The Upper Eastern Shore (including the Chester and Elk River basins) contains mostly freshwater marshes but also some brackish high marshes. The Lower Eastern Shore (including the Nanticoke and Pokomoke River basins) contains a good amount of brackish high and low marshes, and submerged aquatic wetlands. The Choptank watershed contains mostly brackish high marshes and submerged aquatic wetlands. The Upper Western Shore (including the Bush, Gunpowder and Lower Susquehanna River Basins) and Patapsco watersheds predominately contain freshwater marshes. The Lower Western Shore, or West Chesapeake, watershed contains brackish high marshes and submerged aquatic wetlands. The Patuxent watershed contains almost equal proportions of freshwater marsh and brackish high marshes. The Lower Potomac contains mostly brackish high marshes. The Middle Potomac or Washington-Metro watershed contains mostly brackish high marshes, but also contains the highest percent of coastal wooded swamps in the state (26.8%). There are no coastal wetlands in the Upper Potomac watershed.

Nontidal Wetlands

Generally, the Eastern Shore nontidal wetlands are characteristically low and flat. These nontidal wetlands are often difficult to identify and delineate due to the minor variations in regional topography and the similarity of wetland vegetation to vegetation found in surrounding uplands. On the Lower Eastern Shore, the wetlands may cover broad areas. Predominantly clay rich soils, which have slow drainage and form confining layers, help to retain ground water in these wetlands. Landscapes on the Upper Eastern Shore have steeper grades, and wetlands tend to be less extensive and have better drainage. Caroline, Kent, and Queen Anne's Counties have the most abundant numbers of a unique wetland type commonly called a Delmarva Bay. These wetlands are usually isolated from surface water drainage systems and are elliptical in shape with sandy rims. Rare plant species are often found in these wetlands on the Eastern Shore including Bald cypress and Atlantic white cedar swamps.

On the Western Shore of the Coastal Plain, wetlands have more varied topography and are generally easier to delineate in comparison to wetlands on the Eastern Shore. These wetlands are often located near streams, although the prevalence of long-term overbank flooding is rare in these areas. Most Western Shore wetlands are supported by a localized, perched water table than by shallow groundwater.

Nontidal Wetlands of Special State Concern

Nontidal wetlands of Special State Concern are the best example of Maryland's nontidal wetland habitats and are designated for special protection under the State's nontidal wetland regulations. These 365 wetland sites have exceptional ecological and educational value and offer landowners opportunities to observe and safeguard the beauty and natural diversity of Maryland's best remaining wetlands. Many of these special wetlands contain populations of rare and endangered native plants and animals. Other nontidal wetlands of Special State concern represent examples of unique wetland types and collective habitats for species that thrive in specialized environments.

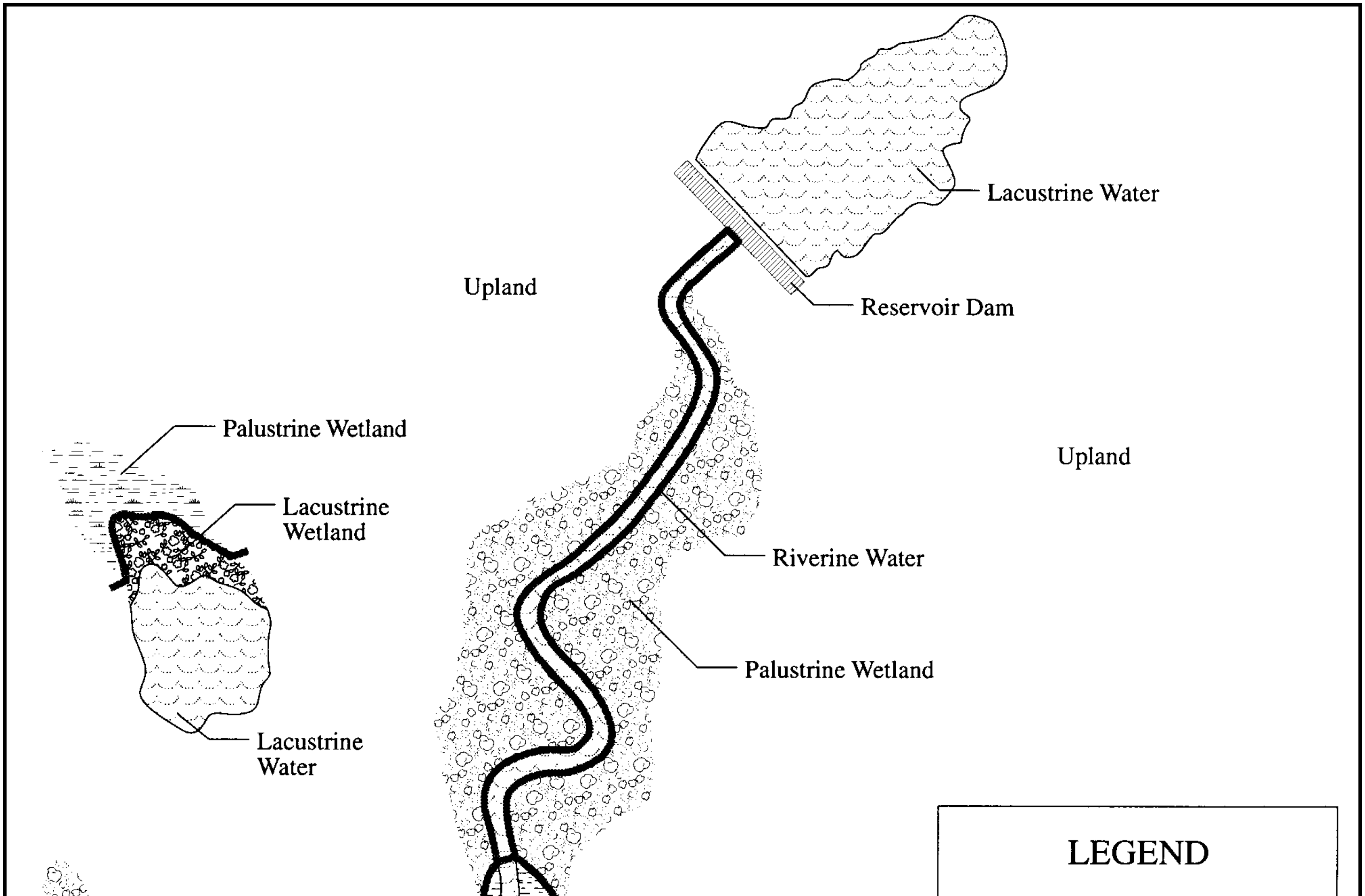
Examples of these special types of wetlands are bogs, Delmarva bays and coniferous swamp forests. Bogs are highly acidic wetlands that lack the nutrients most common plants require and, therefore, provide habitat for specific communities of plants and animals. The Delmarva bays are depressions on the Eastern Shore that fill with water in the winter and spring, and dry in the late summer and fall. Because these environments are self-contained, they support many rare and unique species. Coniferous swamp forests are uncommon to Maryland and found in areas such as Garrett County.

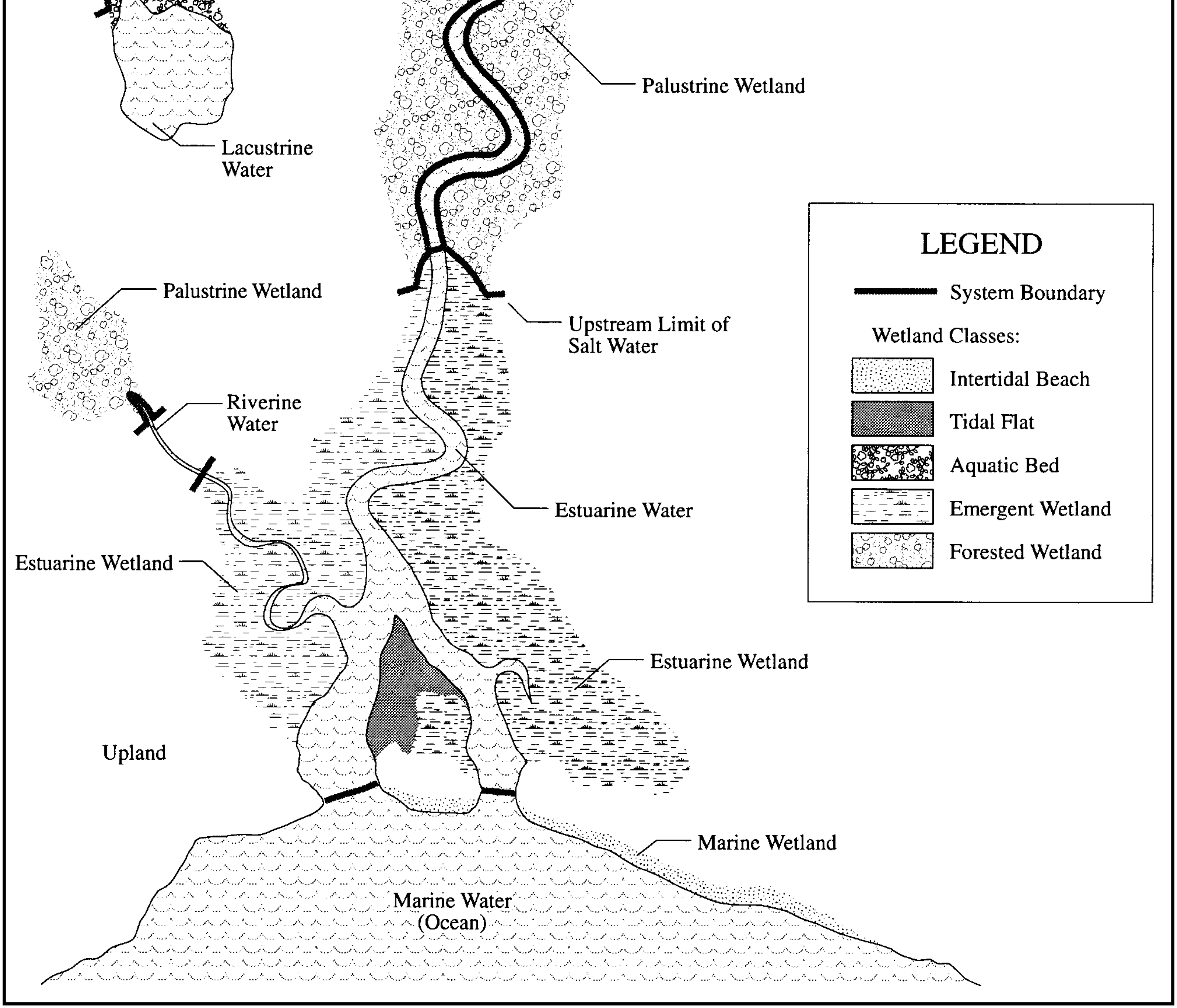
Wetlands Conservation

Although Maryland has lost 45-65 percent of its original wetlands, many of which were drained for agricultural purposes, wetlands remain quite abundant. Increased Federal and State efforts in wetland restoration may eventually help achieve a net gain in wetlands, provided wetland regulatory programs maintain effective control of existing wetland resources (Tiner and Burke, 1995). Government regulatory programs have improved wetland conservation by providing for better protection of wetlands than at anytime before. As populations expand, there will be increased demand for development of commercial, resort, and residential real estate that will undoubtedly place additional pressure on remaining wetlands. To date, the public has supported wetland protection efforts, by recognizing the important water quality, flood storage, wildlife habitat, and other functions that wetlands perform. It is likely this trend of government and public support will continue (Tiner and Burke, 1995).

In addition, wetlands can be negatively impacted by water quality problems throughout the State. Although control of point sources of water pollution, such as industrial effluents and municipal wastewater treatment plants, is improving the quality of many of Maryland's waterways, urban and agricultural runoff continue to degrade water quality. Improved techniques for storm water discharge treatment, riparian habitat management (e.g. streamside fencing) and employment of best management practices on farmland and managed forests, may further enhance water and wetland quality (Tiner and Burke, 1995).

Figure 2. A diagrammatic illustration of the predominant wetland classes that may be present in a continuum of lacustrine, riverine, palustrine, estuarine and marine environments of Maryland. (from Tiner and Burke, 1995)




Palustrine Wetland
Lacustrine Water
LEGEND
System Boundary
Wetland Classes:
Intertidal Beach
Tidal Flat
Aquatic Bed
Emergent Wetland
Forested Wetland
Palustrine Wetland
Upstream Limit of Salt Water
Riverine Water
Estuarine Water
Estuarine Wetland
Estuarine Wetland
Upland
Marine Wetland
Marine Water (Ocean)

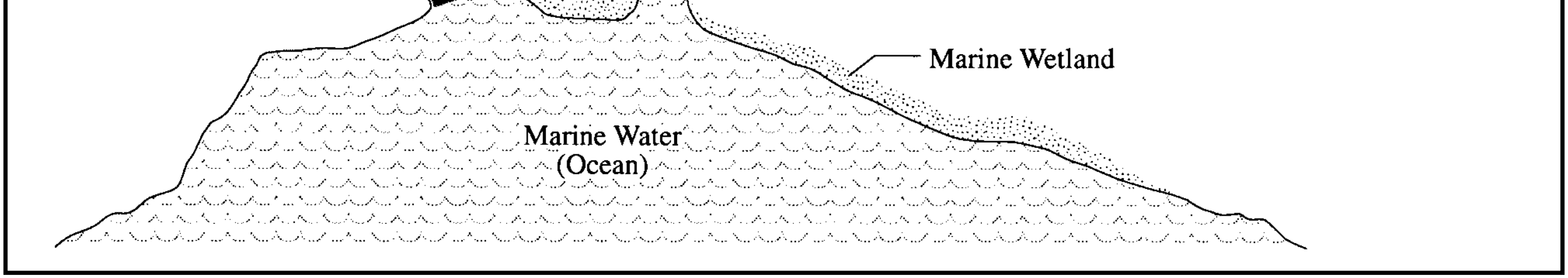

Marine Wetland
Marine Water
(Ocean)

Figure 3. Distribution of Maryland's wetlands by percent total acreage for each county. (from Tiner and Burke, 1995)

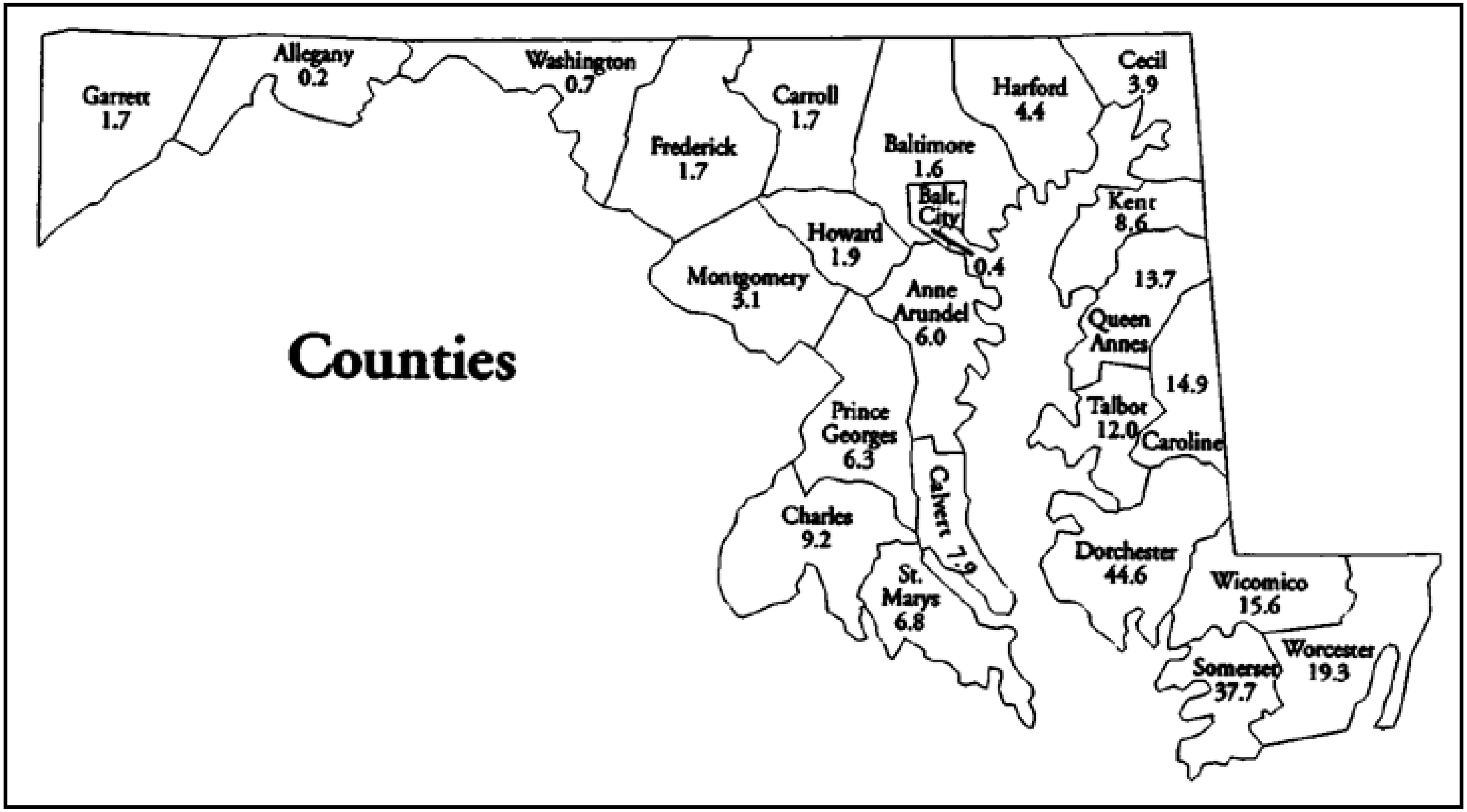


Figure 4. Distribution of the 23 major watersheds of Maryland based on the U.S. Geological Survey hydrologic units. (from U.S.G.S, 1974)

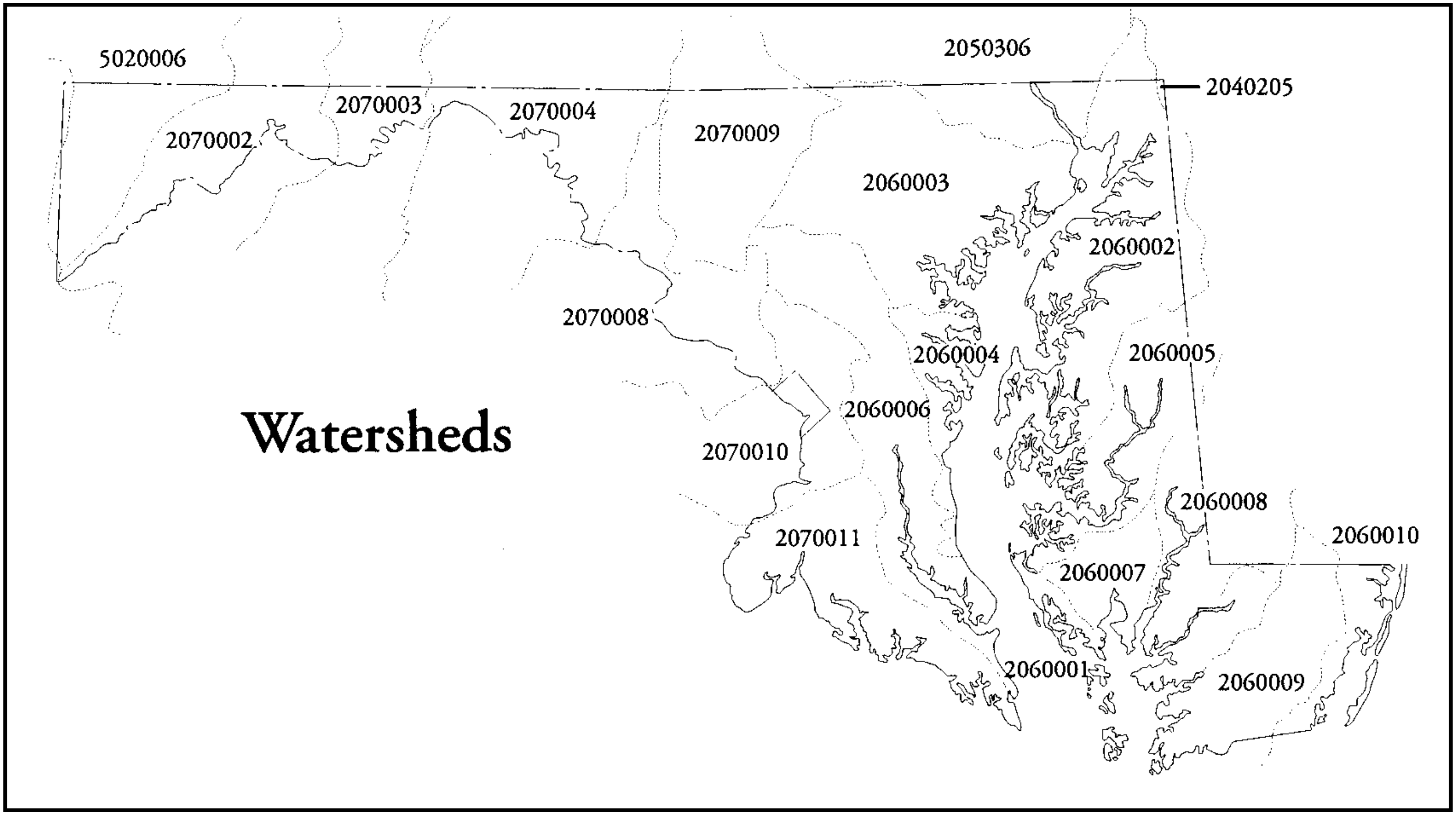
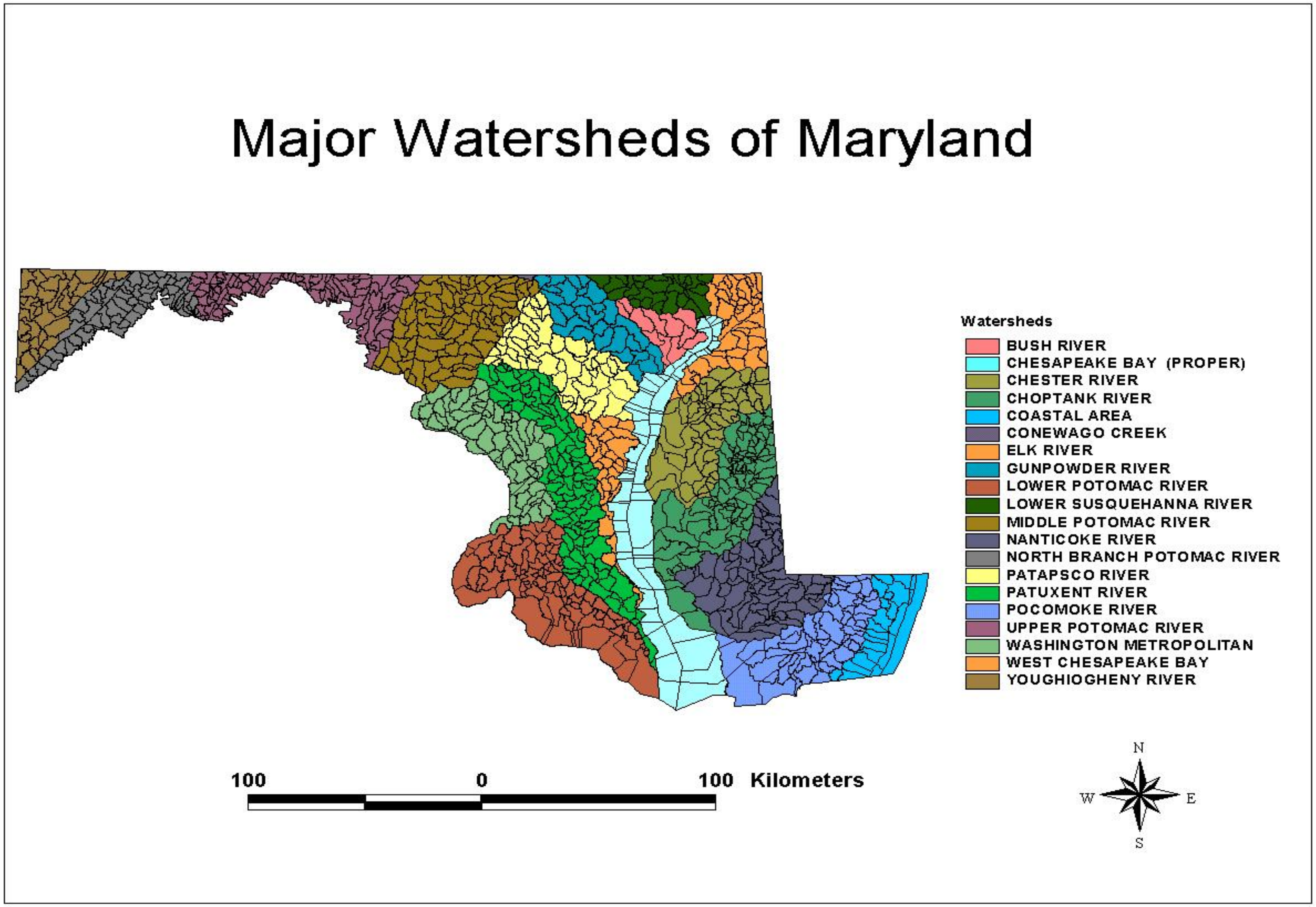


Figure 5. Major watersheds of Maryland based on the State designations (6-digit).



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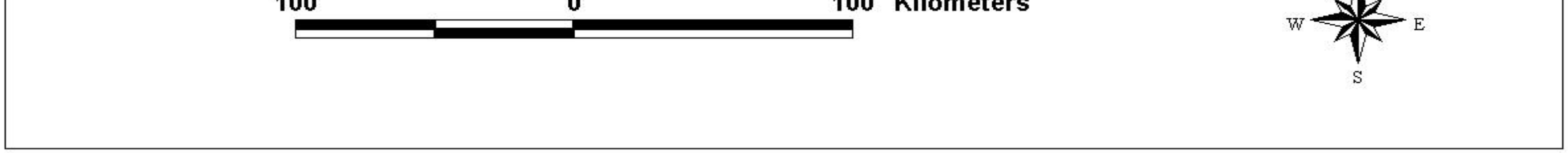
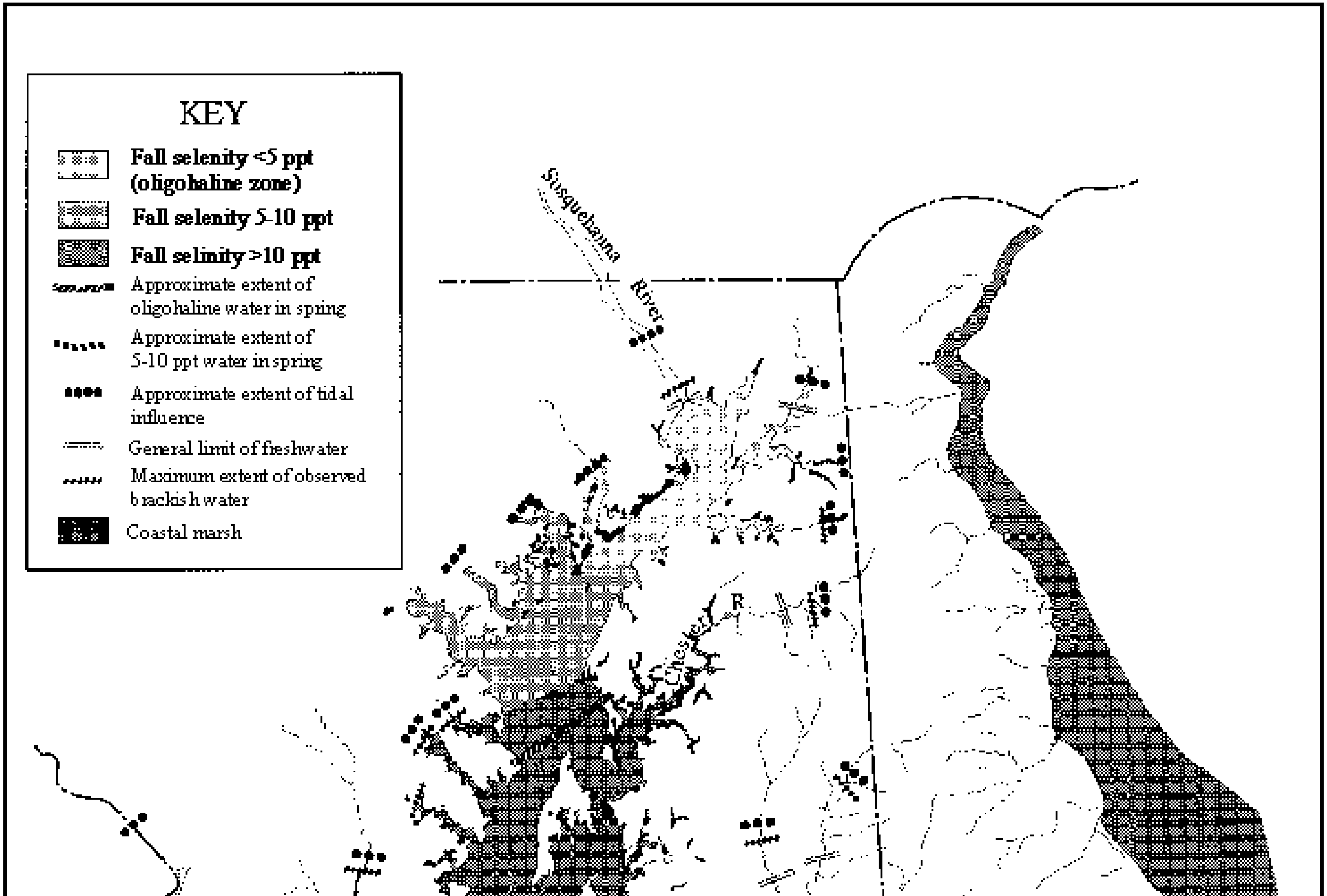
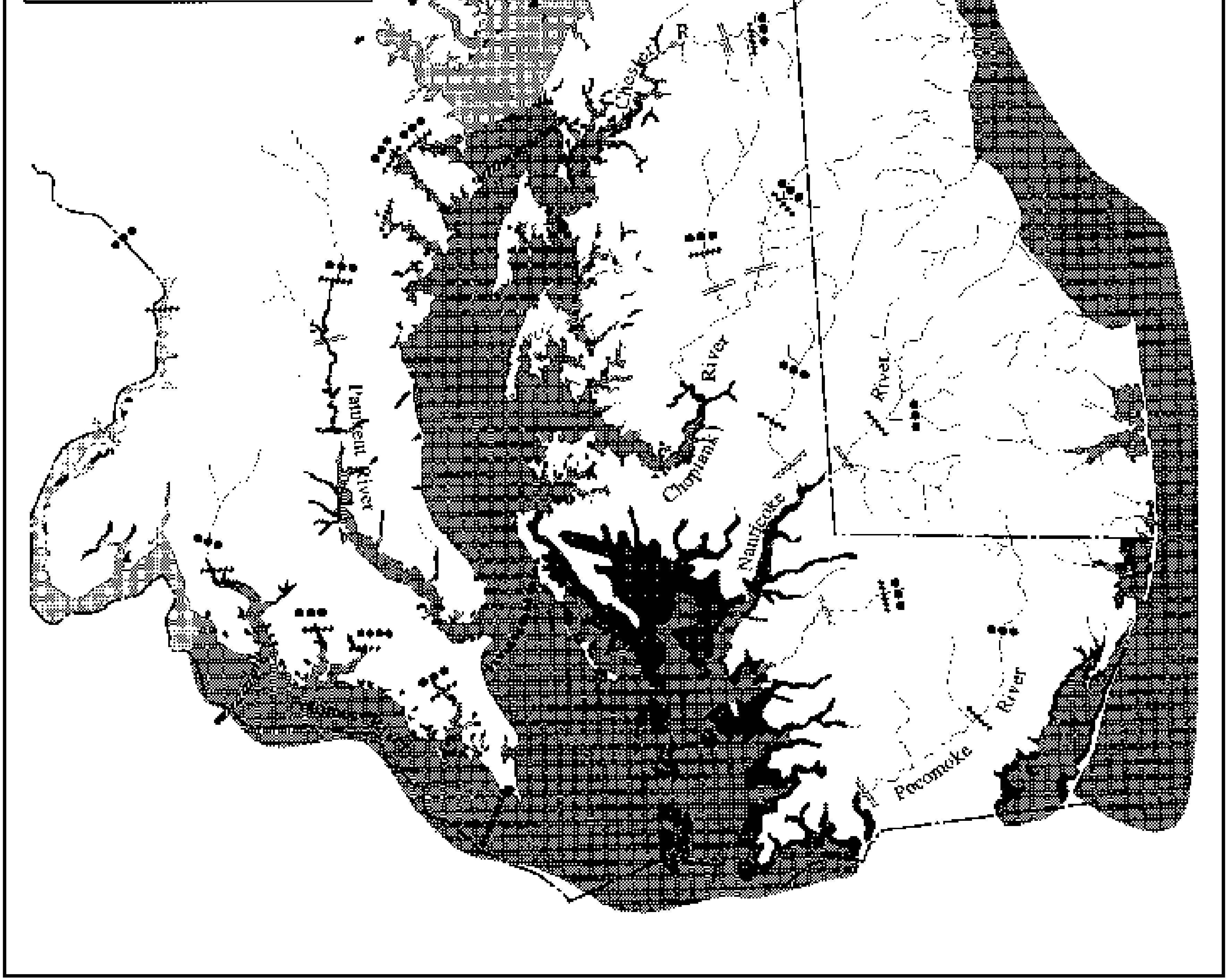


Figure 5. Major watersheds of Maryland based on the State designations.

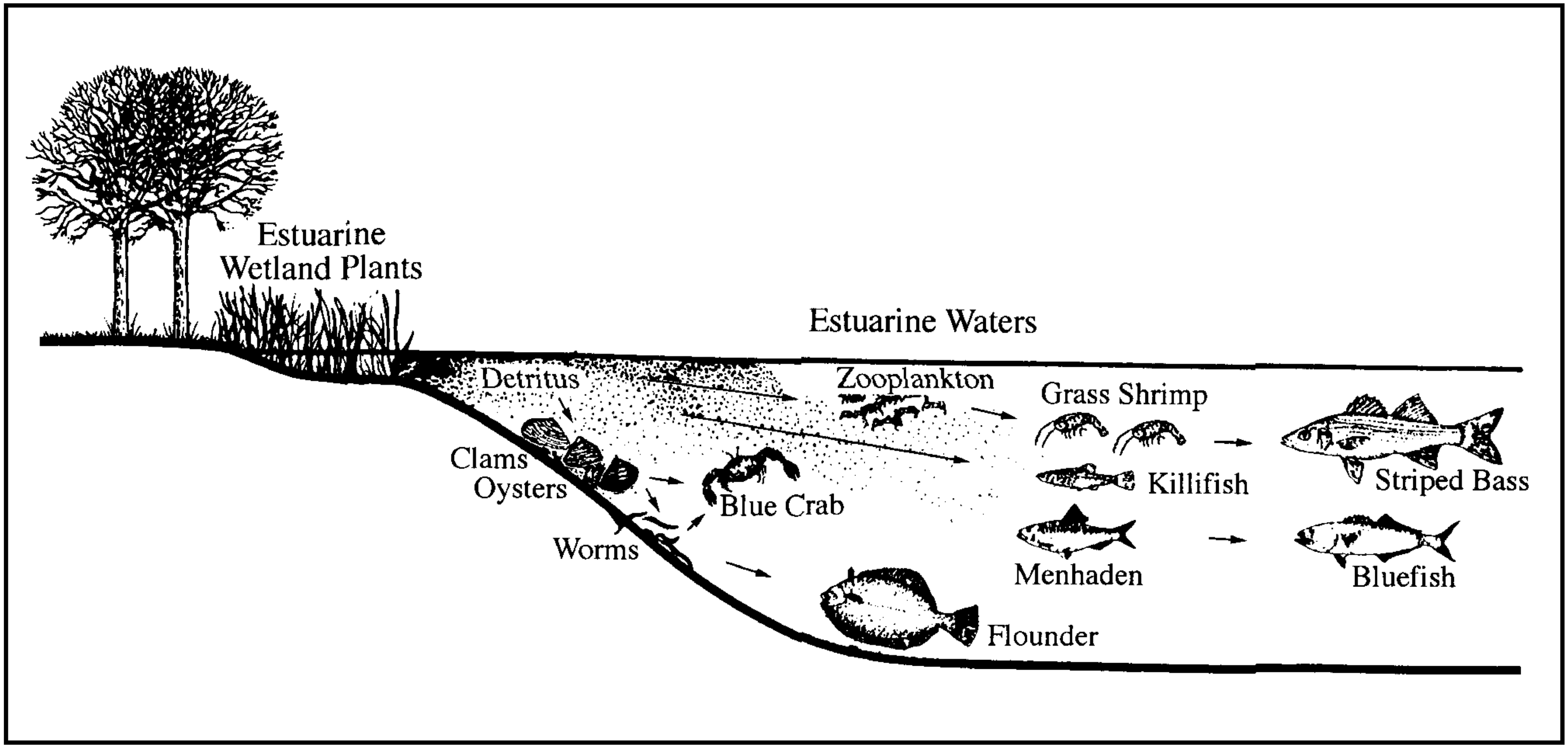
Figure 6. Distribution of Maryland's estuarine and tidal fresh marshes in Chesapeake Bay and its major tributaries. (from Tiner and Burke, 1995)





Chester R
Choptank River
Nanticoke
Patuxent River
River
Pocomoke River

Figure 7. Tidal marshes are the estuarine farmlands that produce tons of food each year that support Chesapeake Bay's living aquatic resources and ultimately, provide food for human consumption. Simplified food pathways from tidal marsh plants to commercial and sport fishes of value to humans are simplified for illustration. (from Tiner and Burke, 1995)



Estuarine
Wetland Plants
Estuarine Waters
Detritus
Zooplankton
Grass Shrimp
Clams
Oysters
Blue Crab
Killifish
Striped Bass
Worms
Menhaden
Bluefish
Flounder

Water Resources of Maryland

INTRODUCTION

A comprehensive assessment of existing water resources (including detailed, physical data) is important for: planning of future development adjacent to streams; implementing flood control measures; determining the potentialities for public water supplies; and managing wetlands throughout the state. The two major sources of water in the State of Maryland are surface water and ground water.

Mitsch and Gosselink (1986) stress the importance of hydrologic processes with respect to wetlands. The following is a summary of the basic components of wetland hydrology. Hydrology is the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. The hydrology of wetlands creates the unique physical and chemical conditions that make this ecosystem different from upland, terrestrial systems and marine and non-marine, deepwater aquatic systems. Hydrologic pathways including groundwater, precipitation, surface water (surface runoff, river floods) and tides transport energy, sediment and nutrients to and from wetlands. Hydrologic parameters, such as water depth, flow patterns and the duration and frequency of flooding, which are the result of all of the hydrologic inputs and outputs, influence the biochemistry of wetland soils and are major factors in the selection of wetland biota. Because wetlands are intermediate environments, between terrestrial and deepwater aquatic systems, they are particularly sensitive to changes in local and regional patterns of water storage, water movement and fluctuations of the water table. The hydrologic budget of wetlands includes the following factors: 1) the balance between the inflows and outflows of surface water and/or groundwater; 2) surface contours of the landscape (local and regional topography); and 3) subsurface soil, geology and groundwater conditions (flow patterns, chemistry).

The availability of surface water and groundwater greatly influences the distribution of wetlands and types of wetlands present in the different physiographic regions of Maryland. Following is an overview of surface water and groundwater resources for the five physiographic provinces of Maryland, including general information about water chemistry, quality, availability, sources and uses.

SURFACE WATER RESOURCES

Surface water is almost wholly derived from rivers in various drainage basins throughout the State. There are no large natural lakes, and saline waters cover the extensive swamps along the shores of Chesapeake Bay. The major drainage basins of Maryland were illustrated previously in **Figure 4**, by U.S.G.S. hydrologic unit, and in **Figure 5**, by the Maryland designation.
The streams in the Piedmont and Appalachian Provinces tend to have fairly steep gradients and flow over underlain by bedrock. Numerous rapids and gorges afford opportunities for water-power development, particularly adjacent to the Fall Line (the boundary between the Piedmont and Coastal Plain Provinces). This energy source was utilized locally by early grain and cotton mills, however, current potential for hydroelectric power has declined (Vokes and Edwards, 1974).

In the Coastal Plain Province, streams have lower gradients and meandering channel forms, and are underlain by unconsolidated, fine-grained deposits (gravel, sand, silt, clay). These streams flow into tidal estuaries before reaching the Chesapeake Bay. On the Coastal Plain, the Eastern Shore streams usually have a longer mainstem, where the Western Shore streams (except for the Patuxent and Potomac) may have more and larger tributaries. The larger streams are navigable in their lower course, but for many streams the head of navigation is now several miles downstream from its original position (Vokes and Edwards, 1974). This loss of navigable waters is caused by the process of siltation; the filling in of drainage systems caused by increased soil erosion resulting from poor farming practices within the Coastal Plain (Vokes and Edwards, 1974).

The volume of water conveyed by streams (the discharge) varies according to seasonal changes in climate and severe storms. In highly developed and agricultural areas, water runs over the land surface rapidly during heavy precipitation events, greatly increasing stream discharges. In wooded or heavily vegetated areas, the water is intercepted as it flows overland and, thus, reaches streams more gradually **(Figure 8)**. This aids in the reduction of flood-related stream discharges and promotes lower, sustained flows and less variation between high and low water stages. This, in turn, promotes stream channel stability by reducing the potential for erosion commonly associated with storm events. Periods of highest stream discharges generally occur in spring months when average precipitation and snowmelt are combined to produce unusually large volumes of water **(Figure 9)**. In addition, maximum flooding events are produced by the torrential rains associated with tropical storms, which are common events in Maryland (Vokes and Edwards, 1974).

GROUND WATER RESOURCES

‘Diversity’ is the best term to describe Maryland’s ground water resources. The state’s elongated shape extends across five physiographic provinces, which results in extremely varied hydrogeologic settings. In general, Maryland has abundant ground water resources. However, in the central (Piedmont area) and in western Maryland, the variability of ground water resources may be so great that water wells, belonging to adjacent property owners, will yield significantly different quantities of water.

The importance of ground water as a major water source cannot be overemphasized despite the fact that it constitutes only 19 percent (excluding water used by power plants) of total water used in Maryland. Ground water represents only a small percentage of total State use because the large urban centers of Washington, D.C and Baltimore are served by surface water sources. However, most of the water used in Southern Maryland and on the Eastern Shore is ground water. In the 12 Maryland counties located entirely within the Coastal Plain, ground water comprises 86 percent of the total water use. In six of these counties, over 90 percent of the water used is ground water. Even in the Coastal Plain, however, there can be a wide diversity in the quantity and quality of ground water. Total ground water use in Maryland exceeds 214 million gallons per day.

Ground water in Maryland exists under both confined (artesian) and unconfined (natural water table) conditions. The major aquifers, or water-bearing geologic formations, are continuously replenished by precipitation. The amount of ground water recharge varies in relation to rainfall, geology and water use. An unanswerable question is “How much ground water do we have left in Maryland?” Ground water is a variable resource because the circulation of water through the earth and the atmosphere is dynamic. Constant replenishment, changing demand and widely varying environmental conditions mean that actual ground water availability can only be measured on a site-specific basis at this time. The State of Maryland, as a whole, does not face a major water supply problem. However, potentially serious local and regional water-supply and water-quality problems exist that require careful monitoring, effective management and long range planning by the parties involved and the appropriate local jurisdictions.

The Coastal Plain Province

The Coastal Plain, largest of the five physiographic provinces in Maryland, covers nearly fifty percent of the State **(Figure 10)**. The relatively flat Coastal Plain is geologically the youngest province in Maryland. The unconsolidated sediments of the Coastal Plain extend westward from the Atlantic Ocean to the Fall Line, which forms the eastern margin of the Piedmont Province. The Chesapeake Bay divides the Coastal Plain nearly in half, forming two geographic subdivisions: the Western and Eastern Shores.

The Eastern Shore is a flat low, almost featureless plain ranging in elevation from sea level to 100 feet. As a result of its low elevation, the Eastern Shore does not have deeply incised drainage systems and the lower portions of its rivers form estuaries. Most of the Eastern Shore is covered by unconsolidated sediments, layers containing gravel, sand, silt and clay, deposited during the present post-glacial period. The western side of the Chesapeake Bay is characterized by subdued topography. Elevation ranges from sea level to approximately 200 feet. The topography of the Western Shore resembles that of the Piedmont more than that of the Eastern Shore.

The Coastal Plain is composed of numerous rock layers and unconsolidated sediments, called geologic formations, ranging from Cretaceous in age (144 million years old) to the present (Maryland Department of Natural Resources, 1987). These formations were deposited in alluvial environments, by streams flowing from the Piedmont Province, and in shallow marine environments of the Atlantic; deposition in these environments fluctuated with changes in relative sea level over time. These formations crop out successively to the northwest (from youngest to oldest) across the Coastal Plain of Maryland (Maryland Department of Natural Resources, 1987). Each formation tilts (or dips) away from the Piedmont Province and generally becomes thicker eastward toward the Atlantic Ocean. As a result, the Coastal Plain forms a wedge of sediment beginning at the Fall Line, reaching over 8,000 feet in thickness at Ocean City
(Figure 11).

Many large tributary streams, from the Western Shore and Eastern Shore of the Coastal Plain, drain in to Chesapeake Bay. These streams include the Northeast, Susquehanna, Bush, Gunpowder, Patapsco, Magothy, Severn, South, Patuxent, and Potomac Rivers. On the Eastern Shore the principal tributaries are Bohemia Creek, Sassafras, Chester, Choptank, Nanticoke, Wicomico, and Pocomoke Rivers.

The emergent portion of the Coastal Plain Province in Maryland includes almost 5,000 square miles, or approximately one-half of the area of the State. It is over 100 miles wide at its broadest point (Vokes and Edwards, 1974). The line between the emerged and submerged divisions of the Coastal Plain, the present shoreline, is extremely irregular and sinuous, especially in the Chesapeake Bay area. In the area near Calvert Cliffs, extending from Herring Bay in Southern Anne Arundel County to Drum Point at the Southern end of Calvert County, the coastline becomes relatively straight and linear. The different types of coastal morphology correspond with the presence of different types of coastal environments. The irregular, sinuous portions of the shore are low and marshy. The relatively straight portions of the coast are often topographically high and rugged. The Atlantic coastline is comprised of an extensive line of barrier beaches. Behind these beaches are lagoons, commonly called bays, which include Chincoteague, Sinepuxent and Assawoman

Bays

Water Resources in the Coastal Plain. Substantial quantities of ground water are available from a number of aquifers throughout much of the Coastal Plain (Vokes and Edwards, 1974). However, only the more permeable units of geologic formations, those composed of coarse-sized particles such as sand and gravel, yield enough water to be productive aquifers **(Figure 12)**. In a single formation, the composition and grain size may vary both laterally and with depth so that, in some cases, only part of the formation may be used as an aquifer. Aquifers are not infinite in subsurface area but some may be extensive enough to be treated, conceptually, as infinite in local assessments of ground water availability.

Groundwater in the Coastal Plain occurs under both unconfined (natural water table) and artesian (confined) conditions **(Figure 13A and 13B)**. Water levels in an unconfined aquifer fluctuate in response to recharge from precipitation, causing the water table to rise and fall periodically. Water levels are highest in early spring, due to snowmelt and lowest in early fall. Unconfined aquifers may be severely affected by drought. In comparison, artesian aquifers receive recharge from areas where water-bearing formations crop out, leakage through confining beds, and lateral movement of water from adjacent aquifers. Therefore, artesian aquifers are much less vulnerable to drought conditions.

Most Coastal Plain aquifers contain both fresh and saline water. Directly below recharge areas the water is fresh, but seaward and with depth, the water becomes saline. The location of the zone of diffusion (where fresh and salt water mix) depends on the volume of fresh water entering the aquifer from recharge or leakage.

One of the most common problems in Coastal Plain aquifers is saltwater intrusion. The position of the freshwater-saltwater boundary depends on the amount of inflow into the aquifer and the amount of fresh water discharging from the aquifer. Locally, the volume of and rate at which water is withdrawn from the aquifer for commercial and residential use greatly affects the severity and extent of saltwater intrusion. Any change in freshwater discharge can change the location of the boundary. Minor variations occur naturally as a result of tidal action and seasonal and annual changes in freshwater discharge.

The natural water quality of Coastal Plain ground water is generally good, although it depends on the composition of the geologic formations that the water originates from and moves through. Water that is withdrawn from limestone formations has a high carbonate content and will be harder than water from non-calcareous or non-fossiliferous formations. Some hardness is always present in groundwater. Ground water of the Coastal Pain ranges from very soft to very hard with the average in the moderately soft range (Vokes and Edwards, 1974). Also, the concentrations of iron in the water are in general reasonably low, but locally it may be excessively high (Vokes and Edwards, 1974).

The major aquifers in Coastal Plain are contained in the Patuxent, Patapsco Group, and the Magothy, Aquia and Piney Point Formations, the Chesapeake Group and the Quaternary deposits. The Patapsco Group and Magothy Formation contain aquifers that are most important for water supply in regions nearest to the Fall Line. The Aquia Formation is an important aquifer in southern Maryland and in some areas of the Eastern Shore. The Piney Point Formation is an important aquifer also in portions of southern Maryland and the central Eastern Shore. Aquifers of the Chesapeake Group and the Quaternary deposits are most important on the lower Eastern Shore (Somerset, Wicomico and Worcester Counties).

The Piedmont Province

The Fall Line defines the boundary between the unconsolidated sediments of the Coastal Plain and the crystalline rocks of the Piedmont **(Figure 14)**. The relatively abrupt change in elevation at the Fall Line marked the terminus of deep-water navigation during colonial times. Here the rapidly flowing water provided a ready source of power for the numerous cities that developed along the Fall Line.

The Piedmont Province extends westward from the Fall Line to Catoctin Mountain, the eastern boundary of the Blue Ridge Province. The Piedmont's 2,500 square miles comprise approximately one-fourth of the total area of Maryland. The rolling, undulating plateau ranges in elevation from 400 to 800 feet. Parrs and Dug Hill Ridges divide the Piedmont Province into two topographically and geologically distinct regions.

The Eastern Division, or Piedmont Upland, is composed primarily of highly metamorphosed rocks, such as schist, gneiss, quartzite, phyllite and marble and, to a lesser extent, of intrusive igneous rocks such as granite. The varying resistance of the rock formations to weathering and erosion has resulted in highly diversified topography. Streams have incised the less resistant rock formations of the otherwise gently rolling upland surface.

The outstanding features of the Piedmont's Western Division are the Frederick Valley and the Triassic Upland. The broad, flat Frederick Valley is underlain by limestone as well as dolomite, and has an average elevation of 300 feet. The Triassic Upland borders much of the Frederick Valley. The low to moderate relief of the Triassic Upland is underlain by layered sandstone, siltstone and red shale. The average elevation of the Upland is approximately 500 feet. A prominent topographic feature of the Piedmont is an erosion-resistant monadnock, known as Sugarloaf Mountain, which is composed of highly weather resistant quartz. Sugarloaf Mountain stands 800 feet above the surrounding land surface.

Water Resources in the Piedmont Province. Movement of water in the Piedmont Provinces is restricted by lack of a continuous network of openings and, as a result, the rocks are relatively impermeable and transmissivity is very low **(Figure 15)**. In spite of low permeability, significant quantities of ground water in the Piedmont are explained below:

1) Fracturing. Fractures, including joints and faults, allow water to flow into and through rock units where subsequent chemical weathering by ground water may enlarge openings and lead to increased storage space and circulation of the ground water. As depth increases, fractures usually close due to the confining pressure from overlying rocks. In the Piedmont, the number of fractures generally begins to decrease below depths of 300 feet; therefore, most wells are less than 200 feet deep (Richardson, 1980).

2) Saprolite. Saprolite is formed when ground water, circulating through the fractured upper layer of bedrock, removes the most soluble minerals and leaves disintegrated rock that maintains the original texture and structure of the parent rock. Large quantities of water may be stored in intergranular spaces of the saprolite, but permeability varies greatly depending on the mineral composition of the saprolite (see Tiner and Burke, 1995 for detailed description). For instance, a clay-rich saprolite is virtually impermeable, whereas a more granular saprolite, composed of quartz and feldspar, may be quite permeable.

Most of the Piedmont bedrock is covered with soil and saprolite, but the thickness of the mantle varies from 0 feet (where bedrock outcrops) to greater than 100 feet, with an average thickness of 45 feet. Saprolite layers are usually thickest on hilltops and thinnest in valleys (Richardson, 1980).

3) Topography. The occurrence and distribution of fractures is difficult to predict, but topography and surface water drainage patterns may be indicative of regional fracture systems in the subsurface. Movement of ground water in fractured rock is also related to configuration of the land surface. Ground water infiltrates on the hilltops, moves downward under the influence of gravity and then moves laterally to discharge in either a spring or a stream. Fractured rock is less resistant to erosion so valleys may form in highly fractured zones which are often occupied by streams. The presence of springs is also indicative of highly fractured bedrock. Sedimentary deposits often occur in valleys and may serve as productive aquifers on a local level.

4) Rock Type. Rock type is an important factor governing occurrence of ground water in the Piedmont. Characteristics of a rock unit such as mineralogy, lithology and texture determine natural water quality and quantity, ease of fracturing and weathering, nature of saprolite and well depth. Several studies have tried to determine which rock types are the most productive. In general, the highest yields occur in fractured limestone and marble, granular rock types such as sandstone and siltstone, and the lowest yields are from phyllite which weathers easily to form clay minerals (Richardson, 1980; Nutter and Otton, 1969).

5) Climate. Ground water in the Piedmont usually occurs under unconfined (natural water table) conditions, so most aquifer recharge is derived from local precipitation. Seasonal fluctuations of the water table are common responses to variable precipitation, evapotranspiration and ground water withdrawal. The water table is usually at its lowest in late fall (Richardson, 1980).

Transmissivity (the rate at which water flows through rocks) can be extremely variable in the Piedmont, ranging from 100 to 35,000 gpd/ft. Small to moderate supplies of ground water are available throughout the region, but locally favorable geological conditions may provide larger amounts (Vokes and Edwards, 1974). The main yield of existing Piedmont wells is about 12,960 gpd (gallons per day), which is usually sufficient for domestic use and most small farm and commercial uses (Nutter and Otto, 1969). Water supplies for large farms and light industry can be developed if favorable hydrogeologic conditions exist; otherwise, surface water supplies are utilized.

Natural water quality in Piedmont aquifers is generally satisfactory, but locally, dissolved iron concentrations may be high (greater than 0.3 ppm). Water is relatively soft in most Piedmont aquifers, although harder water may be pumped from limestone, marble and some of the Triassic sandstone aquifers. Total dissolved solids are usually low and pH usually ranges from 6.0 to 8.0. Piedmont ground water usually exists under natural water table conditions and the depth to the top of the water table averages about 30 feet below land surface, but may vary according to the amount of water that infiltrates as recharge (Wolman et al., 1981). Ground water yields are usually sufficient for most domestic and commercial demands. The high well yields necessary for municipal and many industrial and irrigation needs are difficult to obtain in the Piedmont, so many of these water users rely on surface water to supplement ground water supplies.

The Blue Ridge, Valley and Ridge, and Appalachian Plateau Provinces

The mountains of the Blue Ridge Province, as well as those in the Valley and Ridge and Appalachian Plateau Provinces, are the remnants of an ancient mountain system that was formed by folding and faulting **(refer to Figure 10)**. Over a 200 to 300 million year period, the ancient mountains system was eroded to a flat plain called a peneplain. Slow uplift of the peneplain and subsequent stream erosion cut valleys into the less resistant rocks while more resistant rocks remained as ridges. Therefore, the present mountain system is a result of water erosion rather than a direct product of folding and faulting.

The sedimentary rocks of the Blue Ridge, Valley and Ridge, and Appalachian Plateau Provinces yield small to moderate supplies of ground water **(Figure 16)**. Under favorable conditions large amounts may occur (Vokes and Edwards, 1974). The following is a more detailed description of each of these three geological regions summarized from "The Quantity and Natural Quality of Ground Water in Maryland" (DNR, 1987).

The Blue Ridge Province

The Blue Ridge Province in Frederick County consists of the Middletown Valley and three separate ridges: Catoctin Mountain, South Mountain and Elk Ridge **(refer to Figure 10)**. The area has a maximum elevation of 2,000 feet at the Maryland-Pennsylvania border. Metamorphosed basalt is the predominant rock type in the mountains, although the ridges and crests are formed by erosion-resistant quartzite of Cambrian age (505 to 570 million years old). The Middletown Valley, a rolling upland between the mountain ridges in southwestern Frederick County, is underlain by granodiorite and granitic gneiss of Precambrian age (greater than 570 million years old) (Meyer and Beall, 1958).

Water Resources in the Blue Ridge Province. In both the Middletown Valley and the surrounding ridges, ground water occurs both in fractures and in the overlying saprolite Blue Ridge aquifers supply adequate amounts of water for domestic use, but porosity and permeability are too low for many industrial uses. Most large water supplies are obtained from springs and surface water. In some cases, ground water is used to supplement surface water supplies. The Blue Ridge Province uses about 1 percent of the total ground water used in the state.

Natural water quality is generally good in the Blue Ridge Province, although dissolved iron concentrations may be locally high.

The Valley and Ridge Province

Extending westward from the Blue Ridge for 65 miles, the Valley and Ridge Province is composed of layers of sedimentary rocks that have been folded, faulted and otherwise deformed by tectonic stresses within the earth's crust. The Province is separated into two topographically and geologically distinct zones: a wide, open valley in the eastern part of the region called the Great Valley, and the Allegheny Ridge area **(refer to Figure 10)**. The Great Valley, commonly known as the Hagerstown Valley, is approximately 18 miles wide and average 500 to 600 feet in elevation. The broad, flat valley is underlain by a thick series of layered limestone and shale. For many years the limestone formations have been used as local sources of agricultural lime and building stone. Modern uses include crushed stone for aggregate and cement. A pure, white sandstone in the western region of the province is suitable for glass manufacturing (Vokes and Edwards, 1974). The Allegheny Ridge area extends westward from the Great Valley to the Allegheny Front near Frostburg. The parallel ridges of erosion-resistant sandstone are aligned in a northeast-southwest direction. Intervening valleys are composed of weaker shale and limestone units.

Water Resources of the Valley and Ridge Province. In the Great Valley, ground water usually occurs in joints, fractures and solution channels, much the same as it does in the Frederick Valley **(refer to Figure 16 of Western Maryland)**. Alluvial fan deposits, composed of a chaotic mixture of boulders, cobbles, pebbles, sand and silt, is frequently found along the mountains bordering the Great Valley. The thickness of these deposits varies over short distances, but it is capable of storing considerable quantities of water that slowly seep down and recharge the underlying limestone and dolomite aquifers.

The largest well yields of the Valley and Ridge Province occur in the Great Valley, where locally wells can yield up to 400 gpm (Slaughter and Darling, 1962). These high flow rates are due to large interconnecting solution channels in the limestone and dolomite rock formations. Although high well yields are possible, yields are often unpredictable in new wells and dry holes are common. Natural water quality in the Great Valley is generally good although hard water is common and high dissolved iron concentrations may be found locally.

Rock formations of the Allegheny Ridge have low primary porosity and permeability. Secondary porosity has resulted from fractures and solution of the rocks. In general, sandstone and limestone formations are the most productive aquifers. Yields vary from less than 1 gpm to 400 gpm, but most wells produce only enough water for domestic, light commercial and some agricultural uses (Slaughter and Darling, 1962). Natural water quality varies greatly in the Allegheny Ridge area. Ground water from shale formations frequently has high total dissolved solids because of limited circulation. Significantly high dissolved iron concentration is also a frequent problem (Slaughter and Darling, 1962).

Appalachian Plateau Province

The Appalachian Plateau Province includes parts f Allegany County west of Dans Mountain and all of Garrett County, the western-most county in Maryland. The Allegheny Front in western Allegheny County clearly separates the Appalachian Plateau Province from the Valley and Ridge Province **(refer to Figure 10)**. Although somewhat similar in topographic appearance to the Valley and Ridge, the Appalachian Plateau Province is actually a raised, mountainous plateau. The bedrock of this region consists principally of gently folded layers of siltstone and sandstone. The steep slopes and winding stream valleys of the Plateau dominate the landscape of Garrett County. Ridges generally stand 500 to 800 feet above the surrounding land surface. In some places, the valley walls are almost vertical and stream gradients are steep. Rapids and waterfalls are often present. The Plateau contains Maryland's highest point, Backbone Mountain, at an elevation of 3,360 feet.

Water Resources of the Appalachian Plateau Province. The hydrogeology of the Appalachian Plateau Province is very similar to that of the Valley and Ridge Province **(Figure 17)**. Transmissivity depends on the frequency, density and interconnection of fractures. Each formation fractures and weathers differently, so the degree of transmissivity varies with rock type. In general, the most productive aquifers are in sandstone formations, although yield may vary throughout the formation, depending on degree and type of fracturing and cementation. In some cases, coal beds may also be very productive aquifers, because coal is very brittle and fractures easily; however, the natural water quality of such an aquifer may be extremely poor. Siltstone and shale are relatively poor aquifers, but since they underlie much of the Province, they are frequently relied on for small farm, light commercial and domestic supplies. Except on a local level, limestone is not an important source of ground water because the units are thin in most areas and often contain interbedded shale (Amsden et al., 1954).

Ground water occurs under both natural water table and artesian conditions, but flowing wells are rare. Average yield is about 25 gpm, but yields greater than 200 gpm have been reported (Amsden et al., 1954). Except for water derived from coal beds, natural water quality is generally satisfactory for small farm, light commercial and domestic use. Hardness ranges from soft to hard, but on the average, it may be classified as moderately soft (61-120 ppm). Slightly acidic water (pH less than 7.0) is common and total dissolved solids (TDS) are generally low. High dissolved iron concentration is a frequent problem and water treatment is often necessary

(Amsden et al., 1954).

Figure 8. Wetlands provide important flood control functions in watersheds. They reduce flood volumes and flow rates by delaying peak flood volumes after rainstorms. (from Tiner and Burke, 1995)

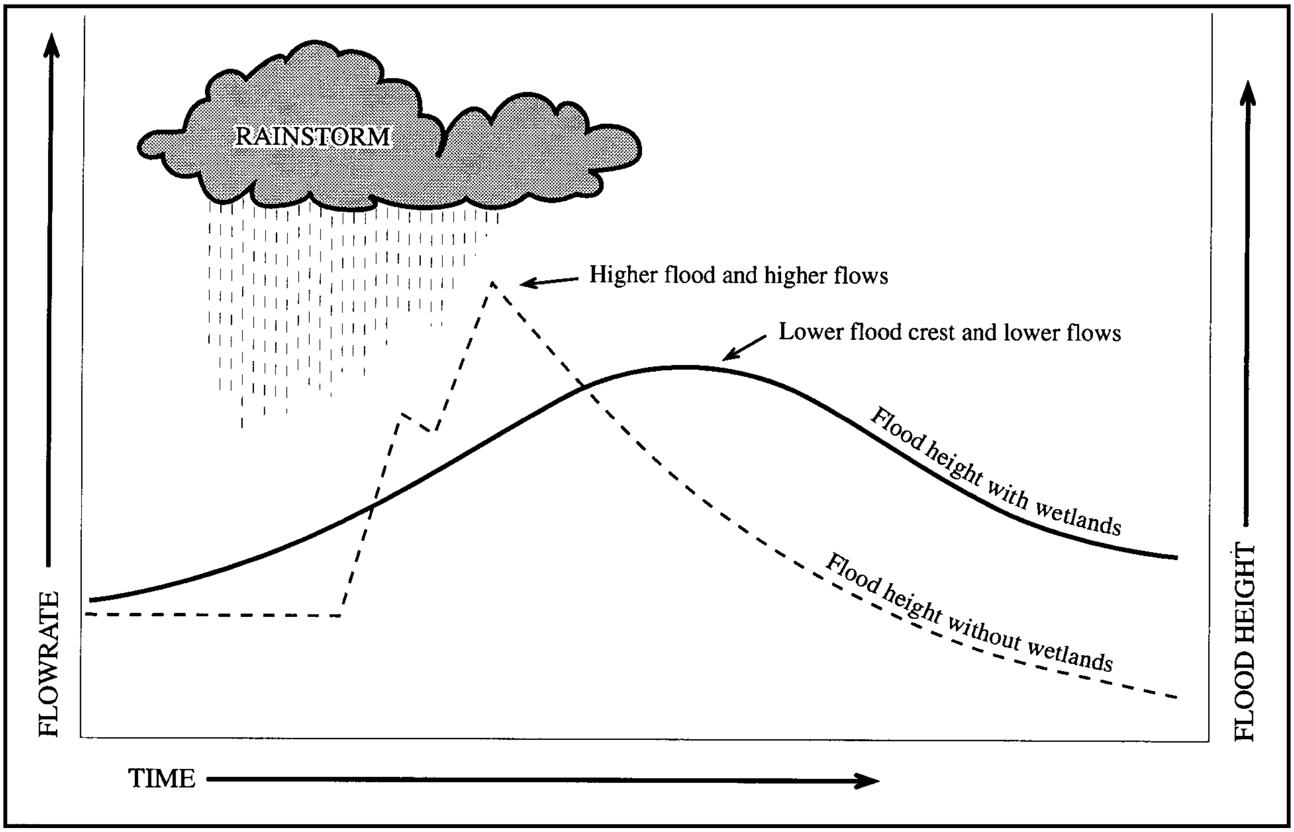


Figure 9. An example of water table fluctuations in a seasonally flooded wetland (from Tiner and Burke, 1995). In general, the water table is at or near the surface through winter and early spring, drops markedly through summer and rises through fall. The water table can fluctuate daily, seasonally and annually.

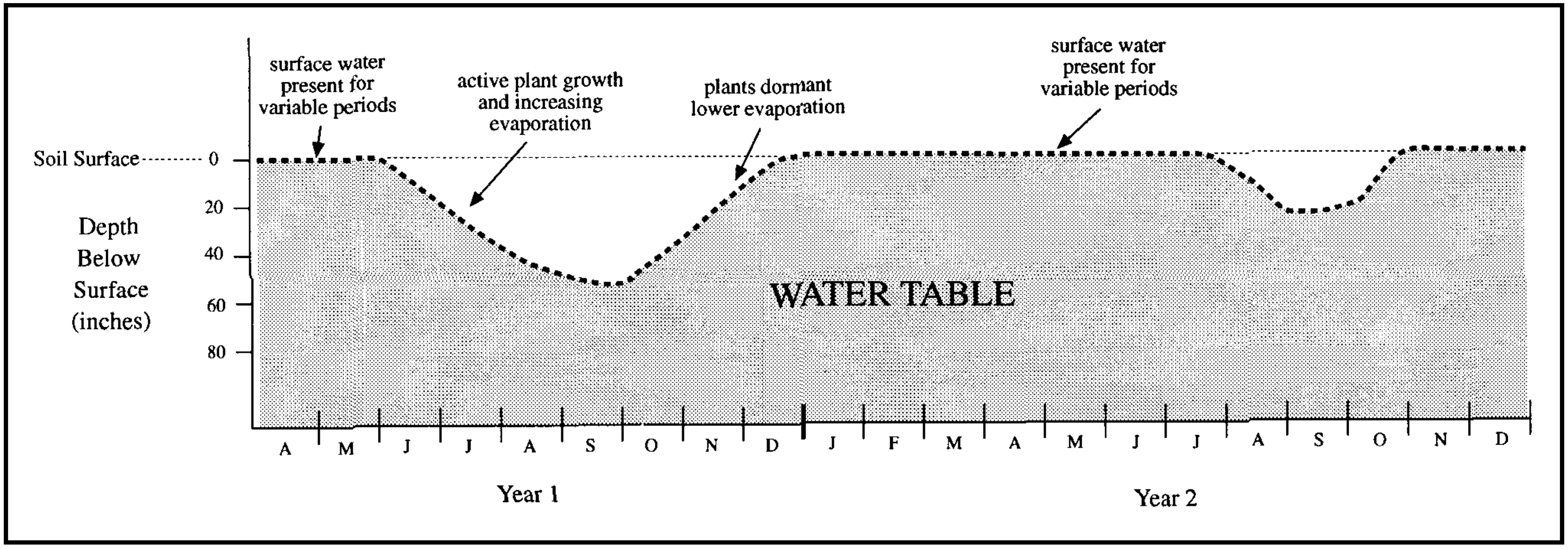


Figure 10. The location and relative elevation of the five physiogrpahic provinces of Maryland, from west to east; the Appalachian Plateau Province, the Ridge and Valley Province, The Blude Ridge Province, the Piedmont Province, and the Coastal Plain Province. (from DNR, 1987)

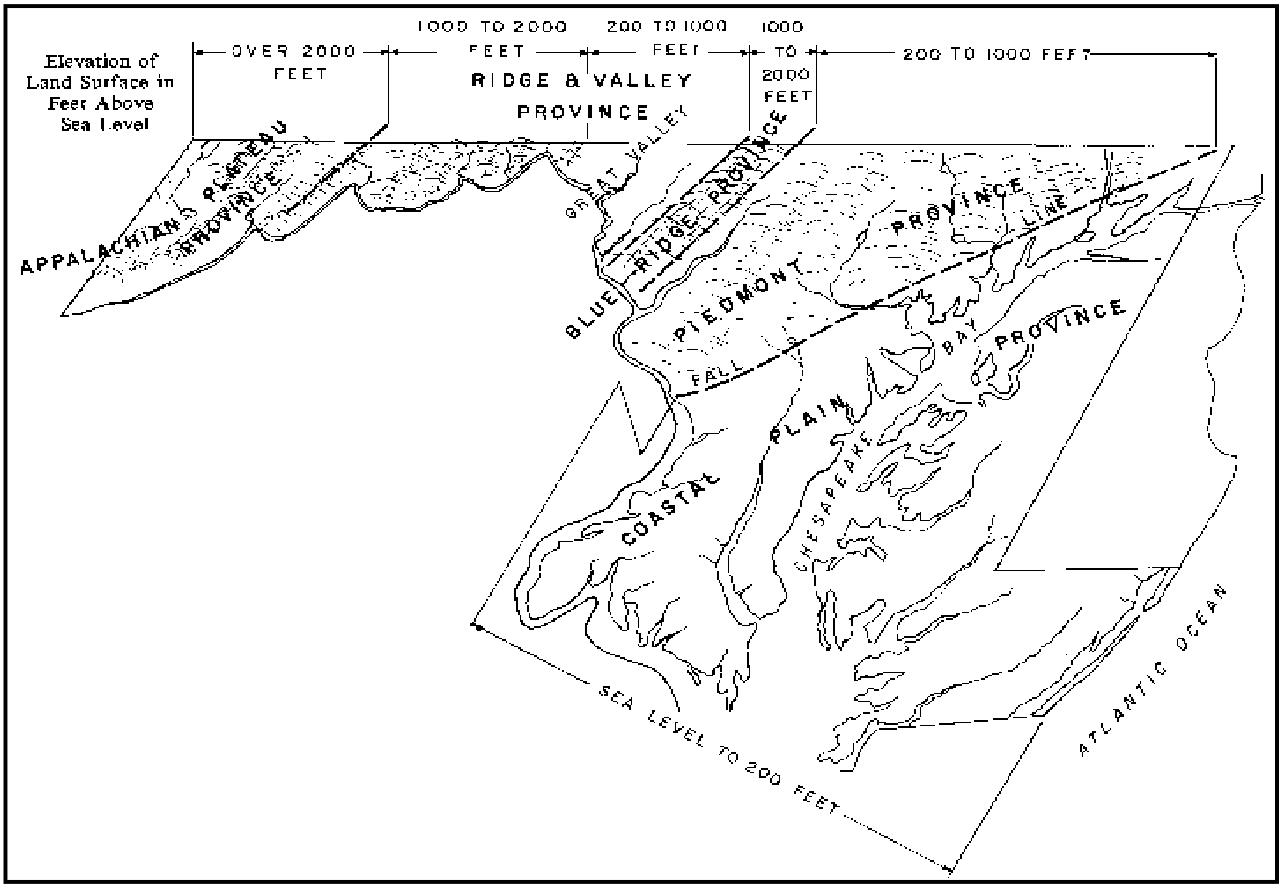


Figure 11. Cross-sectional diagram of Maryland's geology including location of the Fall Line and the sedimentary deposits of the Coastal Plain Province (from DNR, 1987).

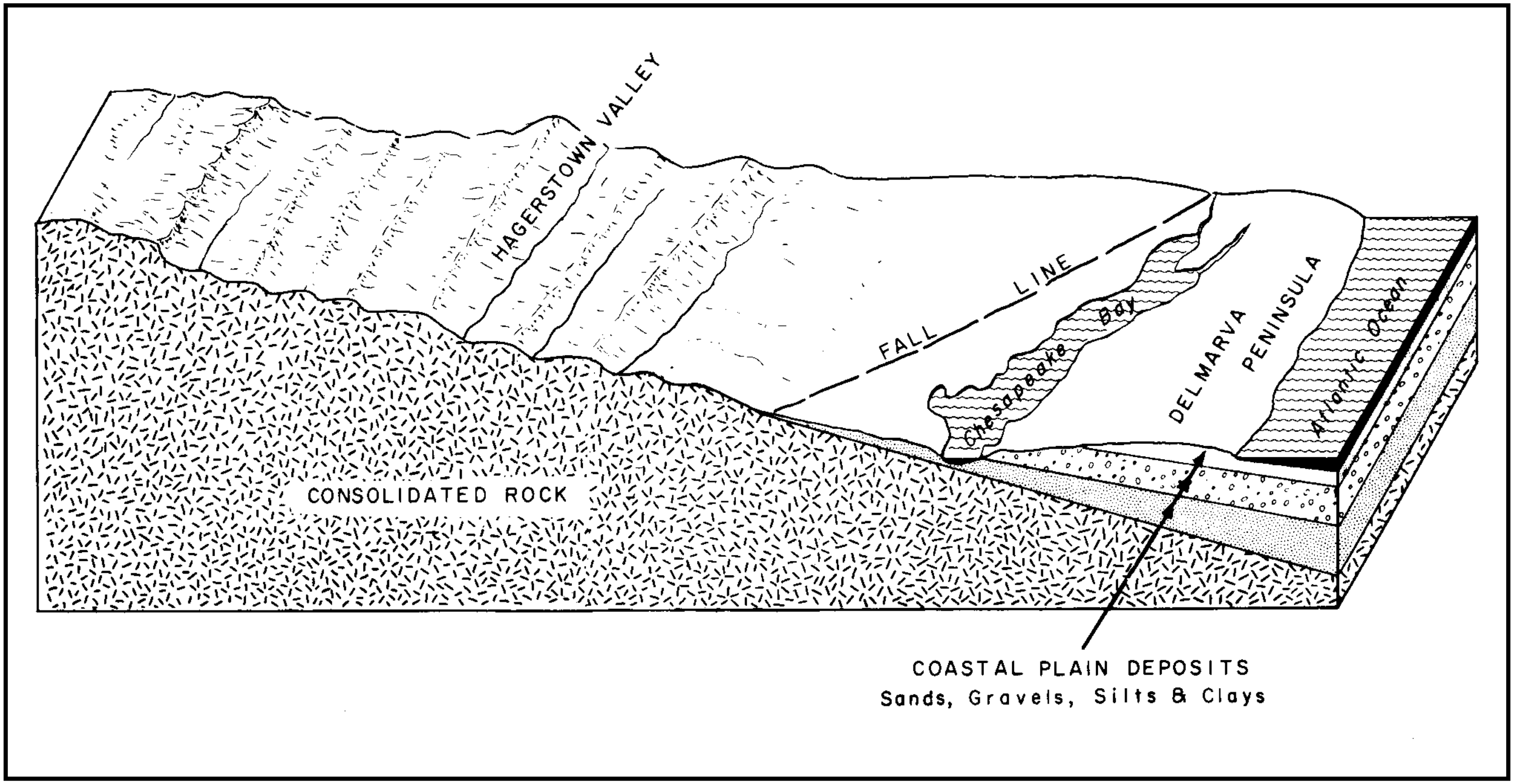
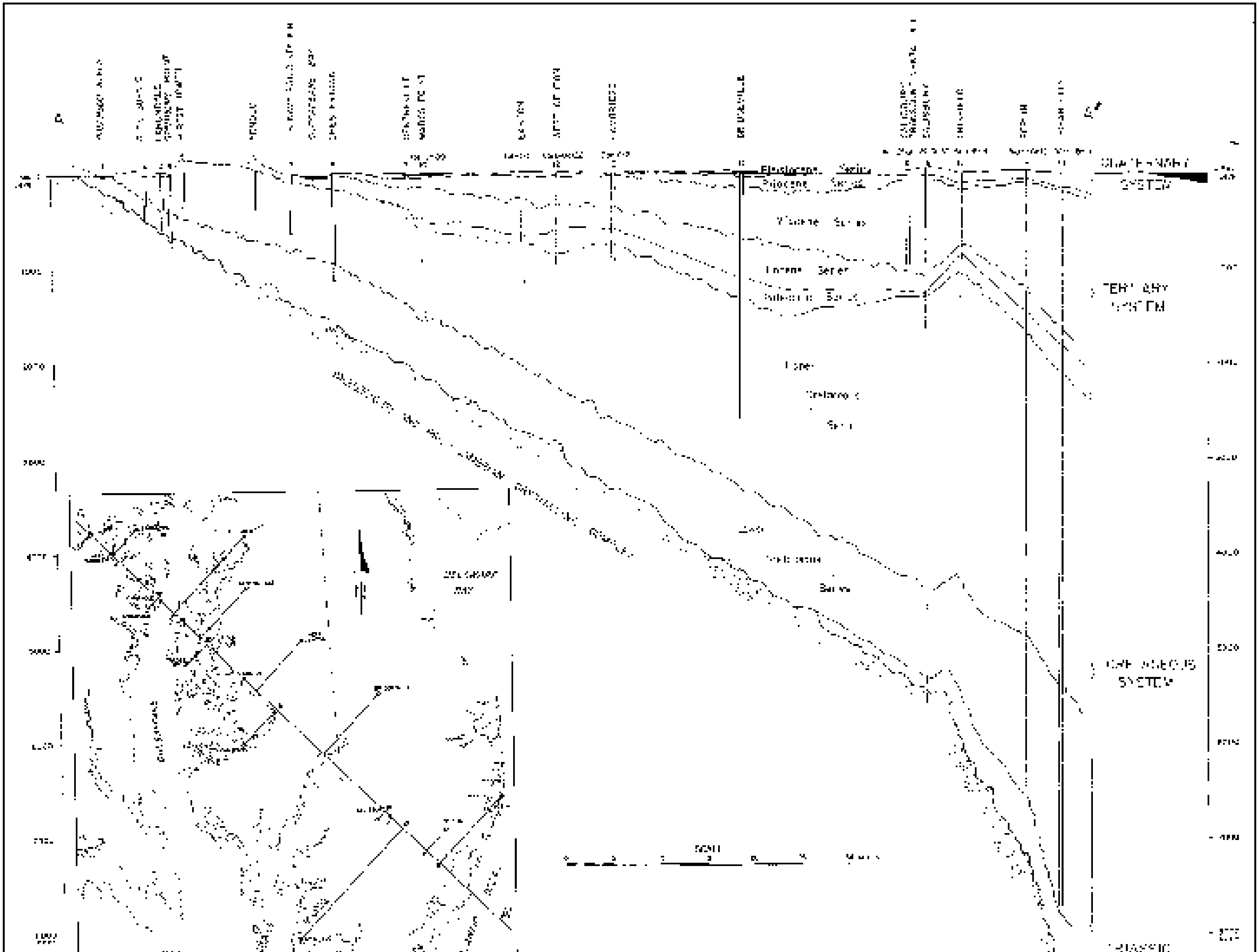


Figure 12. A geologic cross-section showing the major aquifers (water-bearing formations) of the sedimentary wedge beneath the Coastal Plain Province of Maryland. (from DNR, 1987)



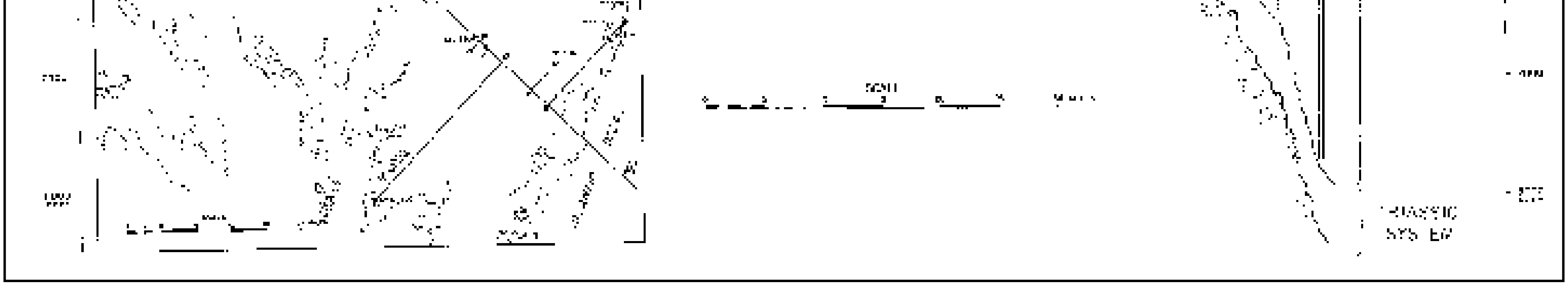
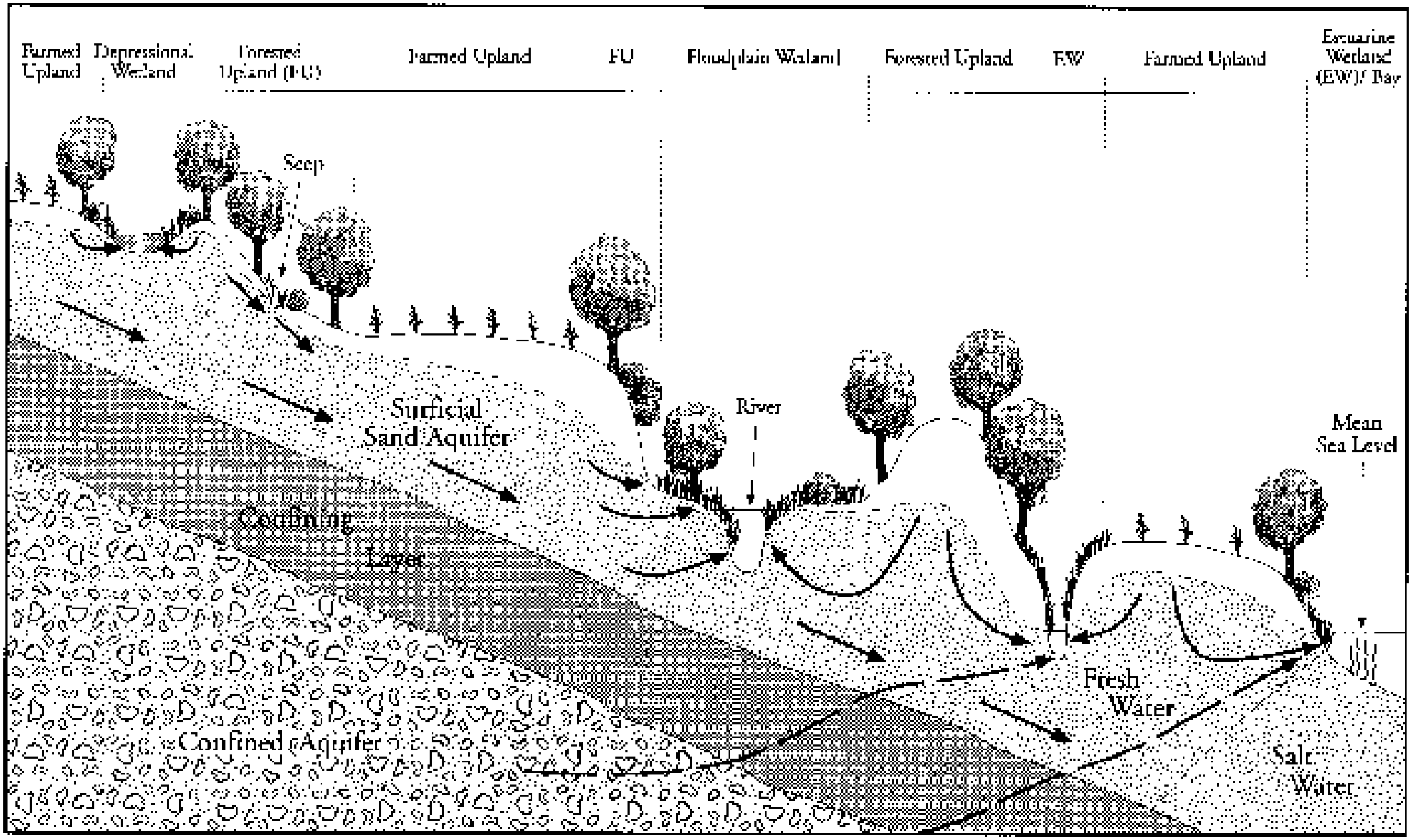


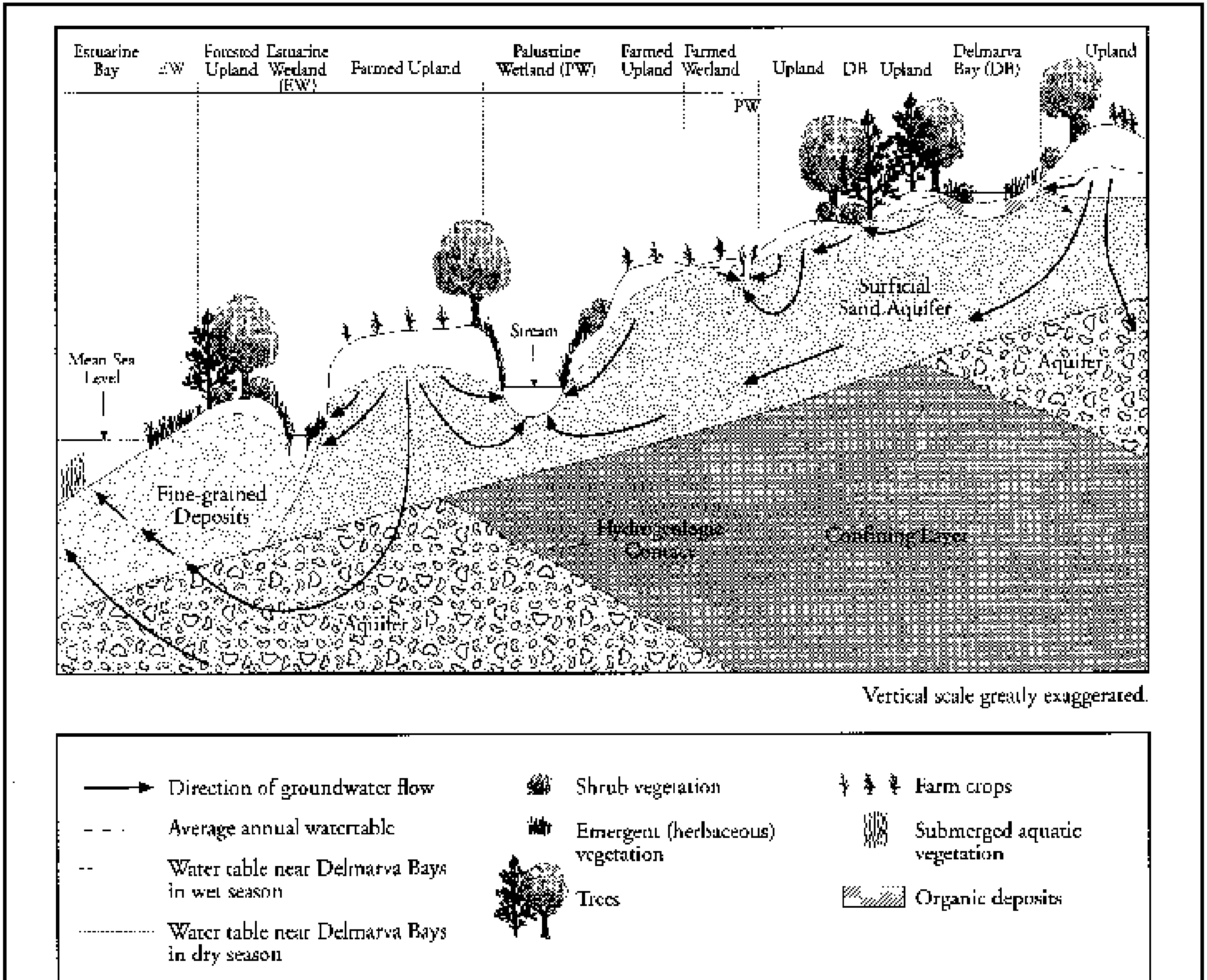
Figure 13. Generalized patterns of groundwater flow for: A) the Upper Coastal Plain, and B) the Lower Coastal Plain. (from Tiner and Burke, 1995)

A. Upper Coastal Plain



Vertical scale greatly exaggerated.

B. Lower Coastal Plain


Estuarine Bay
EW
Forested Upland
Estuarine Wetland (EW)
Farmed Upland
Palustrine Wetland (PW)
Farmed Upland
Farmed Wetland
PW
Upland
DB
Upland
Delmarva Bay (DB)
Upland
Mean Sea Level
Stream
Surficial Sand Aquifer
Aquifer
Fine-grained Deposits
Hydrogeologic Contact
Confining Layer
Aquifer
Vertical scale greatly exaggerated.
Direction of groundwater flow
Average annual watertable
Water table near Delmarva Bays in wet season
Water table near Delmarva Bays in dry season
Shrub vegetation
Emergent (herbaceous) vegetation
Trees
Farm crops
Submerged aquatic vegetation
Organic deposits

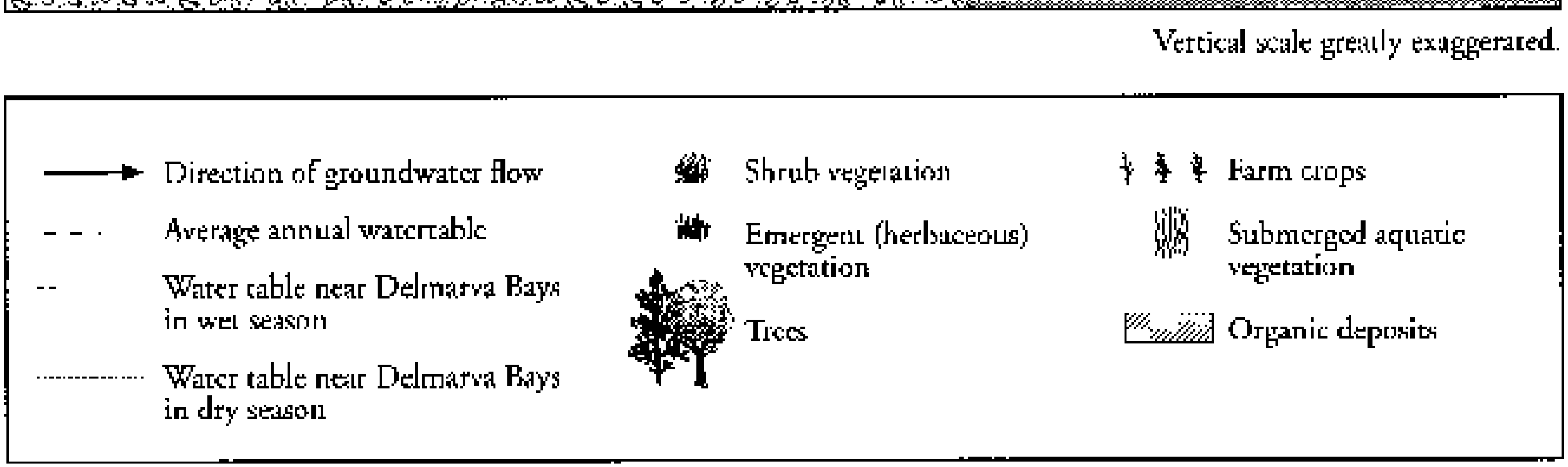
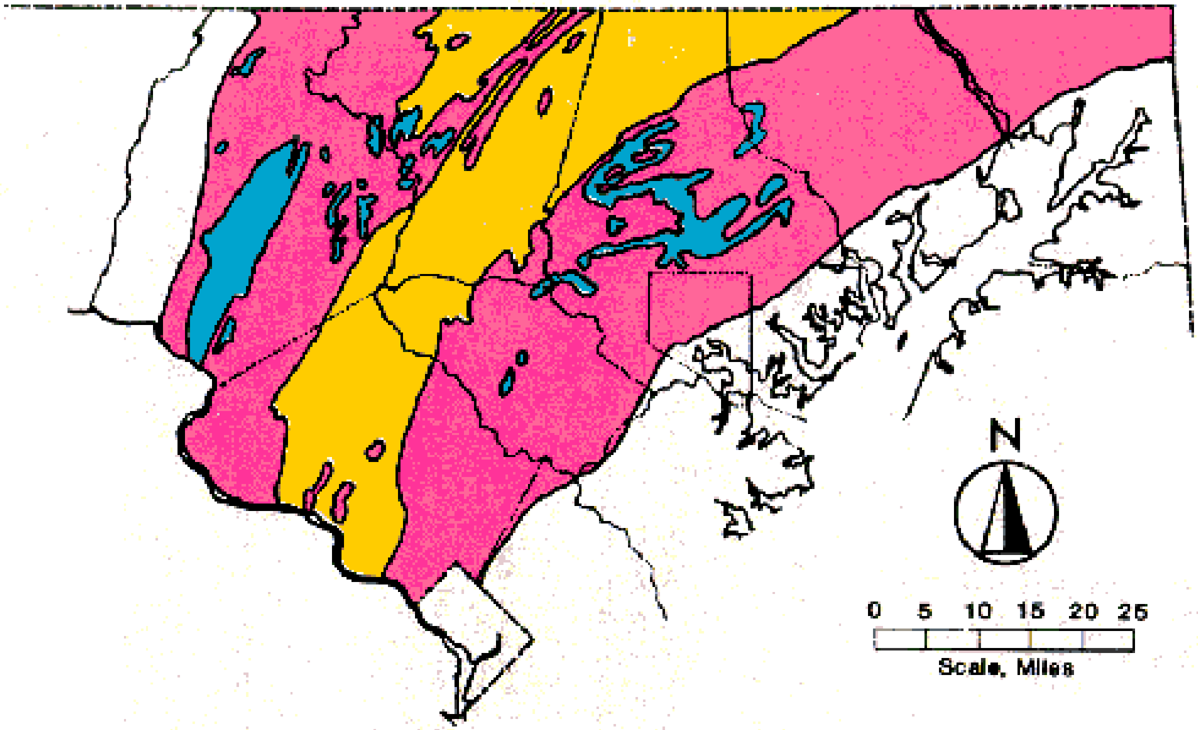

Vertical scale greatly exaggerated.
Direction of groundwater flow
Average annual watertable
Water table near Delmarva Bays in wet season
Water table near Delmarva Bays in dry season
Shrub vegetation
Emergent (herbaceous) vegetation
Trees
Farm crops
Submerged aquatic vegetation
Organic deposits

Figure 14. The distribution of the hydrologic units, based on rock type, of the Piedmont Province (DNR, 1987). The eastern margin of the Piedmont Province is the "Fall Line" (the boundary between the Piedmont and Coastal Plain Provinces).

PIEDMONT PROVINCE

GENERALIZED HYDROLOGIC UNIT MAP *



(adapted from Maryland State Planning Department, 1969)

HYDROLOGIC UNIT I

Limestones of the Frederick Valley including: Grove Limestone and Frederick Limestone

Marbles of the Piedmont including: Wakefield Marble and Cockeysville Marble.

HYDROLOGIC UNIT II

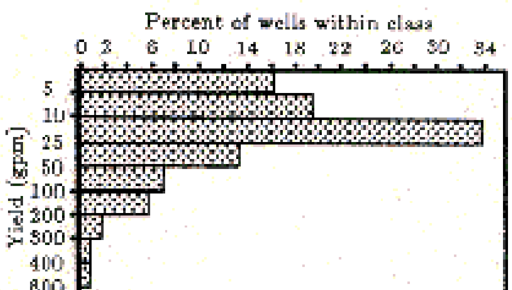
Schists and quartzites of the central Piedmont including: Marburg Schist and Wissahickon Formation.

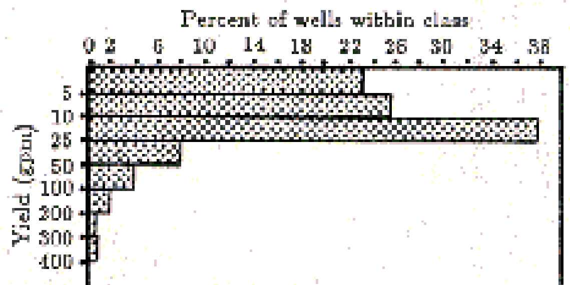
HYDROLOGIC UNIT III

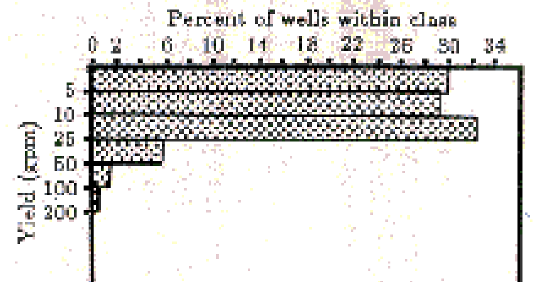
Shales, sandstones and conglomerates of the Triassic Lowland including: Gettysburg Shale and New Oxford Formation.

Phyllites, schists and metavolcanic rocks of the western Piedmont.

Schists, gneisses and intrusive rocks of the eastern Piedmont including granite, gabbro, granodiorite, and metagabbro, Wissahickon Formation, Setters Formation and Baltimore Gneiss.



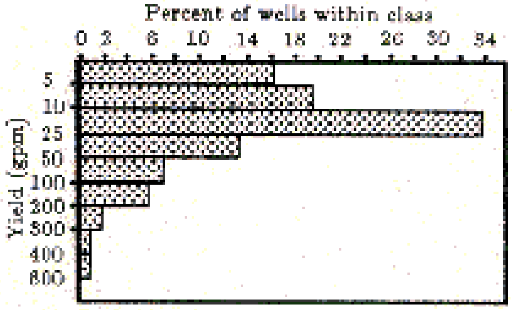


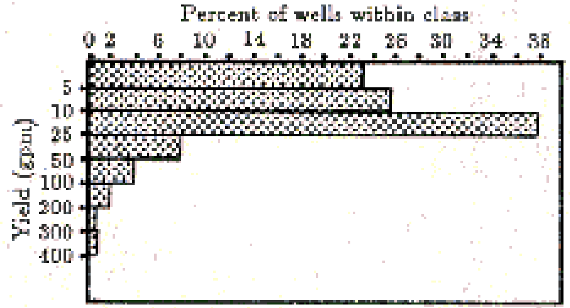


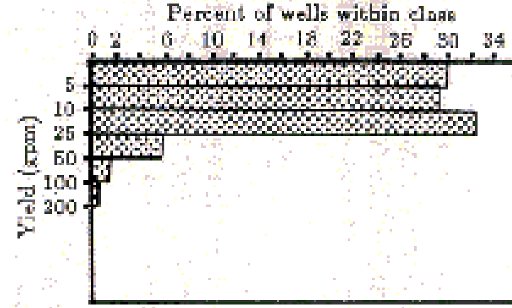
Wakefield Marble and Cockeysville Marble.

Phyllites, schists and metavolcanic rocks of the western Piedmont.

Schists, gneisses and intrusive rocks of the eastern Piedmont including granite, gabbro, granodiorite, and metagabbro, Wissahickon Formation, Setters Formation and Baltimore Gneiss.







*The aquifers of the Piedmont are shown as three hydrologic units. Each geologic unit has been placed into one of three hydrologic units based upon specific capacities and well yields.

Figure 15. Generalized groundwater flow patterns in Central Maryland. (from Tiner and Burke, 1995)

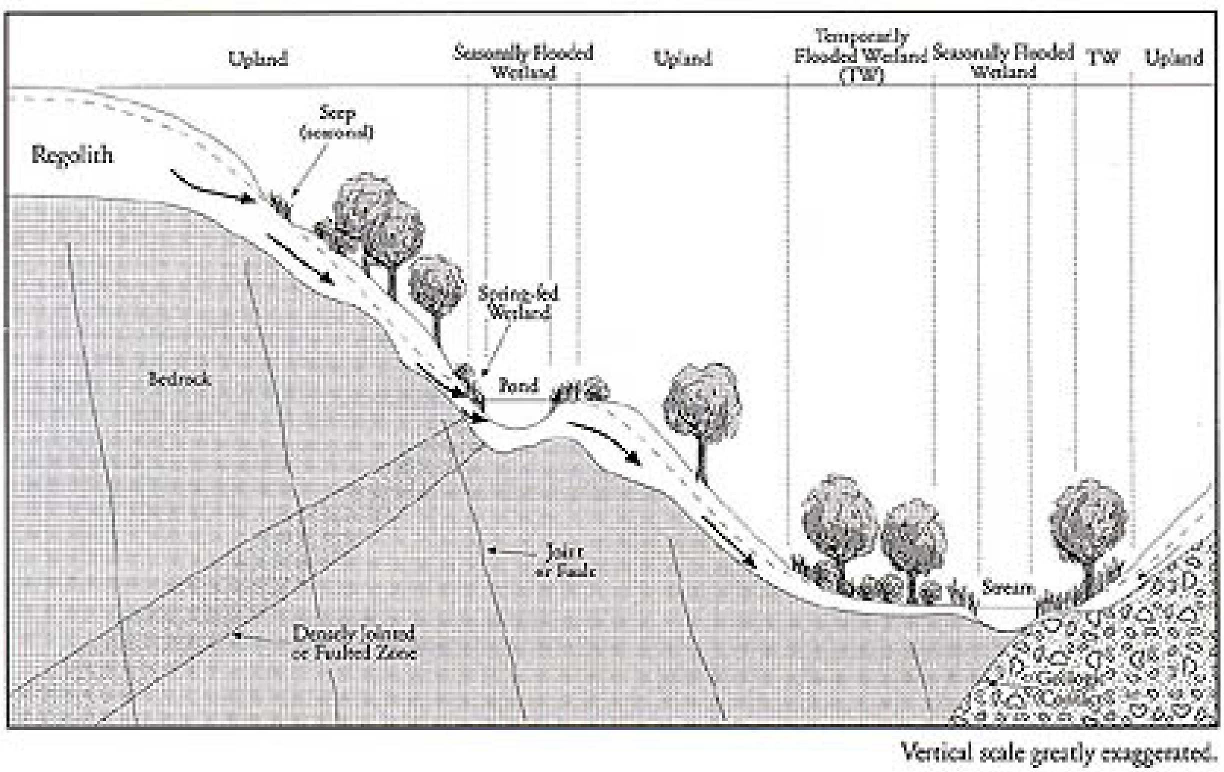
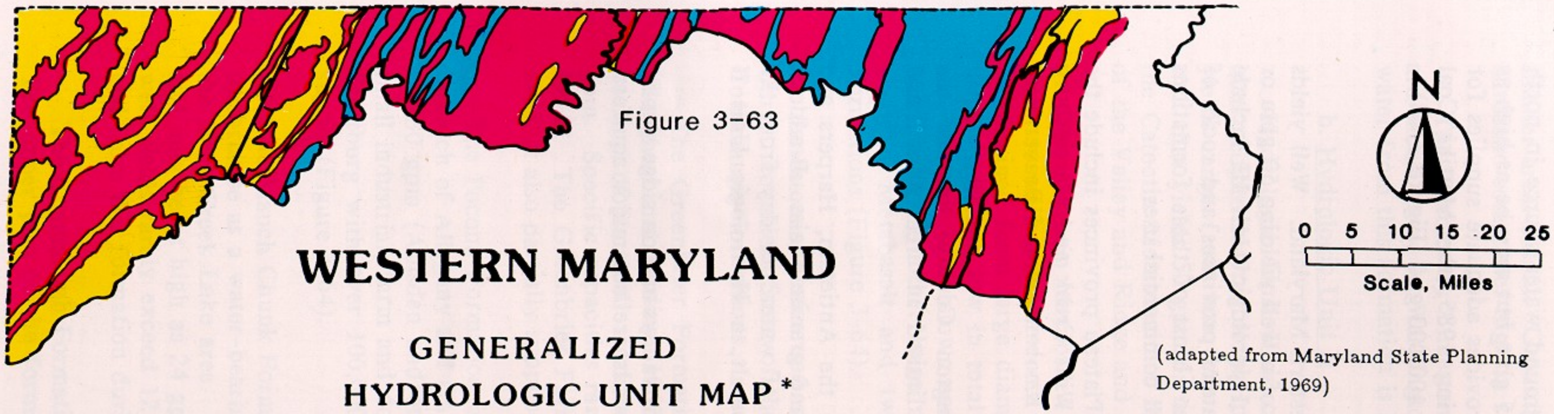


Figure 16. The distribution of hydrologic units, based on rock type, for the Appalachian Plateau and Blude Ridge Provinces of western Maryland. (from DNR, 1987)

Figure 3-63

WESTERN MARYLAND

GENERALIZED HYDROLOGIC UNIT MAP *



(adapted from Maryland State Planning Department, 1969)

HYDROLOGIC UNIT I

Limestones and dolomites of the Great Valley including: Beekmantown, Conococheague and Elbrook Limestones and Tomstown Dolomite

Sandstones and limestones of the Valley and Ridge Province including: Helderberg and Tonoloway Limestone and Oriskany Sandstone

Percent of wells within class

0 2 6 10 14 18 22 26 30 34

HYDROLOGIC UNIT II

Sandstones, shales and limestones of the Valley and Ridge and Allegheny Plateau Province including Conemaugh, Mauch Chunk, Greenbrier and Pocono Formation

Catoctin Metabasalt of the Blue Ridge Province

Percent of wells within class

0 2 6 10 14 18 22 26 30 34 38

HYDROLOGIC UNIT III

Sandstones and shales of the Valley and Ridge and Allegheny Plateau Provinces including: Monongahela, Allegheny, Pottsville, Hampshire, Jennings, Romney, Wills Creek, Clinton and Martinsburg Formation

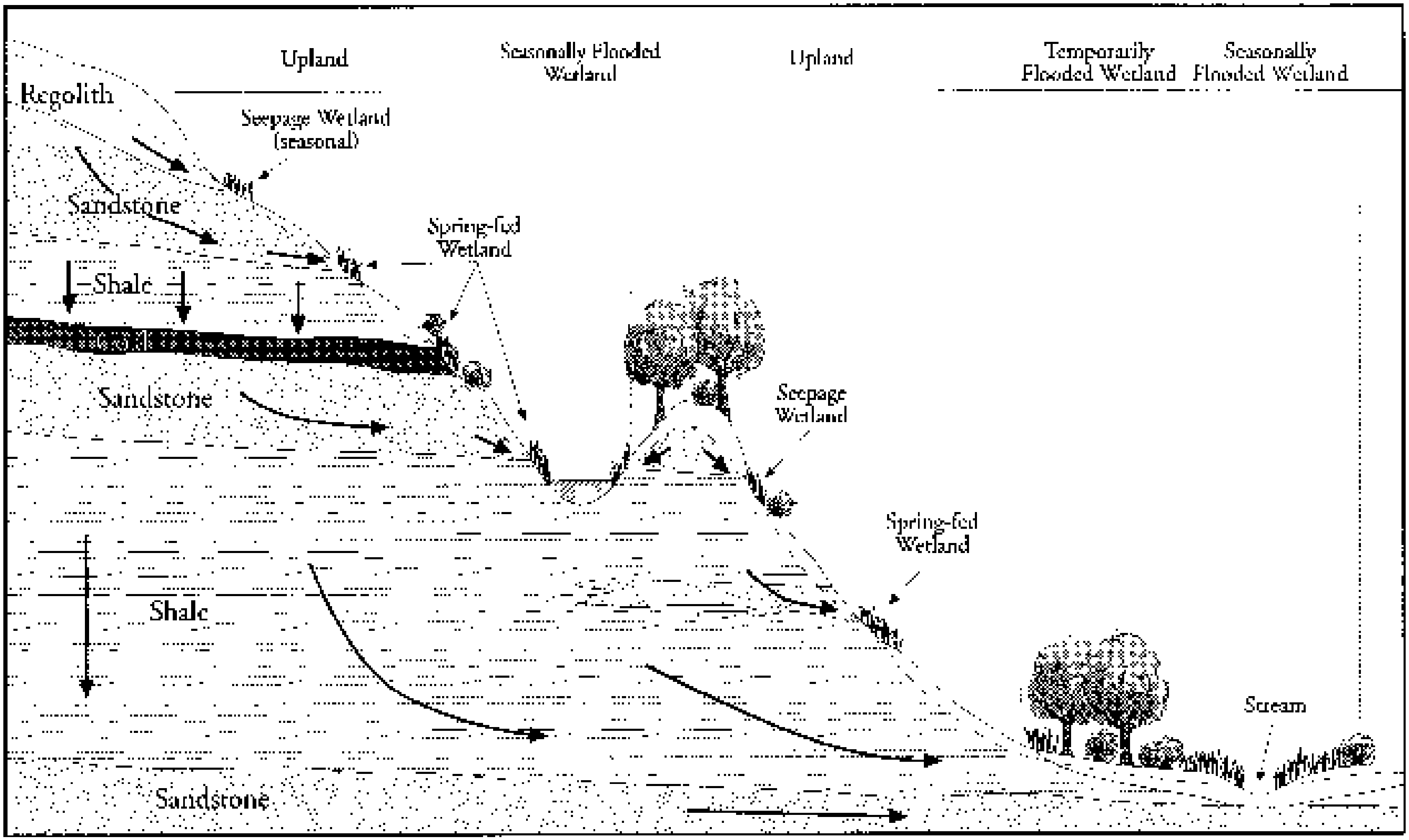
Rocks of varied lithologies in the Great Valley including: Chambersburg Limestone and Waynesboro Formation

Rocks of varied lithologies in the Blue Ridge Province including: Antietam, Harpers, Weaverton, Loudoun, metarhyolite and granite gneiss formation

Percent of wells within class

0 2 6 10 14 18 22 26 30 34

Figure 17. Generalized patterns of groundwater flow in the Appalachian Plateau region. (from Tiner and Burke, 1995).



Vertical scale greatly exaggerated.

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