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Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia
HA 730-L

Regional summary

(figures 1-11)

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Surficial aquifer system

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- **Figure 12** Map of Surficial aquifer system

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- **Figure 16** Chart showing the median concentrations of dissolved chemical constituents in water

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- **Figure 17** Chart showing the use of fresh ground-water withdrawals during 1985

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Severn-Magothy aquifer (Click to view thumbnails and download figures)

Peedee-upper Cape Fear aquifer (Click to view thumbnails and download figures)

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- **Figure 87** Chart showing use of fresh ground-water withdrawals during 1985

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- Figure 88 Map of Appalachian Plateaus aquifers
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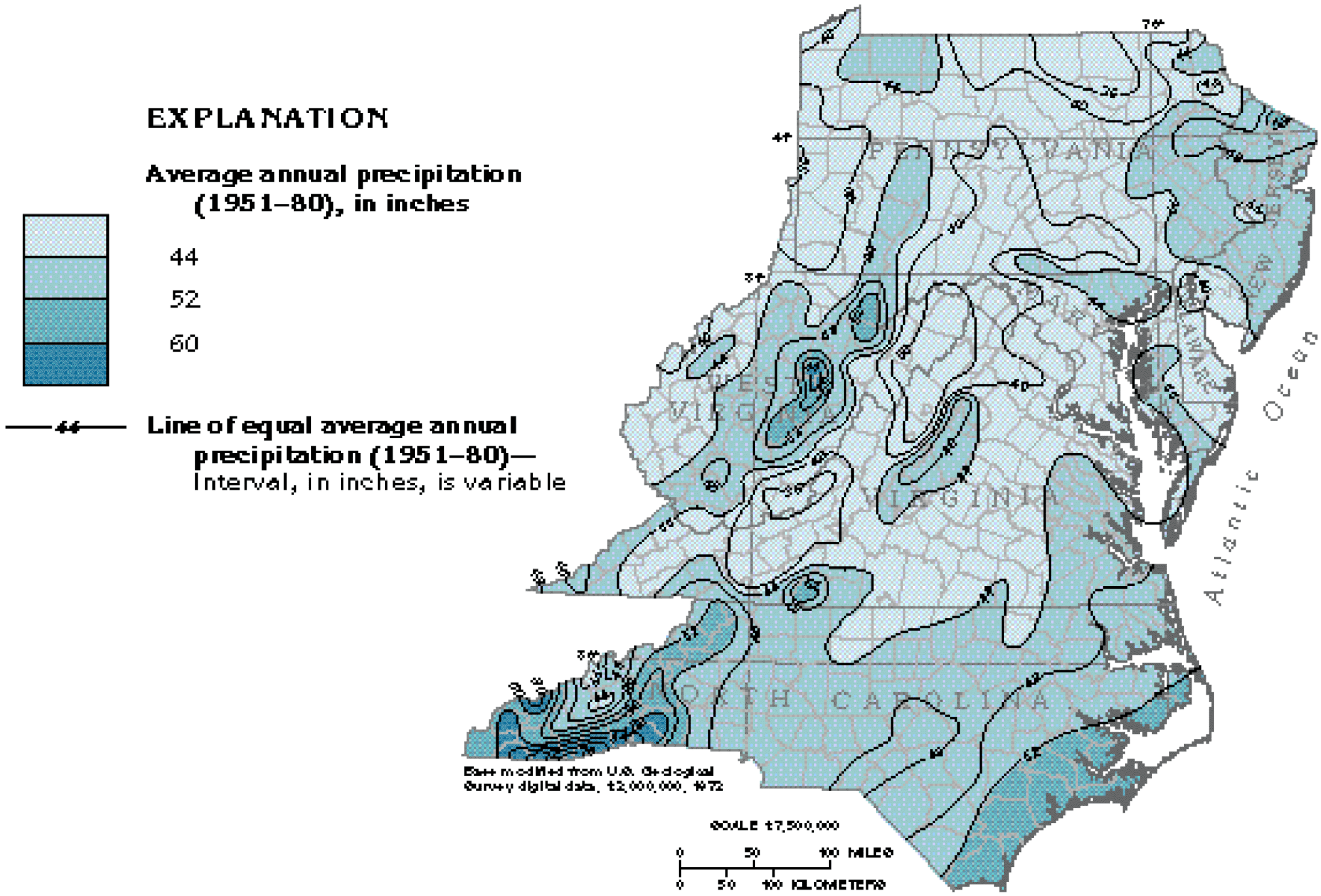


Figure 1. Average annual precipitation (1951–80) is greatest in the areas of high altitude on the western side of the segment and near the coast.

Modified from U.S. Geological Survey, 1986, National water summary 1985—Hydrologic events and surface-water resources: U.S. Geological Survey Water-Supply Paper 2300, 506 p.

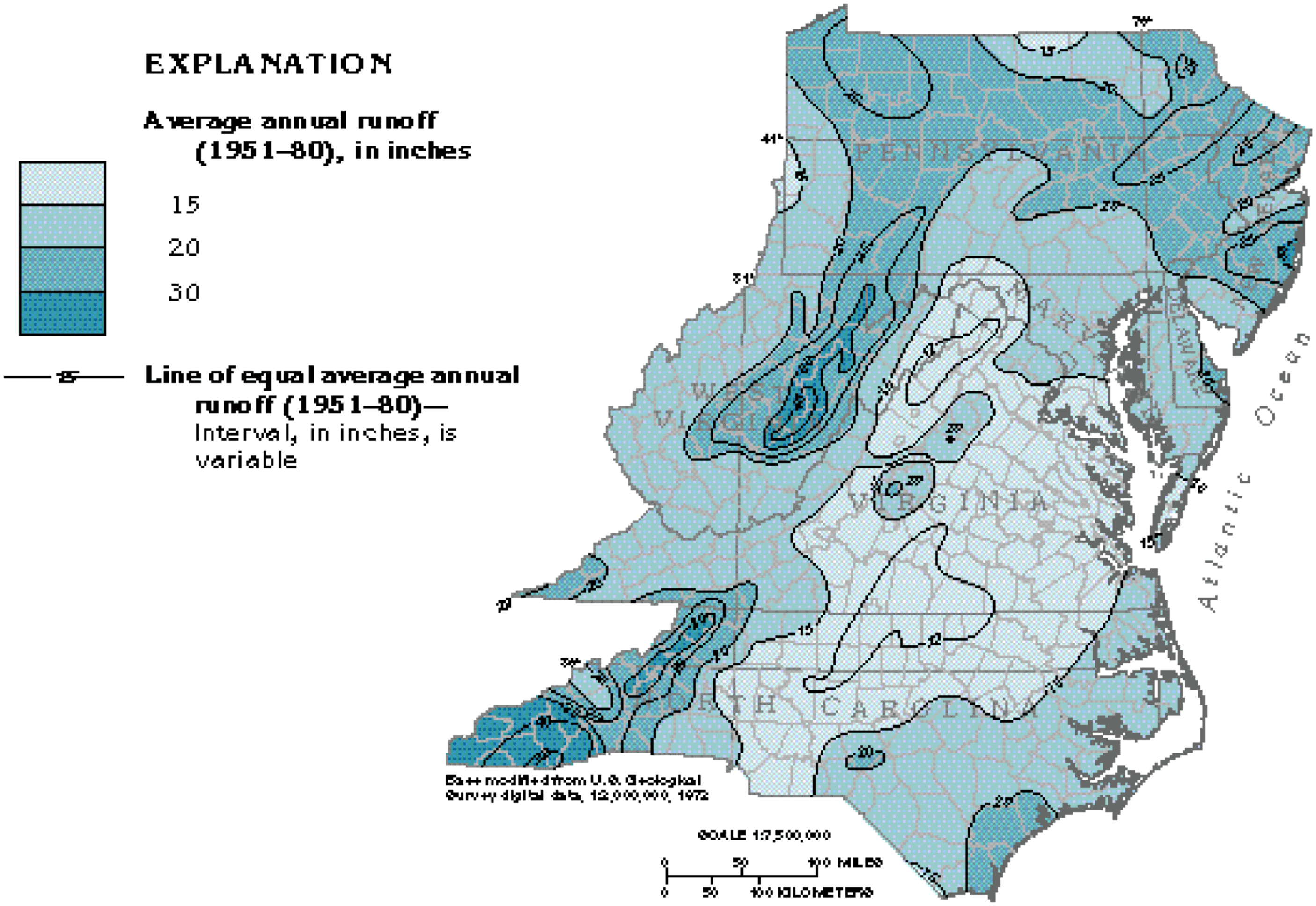
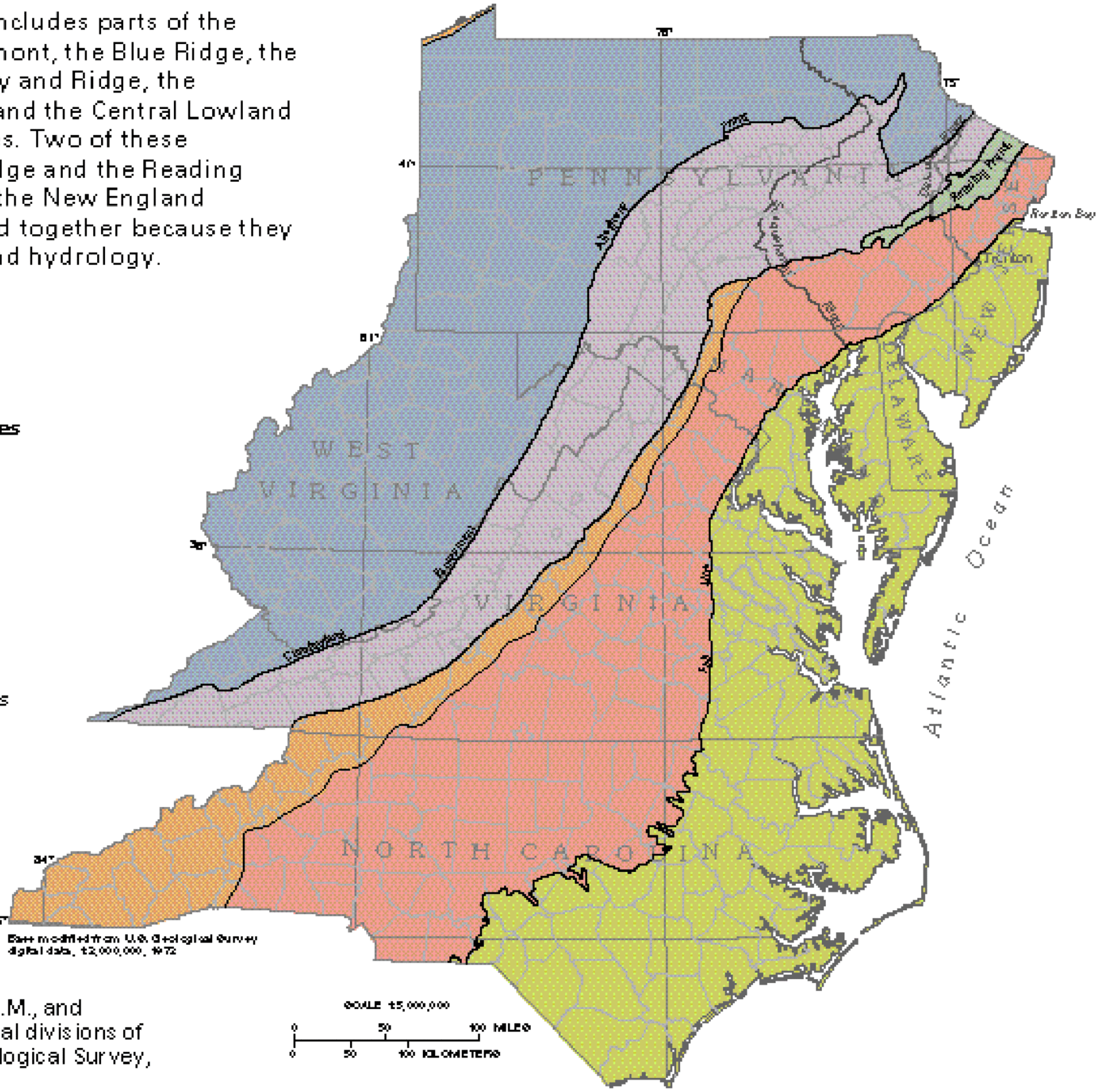


Figure 2. The patterns of average annual runoff from 1951 to 1980 are similar to those of precipitation.

Modified from Gebert, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average annual runoff in the United States, 1951–1980: U.S. Geological Survey Hydrologic Investigations Atlas HA-710, scale 1:7,500,000, 1 sheet.

Figure 3. Segment 11 includes parts of the Coastal Plain, the Piedmont, the Blue Ridge, the New England, the Valley and Ridge, the Appalachian Plateaus, and the Central Lowland Physiographic Provinces. Two of these provinces—the Blue Ridge and the Reading Prong, which is part of the New England Province—are discussed together because they have similar geology and hydrology.



EXPLANATION

Physiographic provinces

- Coastal Plain
- Piedmont
- Blue Ridge
- New England
- Valley and Ridge
- Appalachian Plateaus
- Central Lowland

Modified from Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.

Figure 5. The Allegheny Front, which forms the eastern margin of the northern Appalachian Plateaus, was an obstacle to east–west transportation in Pennsylvania. The Pennsylvania Railroad's ascent of the Front by construction of the Horseshoe Curve in 1854 was a major engineering feat.

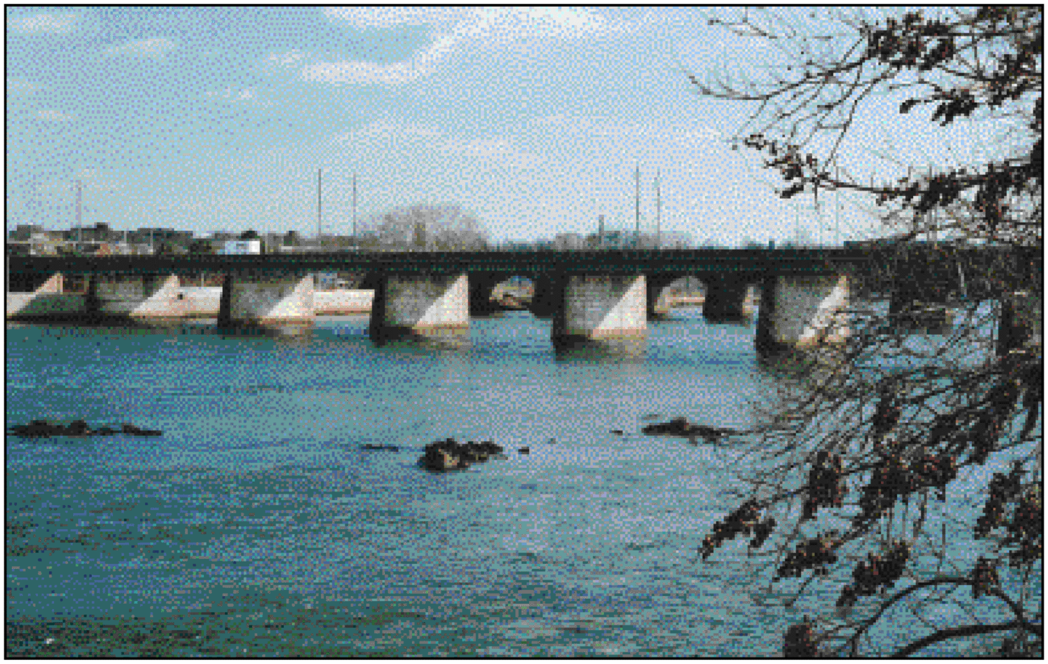


Figure 4. Consolidated rocks that protrude above the surface of the Delaware River mark the Fall Line at Trenton, N.J. Only small, shallow-draft boats can navigate the river upstream of the Fall Line.

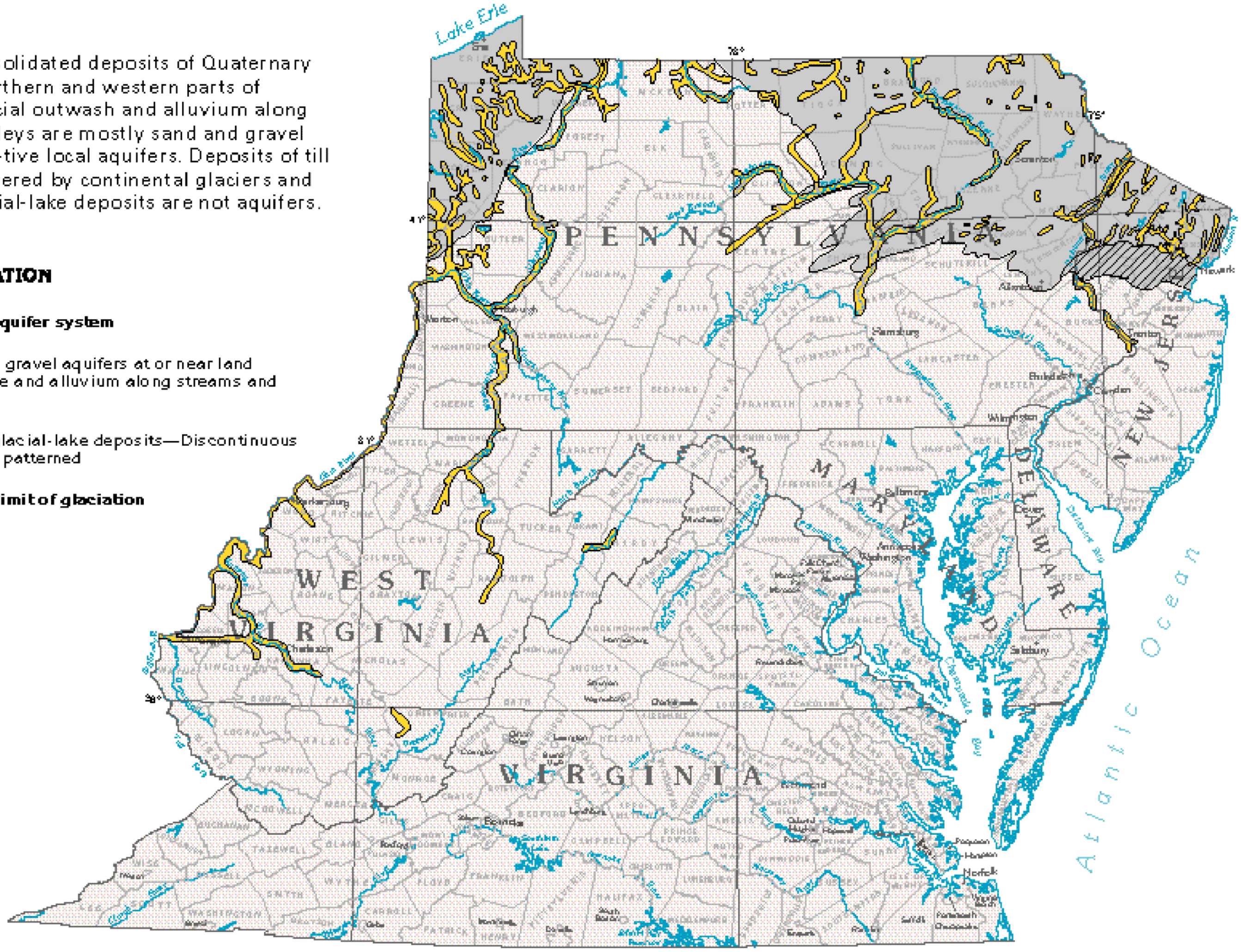
Figure 6. Unconsolidated deposits of Quaternary age are in the northern and western parts of Segment 11. Glacial outwash and alluvium along major stream valleys are mostly sand and gravel that form produc-tive local aquifers. Deposits of till in areas once covered by continental glaciers and fine-grained glacial-lake deposits are not aquifers.

EXPLANATION

Surficial aquifer system

- Sand and gravel aquifers at or near land surface and alluvium along streams and rivers
- Till and glacial-lake deposits—Discontinuous where patterned

Southern limit of glaciation



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 96°00'

SCALE 1:2,500,000

0 25 50 75 100 MILES

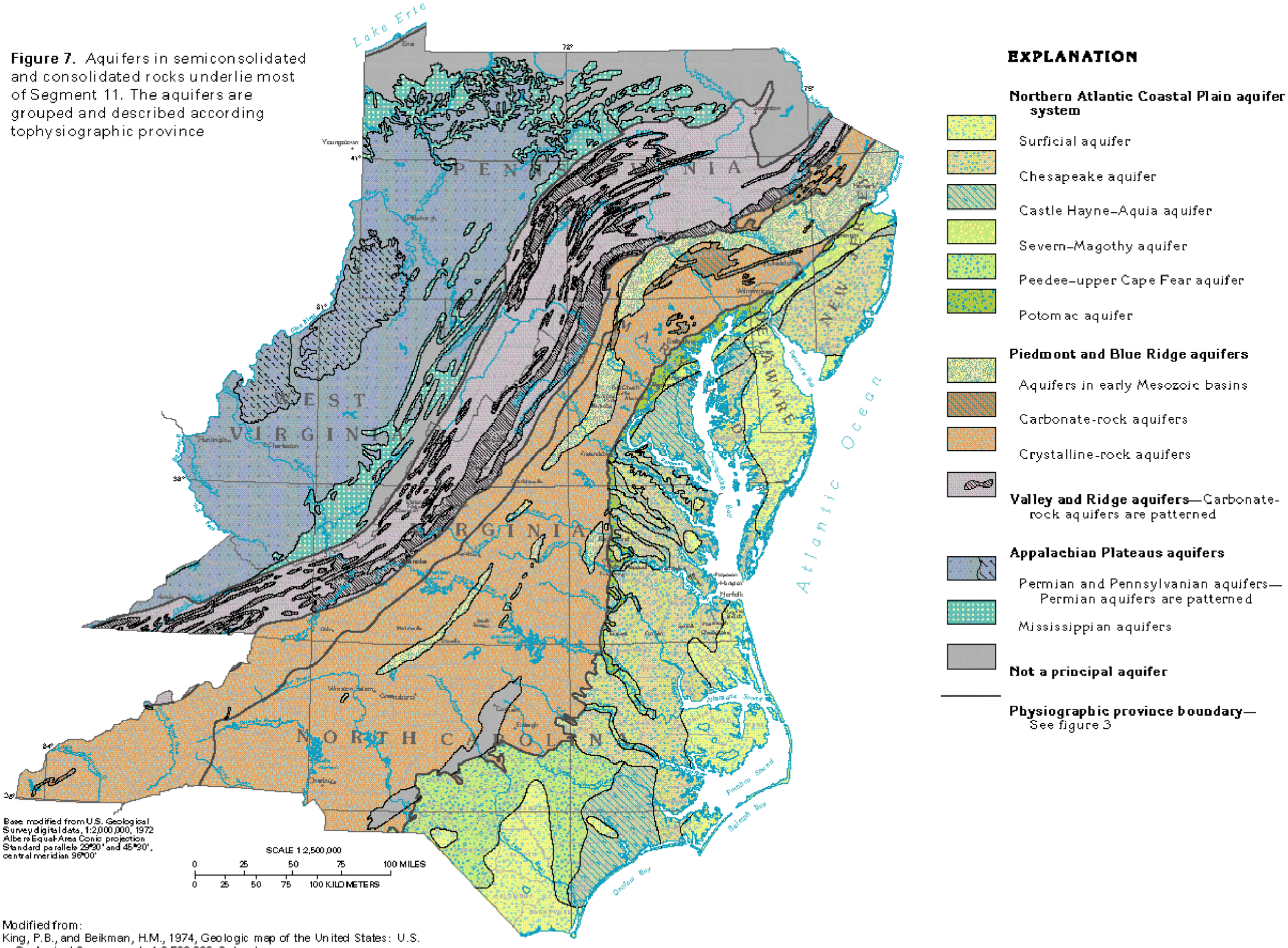
0 25 50 75 100 KILOMETERS

Modified from:

Stanford, S.D., White, R.W., and Harper, D.P., 1990, Hydrogeologic character and thickness of the glacial sediment of New Jersey: New Jersey Geological Survey Open File Map 3, scale 1:100,000, 2 sheets.

Soller, D.R., 1993, Map showing the thickness and character of Quaternary sediments in the glciated United States east of the Rocky Mountains; northeastern states, the Great Lakes, and parts of southern Ontario and the Atlantic offshore area (east of 80°31' west longitude): U.S. Geological Survey Miscel-laneous Investigations Map I-1970-A, scale 1:1,000,000, 1 sheet.

Figure 7. Aquifers in semiconsolidated and consolidated rocks underlie most of Segment 11. The aquifers are grouped and described according tophysiographic province



Modified from:
King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, scale 1:2,500,000, 3 sheets.
Pennsylvania Topographic and Geologic Survey, 1990a, Geologic map of Pennsylvania: Pennsylvania Topographic and Geological Survey Map 7, scale 1:2,000,000, 1 sheet.
_____1990b, Limestone and dolomite distribution in Pennsylvania: Pennsylvania Topographic and Geological Survey Map 15, scale 1:2,000,000, 1 sheet.
Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.

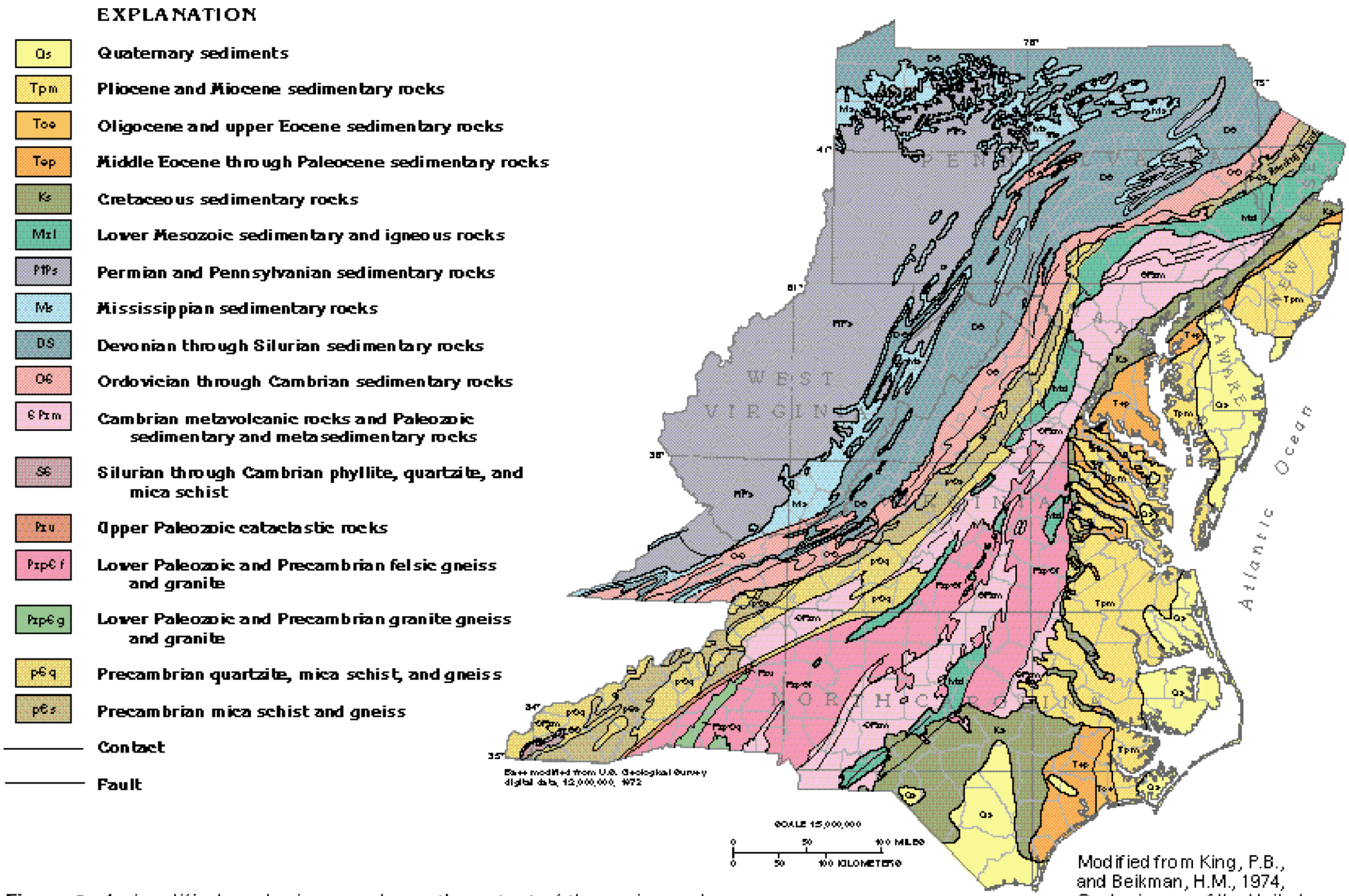


Figure 8. A simplified geologic map shows the extent of the major rock units in Segment 11. Glacial and alluvial deposits in the northern and western parts of the segment are not mapped.

Modified from King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, scale 1:2,500,000, 3 sheets.

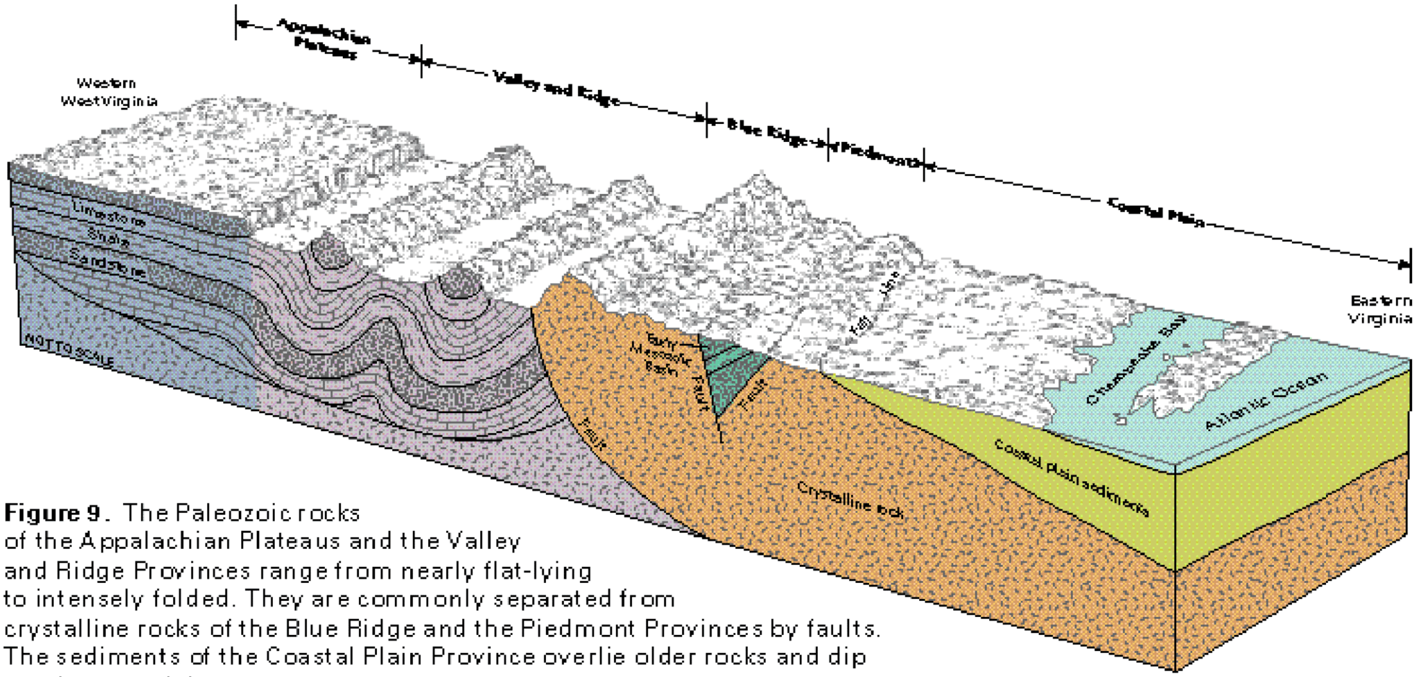


Figure 9. The Paleozoic rocks of the Appalachian Plateaus and the Valley and Ridge Provinces range from nearly flat-lying to intensely folded. They are commonly separated from crystalline rocks of the Blue Ridge and the Piedmont Provinces by faults. The sediments of the Coastal Plain Province overlie older rocks and dip gently toward the ocean.

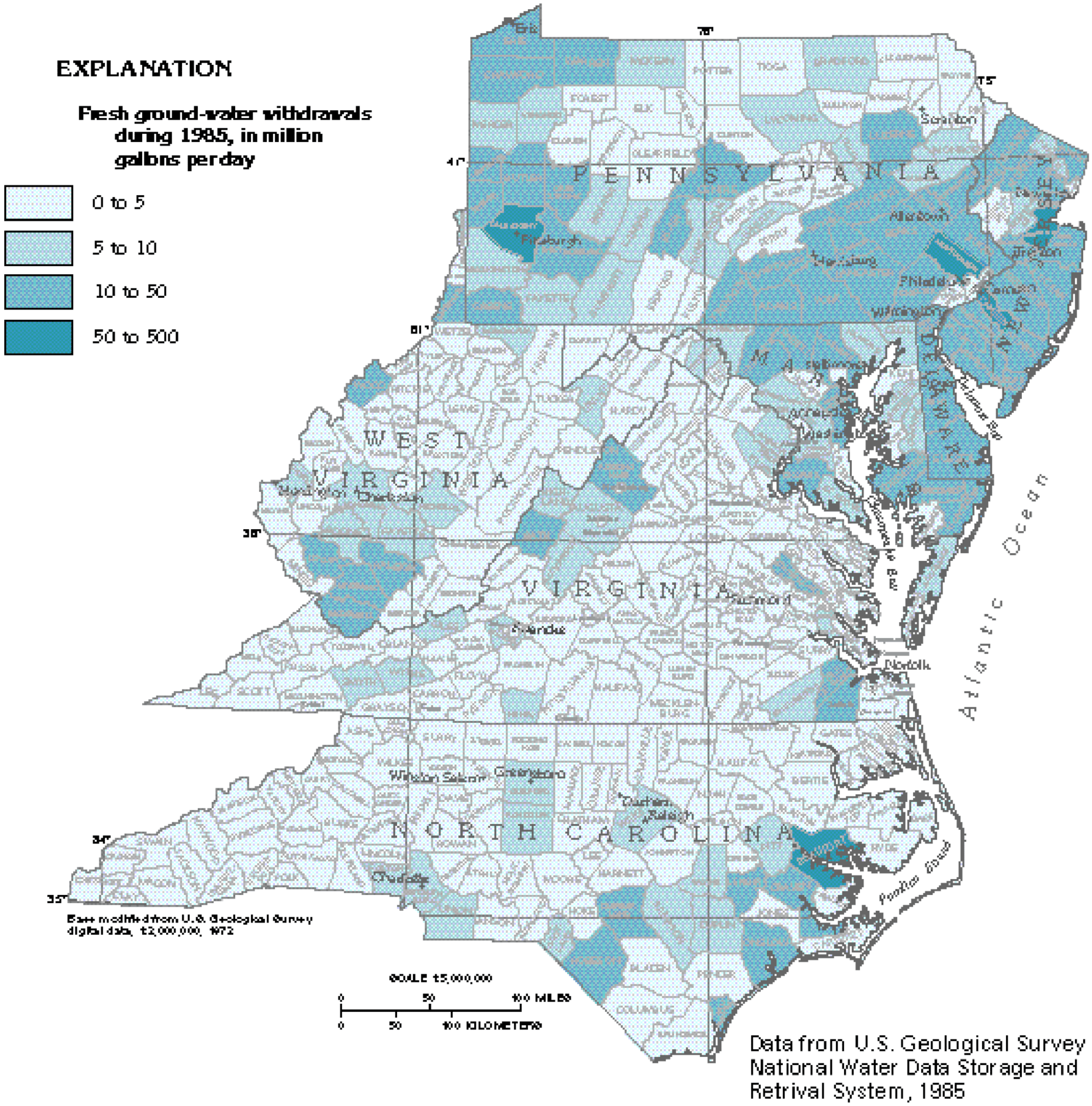
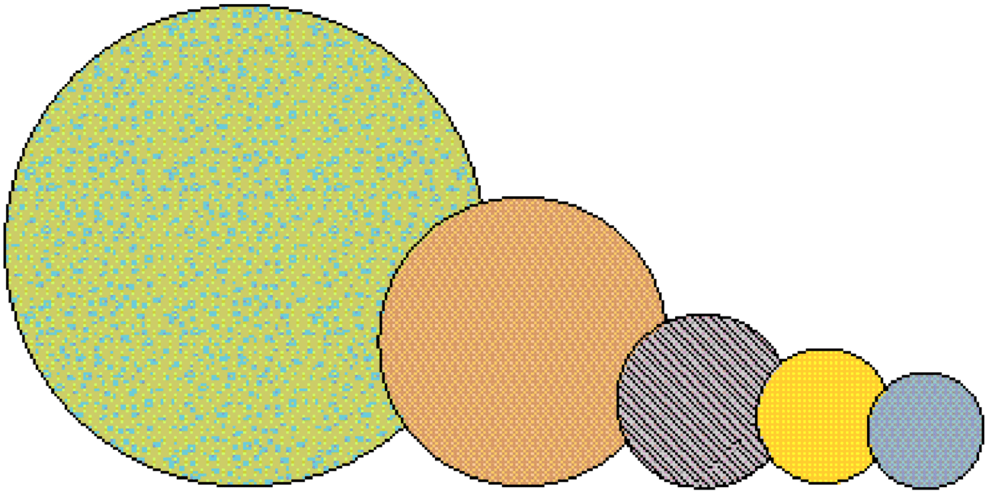


Figure 10. Fresh ground-water withdrawals during 1985 generally were greatest in counties with large populations or with industries that require large volumes of water.



Data from U.S. Geological Survey files, 1990

EXPLANATION

Fresh ground-water withdrawals during 1985, in million gallons per day

- Surficial aquifer system—320
- Northern Atlantic Coastal Plain aquifer system—1,029
- Piedmont and Blue Ridge aquifers—634
- Valley and Ridge aquifers—371
- Appalachian Plateaus aquifers—282

Figure 11. Total withdrawals of ground water were about 2,600 million gallons per day during 1985. The Northern Atlantic Coastal Plain aquifer system yielded about 40 percent of the fresh ground water withdrawn. Aquifers of the Piedmont and the Blue Ridge Physiographic Provinces were the second most-used aquifers.

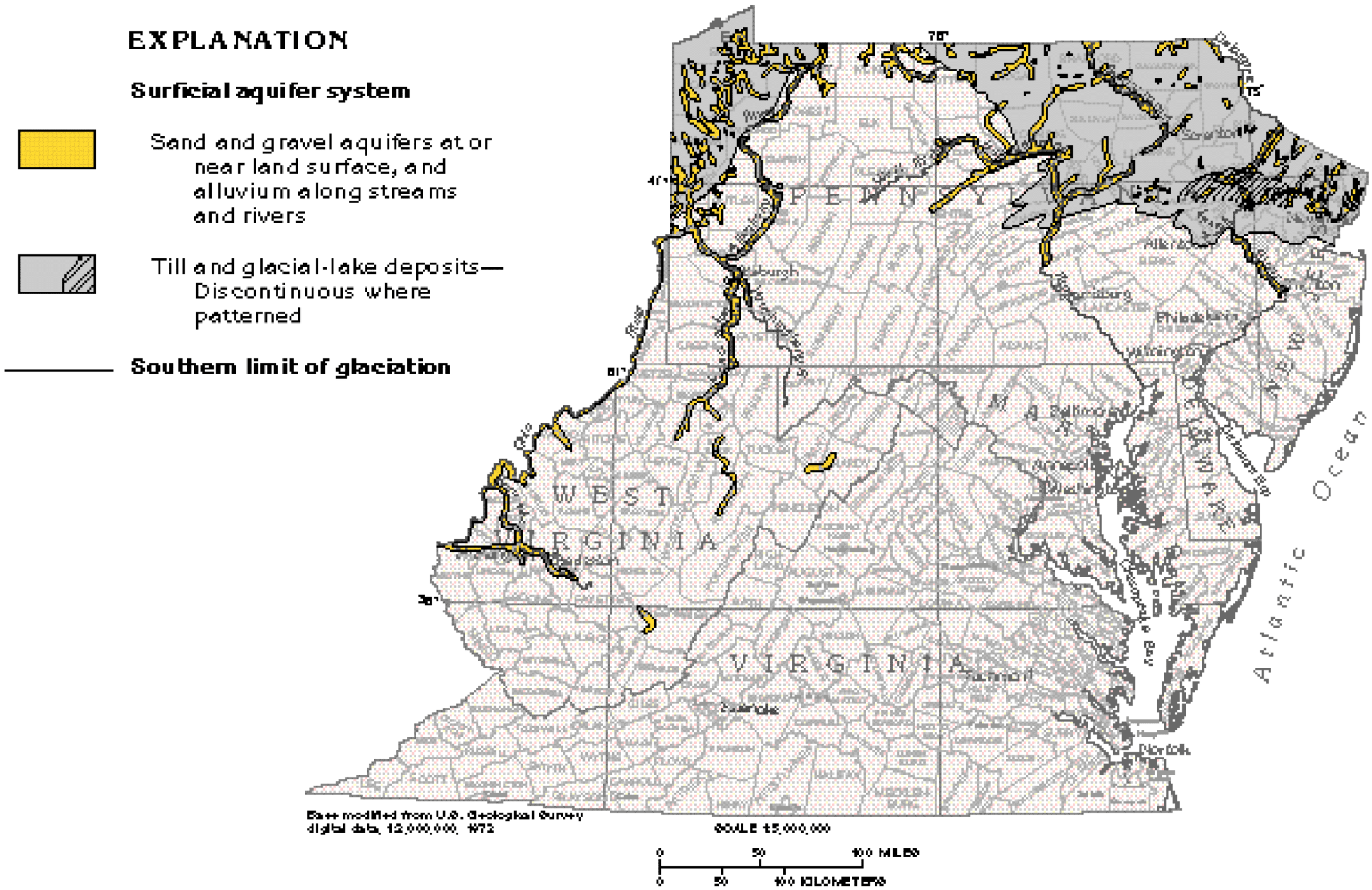


Figure 12. Aquifers in unconsolidated deposits of sand and gravel are at or near the land surface in the northern and western parts of Segment 11. These aquifers consist of glacial outwash and stream-valley alluvium, and are collectively called the surficial aquifer system.

Modified from:
Stanford, S.D., White, R.W., and Harper, D.P., 1990, Hydrogeologic character and thickness of the glacial sediment of New Jersey: New Jersey Geological Survey Open-File Map 3, scale 1:100,000, 2 sheets.
Unpublished Maps by D.R. Soller, U.S. Geological Survey

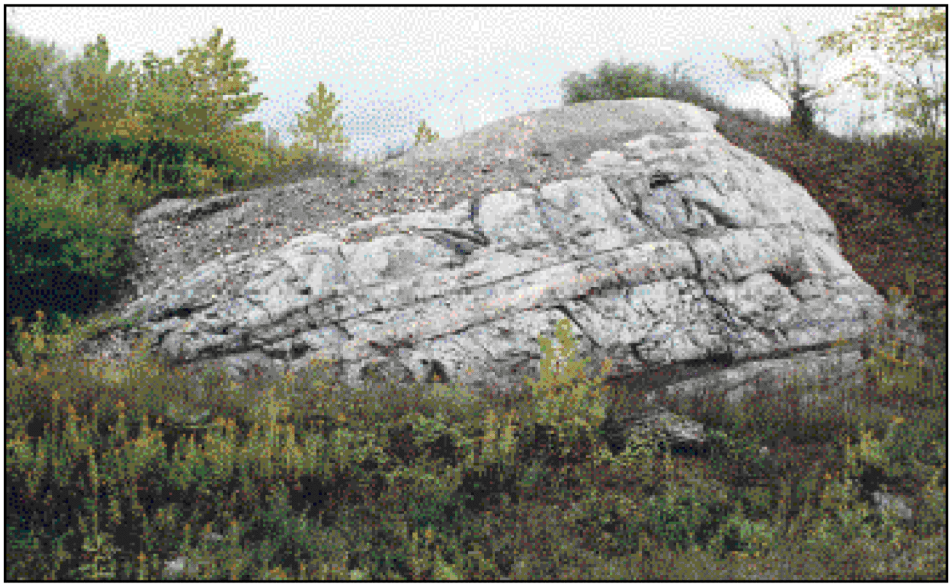
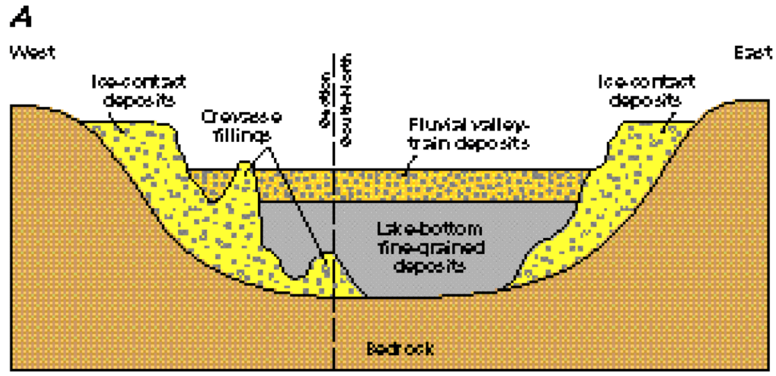
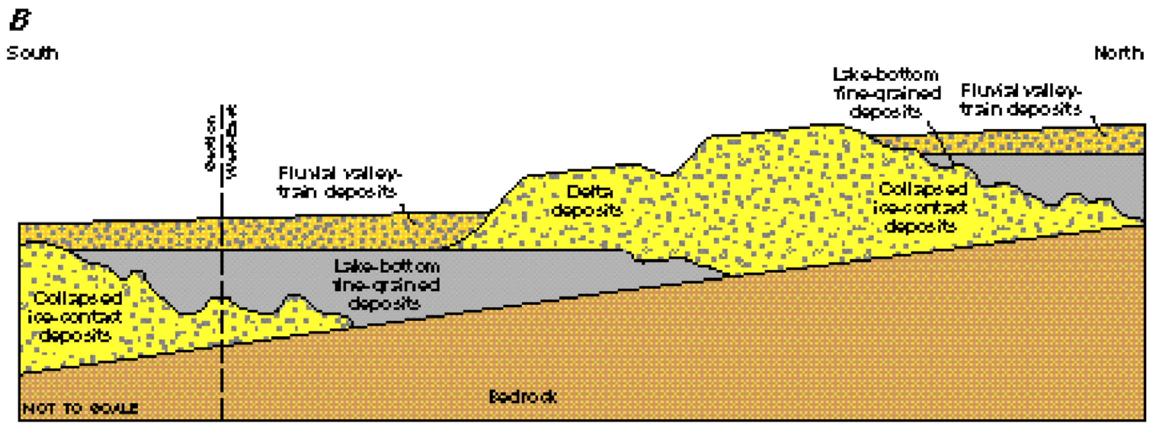


Figure 13. Outwash sand and gravel, such as the material shown here that overlies metamorphic bedrock in northern New Jersey, form productive aquifers where they are thick and saturated.

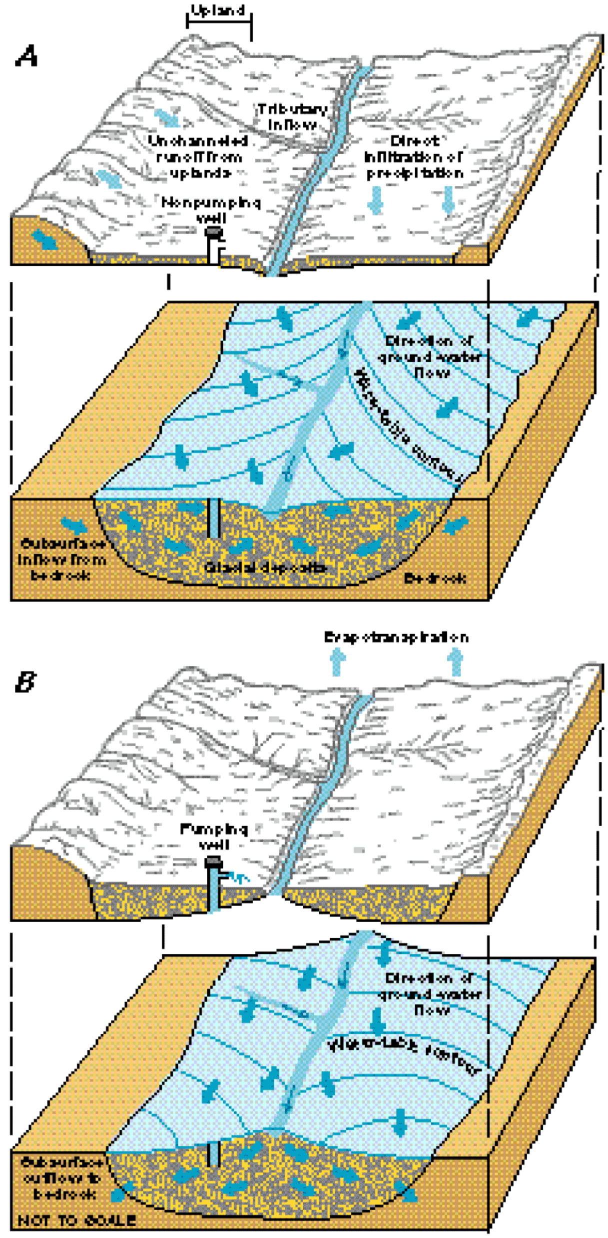
Figure 14. Coarse-grained glacial deposits commonly are in bedrock valleys. Some of these deposits (A) formed at the ice-bedrock contact, and some filled cracks or crevasses in the ice. As the ice melted, outwash deposits of sand and gravel formed deltas at the ice front or in glacial lakes and fluvial valley-train deposits (B) downstream from the ice front.





Modified from Lyford, F.P., 1986, Northeast glacial regional aquifer-system study, in Sun, R.J., ed., Regional aquifer-system analysis program of the U.S. Geological Survey—Summary of projects, 1978–1984: U.S. Geological Survey Circular 1002, p. 162–167.

Figure 15. Recharge to valley-fill aquifers is from multiple sources, and, during periods of normal precipitation, is adequate to maintain aquifer water levels above those of streams (A); water moves from the aquifer to the stream. During droughts, discharge by seepage to adjacent bedrock, evapotranspiration, and withdrawals from wells, coupled with a decrease in recharge, can lower aquifer water levels until flow is reversed and water moves from the stream to the aquifer (B).



Modified from Rosenshein, J.S., 1988, Region 18, Alluvial valleys, in Back, William, Rosenshein, J.S., and Seaber, P.R., eds., Hydrogeology: Geological Society of America, The Geology of North America, v. 0-2, p. 165-175.

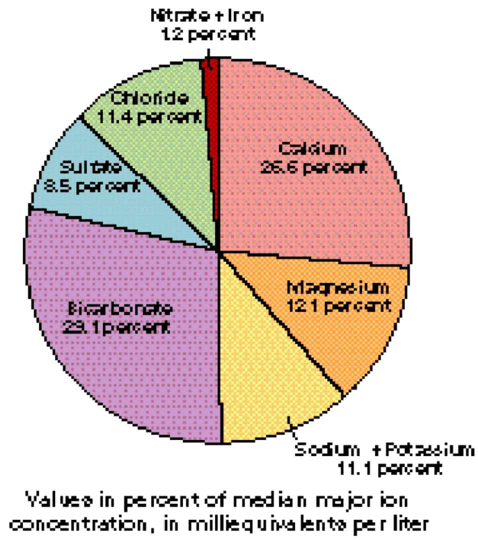


Figure 16. The median concentrations of dissolved chemical constituents in water from the sand and gravel aquifers of the surficial aquifer system show that the water is a calcium bicarbonate type.

Modified from:

Roth, D.K., Engelke, M.J., Jr., and others, 1981, Area 4, eastern coal province, Pennsylvania, Ohio, and West Virginia [Upper Ohio River, Shenango River, Mahoning River, Beaver River]: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-343, 62 p.

Ehlke, T.A., Runner, G.S., and Downs, S.C., 1982, Hydrology of Area 9, eastern coal province, West Virginia [Kanawha River, Coal River, New River, Elk River]: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-902, 63 p.

Herb, W.J., Shaw, L.C., and Brown, D.E., 1981a, Hydrology of Area 3, eastern coal province, Pennsylvania [Lower Allegheny River, Kiskiminetas River, Mahoning Creek, Redbank Creek]: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-537, 88 p.

_____1981b, Hydrology of Area 5, eastern coal province, Pennsylvania, Maryland, and West Virginia [Youghioheny, Monongahela, Tygart Valley, and Cheat Rivers]: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-538, 92 p.

Herb, W.J., Brown, D.E., Shaw, L.C., and Becher, A.E., 1983, Hydrology of Area 1, eastern coal province, Pennsylvania [West Branch Susquehanna River, Sinnemahoning Creek, Upper Juniata River, Clearfield Creek]: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-223, 78 p.

Herb, W.J., Brown, E.D. Shaw, L.C., Stoner, J.D., and Felbinger, J.K., 1983, Hydrology of Area 2, eastern coal province, Pennsylvania and New York [Middle Allegheny River, French Creek, Clarion River]: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-647, 93 p.

Friel, E.A., Ehlke, T.A., Hobba, W.A., Ward, S.M., and Schultz, R.A., 1987, Hydrology of Area 8, eastern coal province, West Virginia and Ohio [Little Kanawha River, Hocking River, Ohio River]: U.S. Geological Survey Water-Resources Investigations Open-File Report 84-463, 78 p.

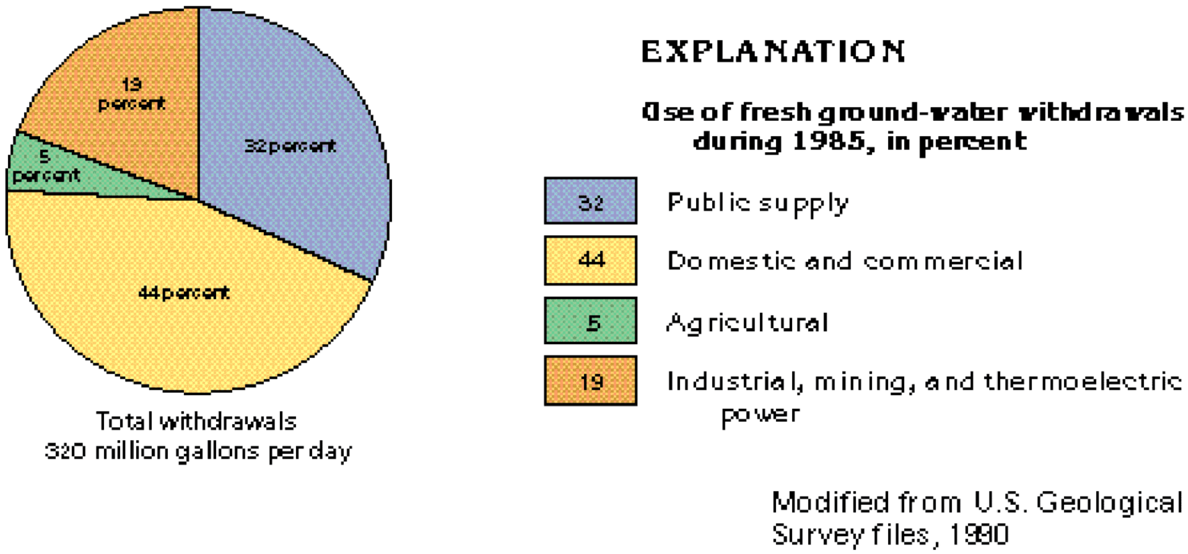


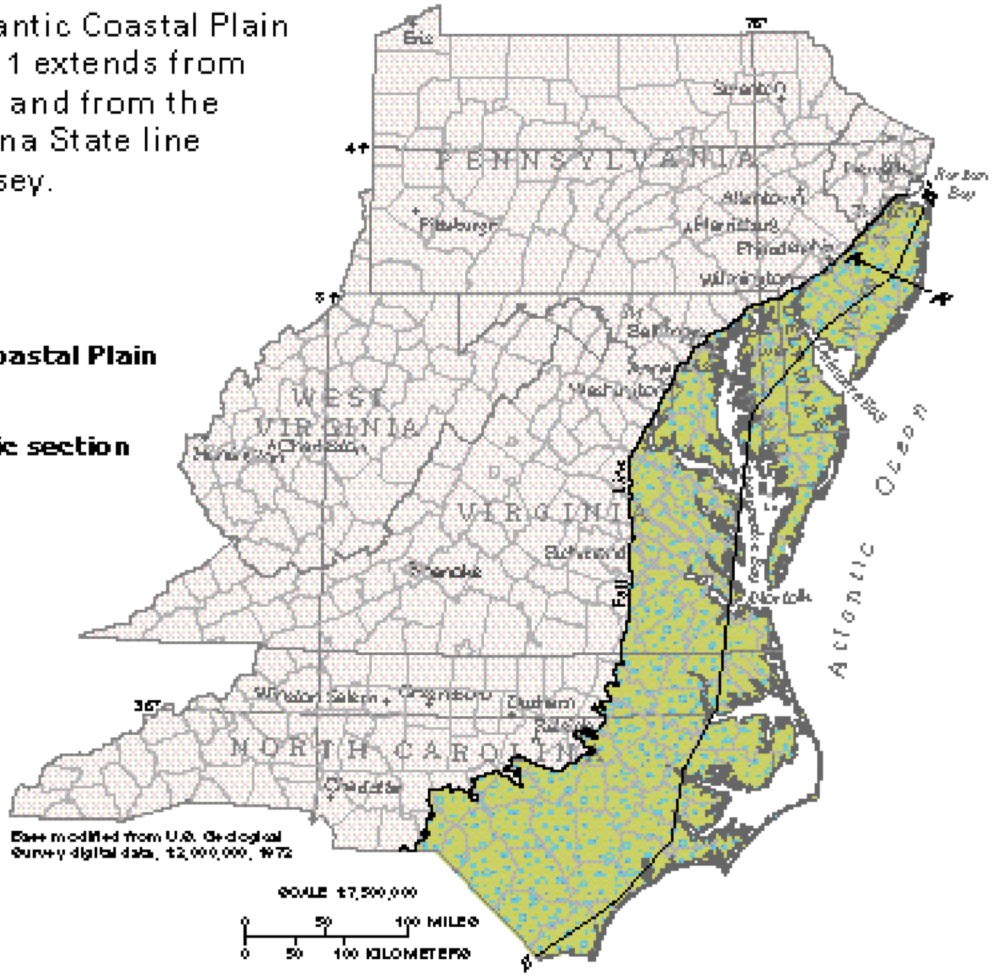
Figure 17. Most of the freshwater withdrawn from the surficial aquifer system in Segment 11 during 1985 was used for domestic and commercial purposes and public supply.

Figure 18. The Northern Atlantic Coastal Plain aquifer system in Segment 11 extends from the Fall Line to the shoreline and from the North Carolina–South Carolina State line northward through New Jersey.

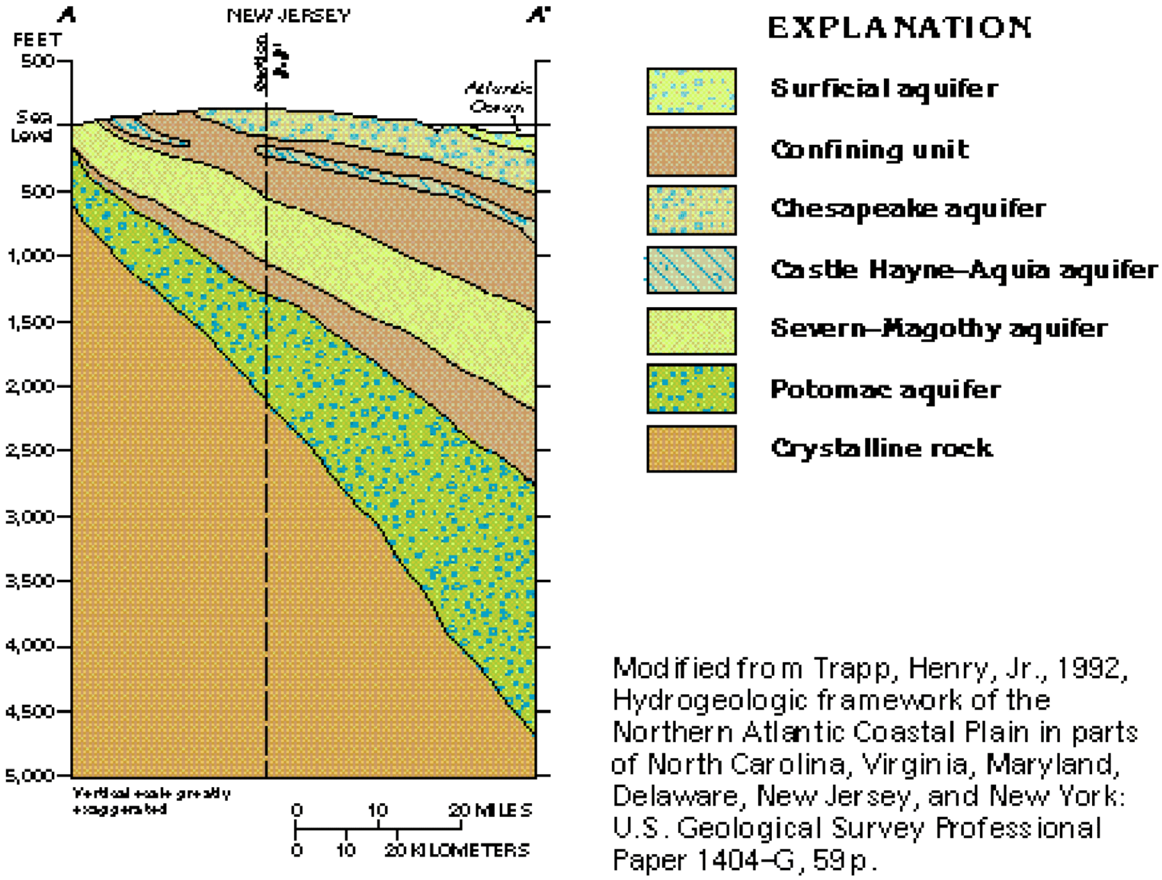
EXPLANATION

Northern Atlantic Coastal Plain aquifer system

A——*A'* **Line of hydrogeologic section**

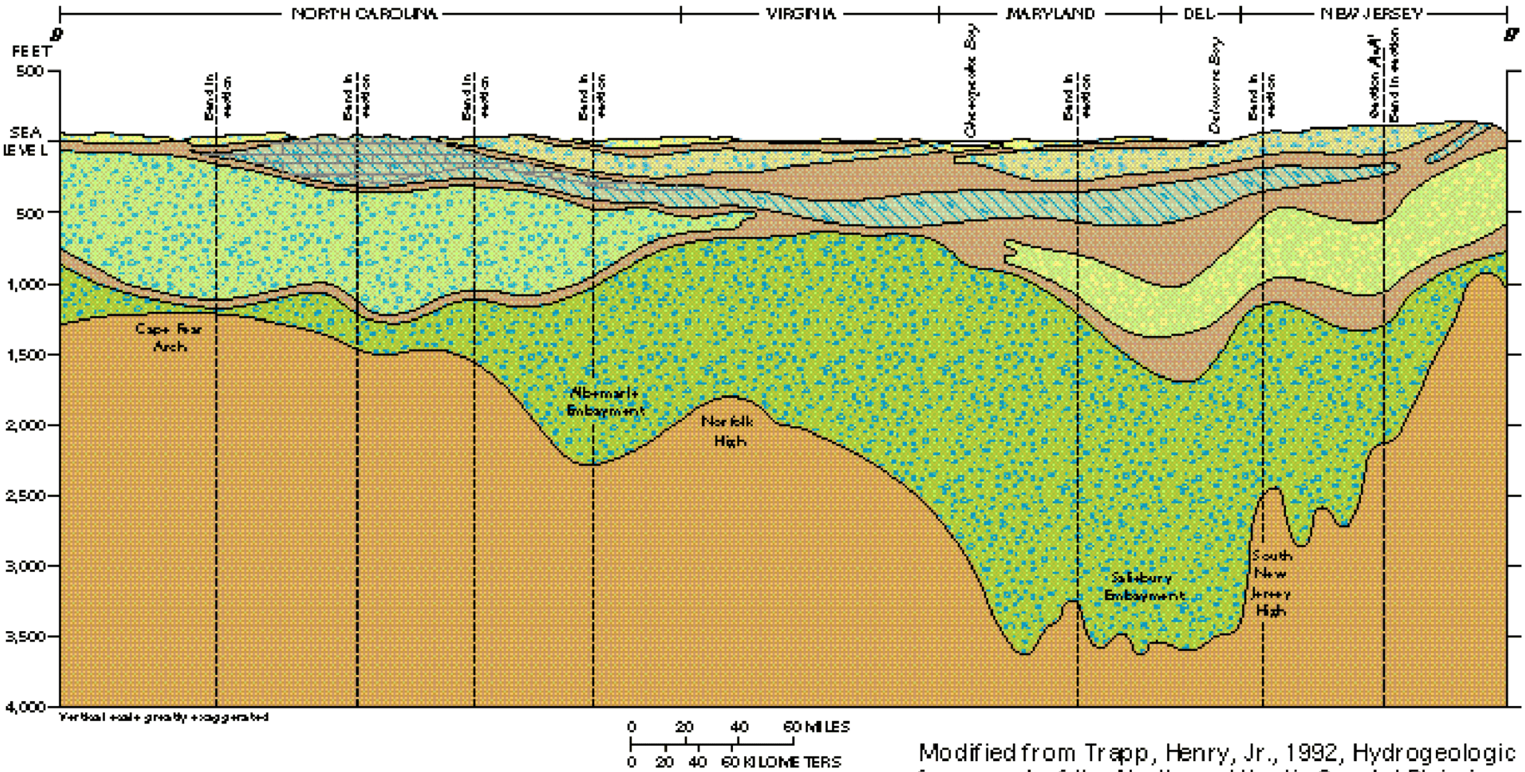


Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.



Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.

Figure 19. The sediments that compose the aquifer system are in the general shape of a wedge that thickens seaward. The line of the hydrogeologic section is shown in figure 18.



Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.

EXPLANATION

- **Surficial aquifer**
- **Confining unit**
- **Chesapeake aquifer**
- **Castle Hayne–Aquia aquifer**—Gray block pattern indicates limestone; otherwise glauconitic sand pattern indicates limestone
- **Severn–Magothy aquifer**
- **Peedee–upper Cape Fear aquifer**
- **Potomac aquifer**—Includes local basal confining unit from Delaware southward
- **Crystalline rock**

Figure 20. The aquifer system is thinner where parts of the underlying crystalline-rock surface have been upwarped and thicker where the crystalline rocks have been down-warped. The line of the hydrogeologic section is shown in figure 18.

System	Series	North Carolina	Virginia	Maryland and Delaware: Western Shore	Maryland and Delaware: Eastern Shore	New Jersey	Northern Atlantic Coastal Plain aquifer system Trapp, 1992	Principal lithology	Hydrogeologic nomenclature used in this chapter
Quaternary	Holocene	Surficial aquifer	Columbia aquifer	Surficial aquifer	Surficial aquifer	Holly Beach aquifer	Surficial aquifer	Sand and gravel	Surficial aquifer (Northern Atlantic Coastal Plain aquifer system)
	Pleistocene					Cape May confining unit			
Tertiary	Pliocene	Confining unit	Yorktown confining unit		Upper Chesapeake confining unit		Confining unit	Clay and silty clay	Confining unit
	Miocene	Yorktown aquifer	Yorktown–Eastover aquifer		Upper Chesapeake aquifer	Kirkwood–Cohansey aquifer system (upper part)	Upper Chesapeake aquifer	Sand	Chesapeake aquifer
		Confining unit	St. Marys confining unit	Lower Chesapeake confining unit	St. Marys confining unit		Confining unit	Silt and clay	
		Pungo River aquifer	St. Marys–Choptank aquifer		Lower Chesapeake aquifer	Kirkwood–Cohansey aquifer system (lower part)	Lower Chesapeake aquifer	Sand, locally phosphatic	
		Confining unit	Calvert confining unit	Lower Chesapeake confining unit	Lower Chesapeake confining unit	Basal Kirkwood confining unit	Confining unit	Clay and sandy clay	Confining unit
	Oligocene	Castle Hayne aquifer	Chickahominy–Piney Point aquifer	Piney Point–Nanjemoy aquifer	Piney Point–Nanjemoy aquifer	Piney Point aquifer	Castle Hayne–Piney Point aquifer	Limestone and fine to coarse, glauconitic sand	Castle Hayne–Aquia aquifer
	Eocene	Confining unit	Nanjemoy–Marlboro confining unit	Nanjemoy–Marlboro confining unit	Nanjemoy–Marlboro confining unit	Vincentown–Manasquan confining unit	Confining unit	Silt and clay	
	Paleocene	Beaufort aquifer	Aquia aquifer	Aquia–Rancocas aquifer	Aquia–Rancocas aquifer	Vincentown aquifer	Beaufort–Aquia aquifer	Fine to coarse, glauconitic or shelly sand	
		Confining unit		Brightseat confining unit	Brightseat confining unit	Navesink–Hornerstown confining unit	Confining unit	Silt and clay	Confining unit
Cretaceous		Peedee aquifer		Severn aquifer	Severn aquifer	Wenonah–Mt. Laurel aquifer	Peedee–Severn aquifer	Fine to medium, glauconitic sand	[1] Peedee–upper Cape Fear aquifer / [2] Severn–Magothy aquifer
		Confining unit		Severn confining unit	Severn confining unit	Marshalltown–Wenonah confining unit	Confining unit	Clay and silt	
		Black Creek aquifer			Matawan aquifer	Englishtown aquifer	Black Creek–Matawan aquifer	Fine to medium, clayey sand	
		Confining unit	Upper Potomac confining unit	Matawan confining unit	Matawan confining unit	Merchantville–Woodbury confining unit	Confining unit	Clay and silty clay	
		Upper Cape Fear aquifer	Upper Potomac aquifer	Magothy aquifer	Magothy aquifer	Potomac–Raritan–Magothy aquifer system: Upper Potomac-Raritan-Magothy aquifer	[1] Potomac aquifer / [2] Magothy aquifer	Fine to medium sand	
		Confining unit	Middle Potomac confining unit	Patapsco confining unit	Patapsco confining unit	Confining unit	Confining unit	Clay and sandy clay	Confining unit
		Lower Cape Fear aquifer	Middle Potomac aquifer	Patapsco aquifer	Patapsco aquifer	Middle Potomac-Raritan-Magothy aquifer	Middle Potomac aquifer	Fine to medium sand	Potomac aquifer
		Confining unit	Lower Potomac confining unit	Potomac confining unit	Potomac confining unit	Confining unit	Confining unit	Clay and sandy clay	
		Lower Cretaceous aquifer	Lower Potomac aquifer	Patuxent aquifer	Patuxent aquifer	Lower Potomac-Raritan-Magothy aquifer	Lower Potomac aquifer	Fine to coarse sand	
		Confining unit	Confining unit	Confining unit	Confining unit		Sediments underlying the lower Potomac aquifer	Clay and silt	Confining unit

[1]Southern Virginia and southward
[2]Delmarva Peninsula and northward

Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.

Figure 21. Although a large number of local aquifers and confining units have been identified in the sediments of the Northern Atlantic Coastal Plain, these hydrogeologic units can be grouped into six regional aquifers separated by four confining units. The chart does not show exact thicknesses or correlations of the aquifers and confining units. The gray areas represent missing rocks.

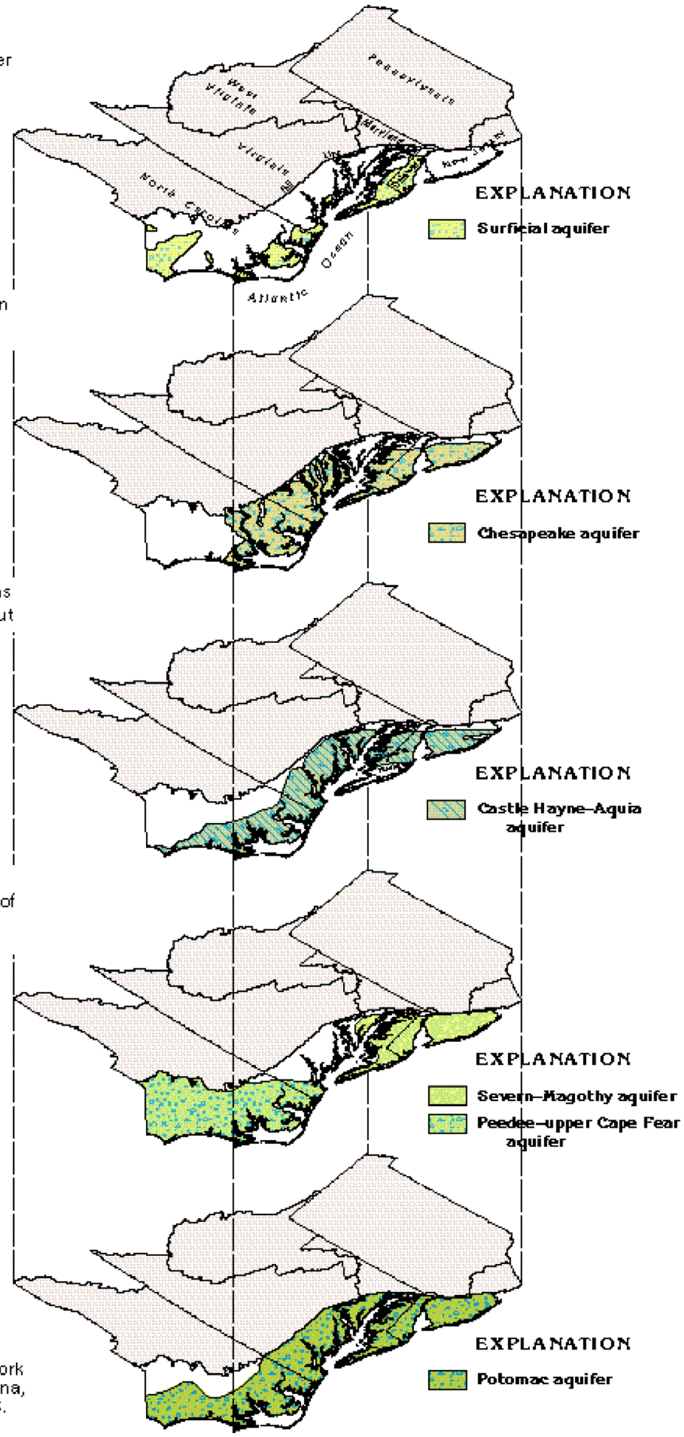


Figure 22. The surficial aquifer is the uppermost aquifer in the Northern Atlantic Coastal Plain aquifer system but is of limited extent.

Figure 23. Sands of the Chesapeake aquifer form an extensive water-yielding unit that extends from the Fall Line to the coastline in places.

Figure 24. The Castle Hayne–Aquia aquifer is not as widespread as the overlying Chesapeake aquifer, but yields large volumes of water in North Carolina where it consists of limestone. Elsewhere, the aquifer consists of sand that becomes clayey and almost impermeable on the Delmarva Peninsula.

Figure 25. The Severn–Magothy and the Peedee–upper Cape Fear aquifers are in sand beds of equivalent age, but are not known to be connected. Both aquifers are underlain and overlain by confining units that consist mostly of clay.

Figure 26. The Potomac aquifer is the lowermost and most widespread aquifer in the Northern Atlantic Coastal Plain aquifer system. The aquifer consists of a thick sequence of sand beds and lies directly on crystalline bedrock in most places but locally is underlain by a clayey confining unit.

Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Caro-lina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

Figure 22. The surficial aquifer is the uppermost aquifer in the Northern Atlantic Coastal Plain aquifer system but is of limited extent.

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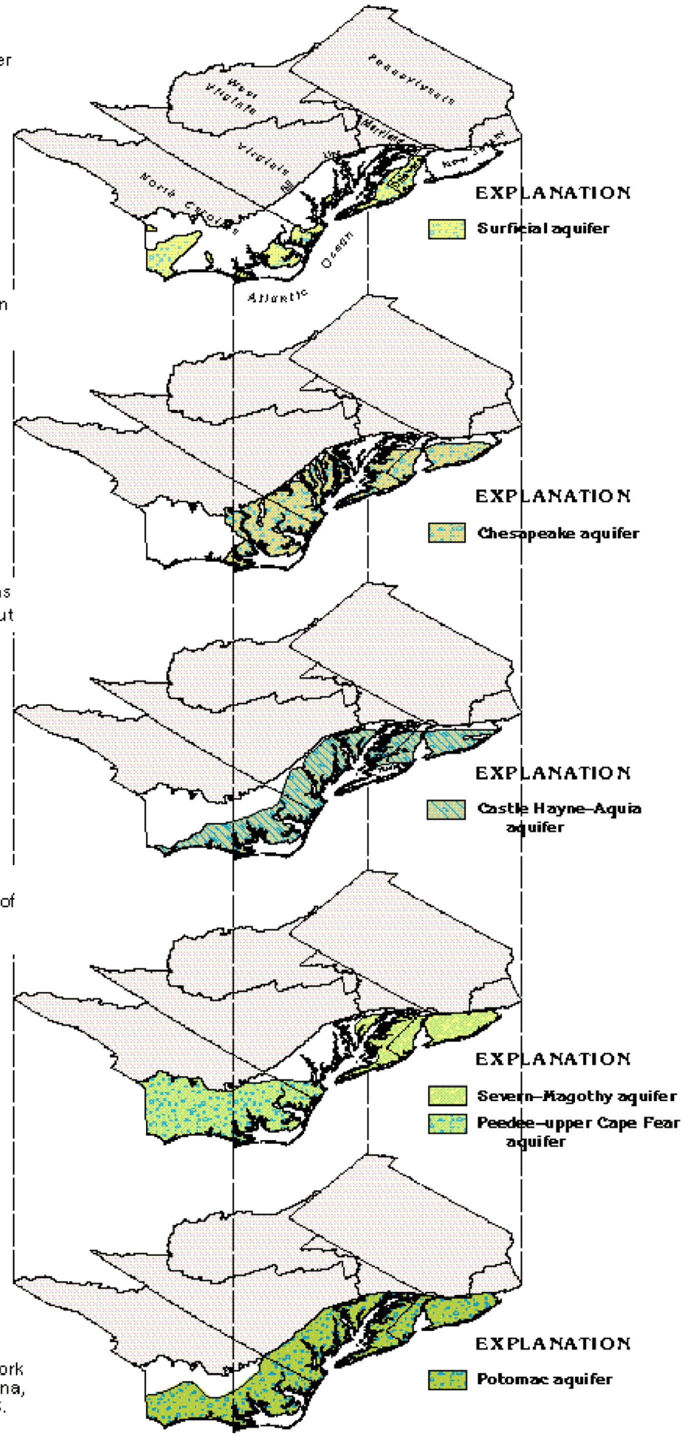

Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Caro-lina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

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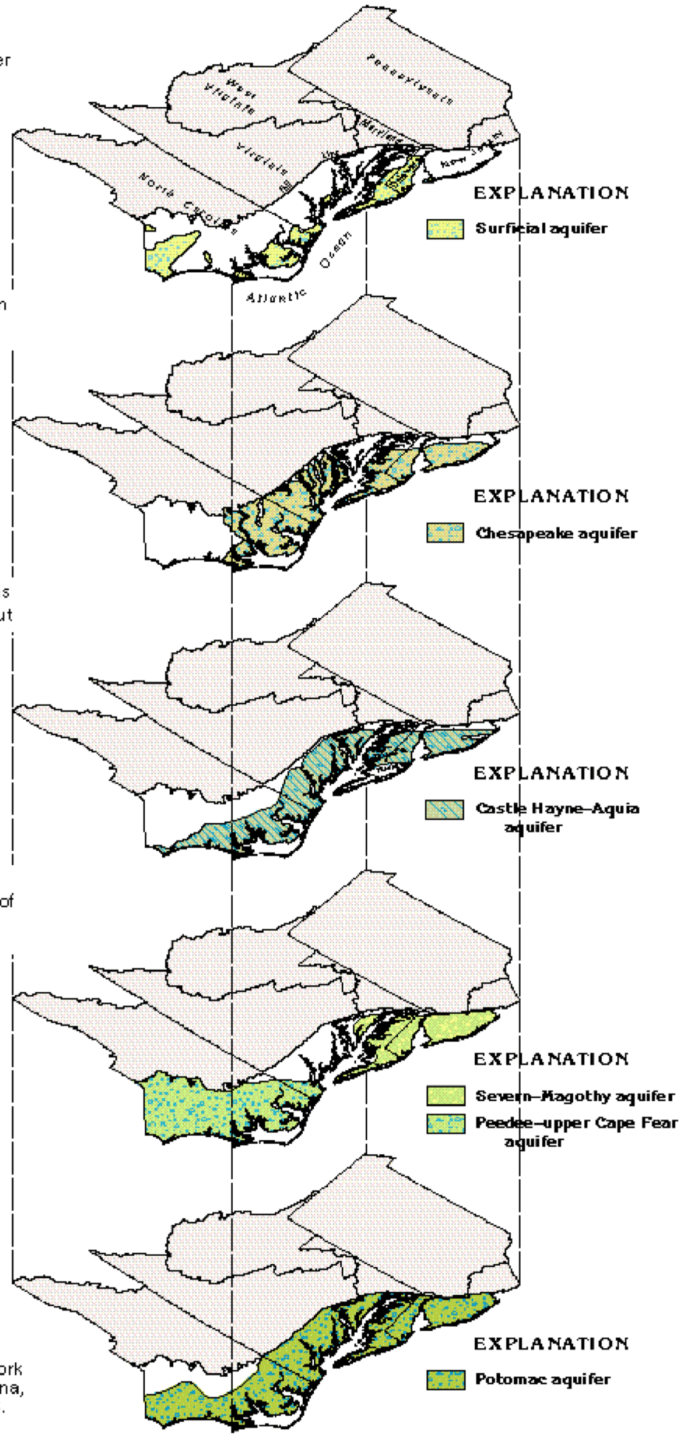
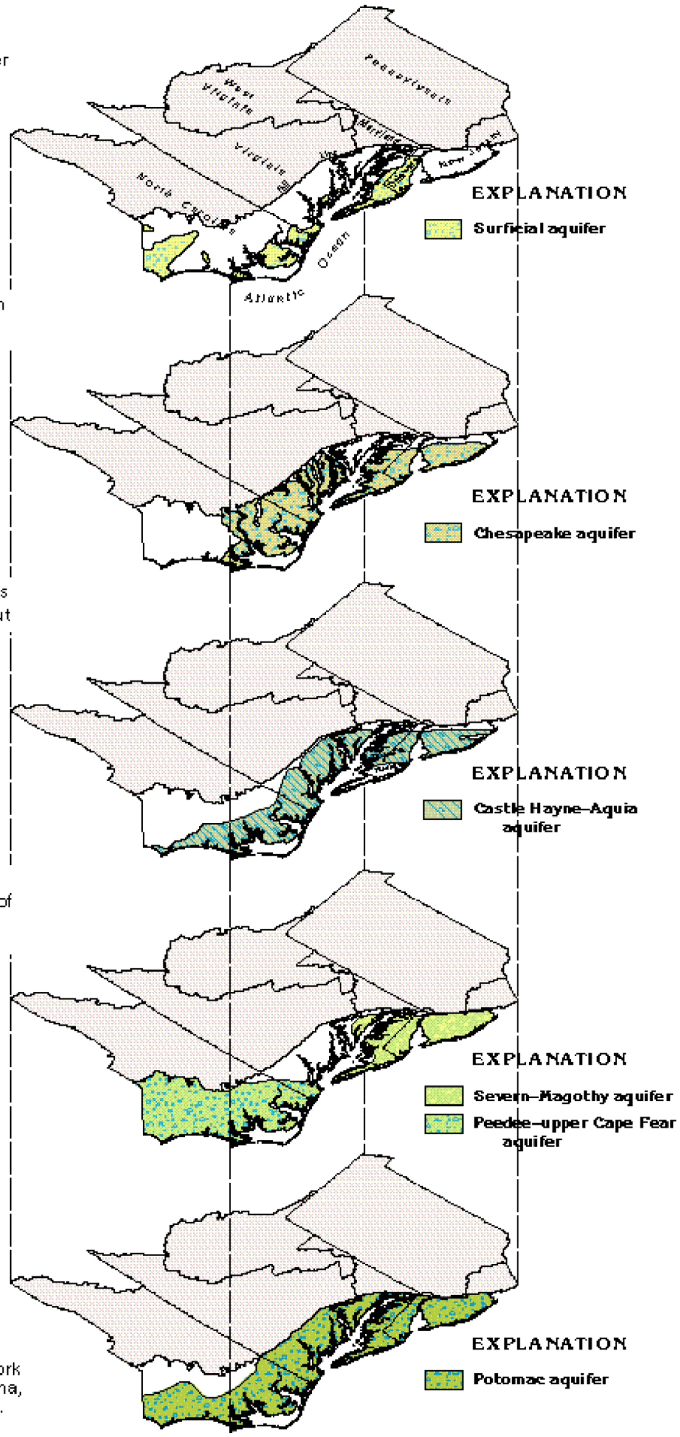


Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Caro-lina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.



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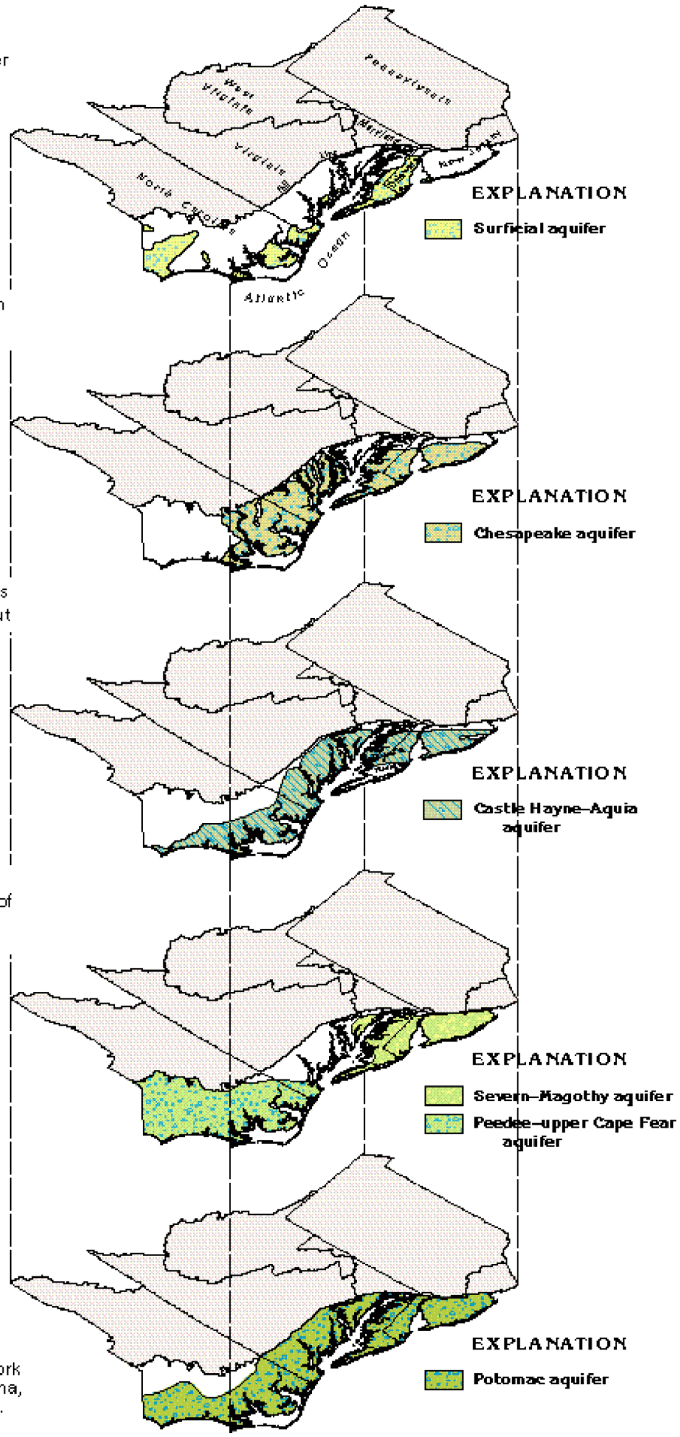
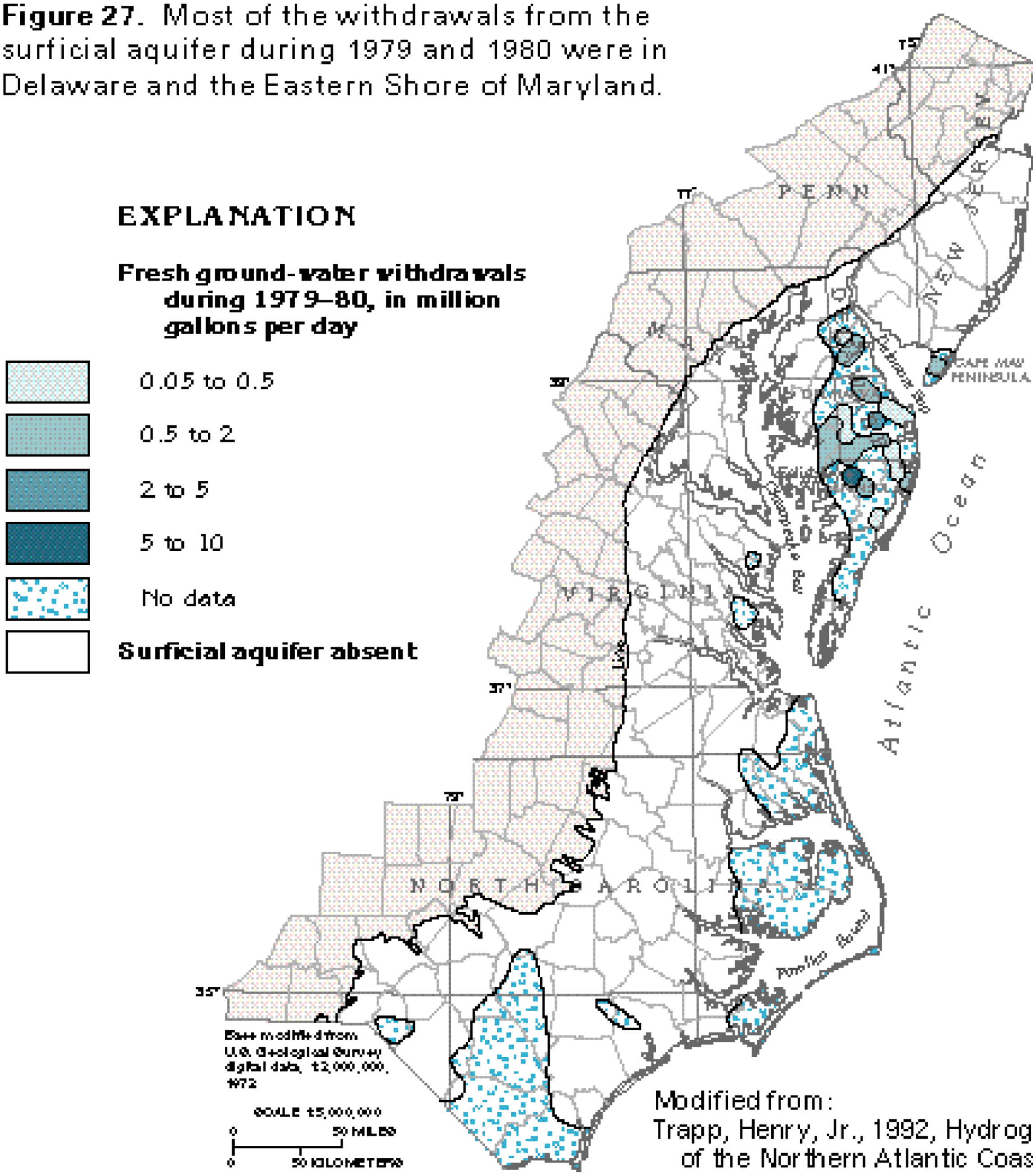


Modified from Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Caro-lina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

Figure 27. Most of the withdrawals from the surficial aquifer during 1979 and 1980 were in Delaware and the Eastern Shore of Maryland.



Modified from:

Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.

Data in the files of the U.S. Geological Survey

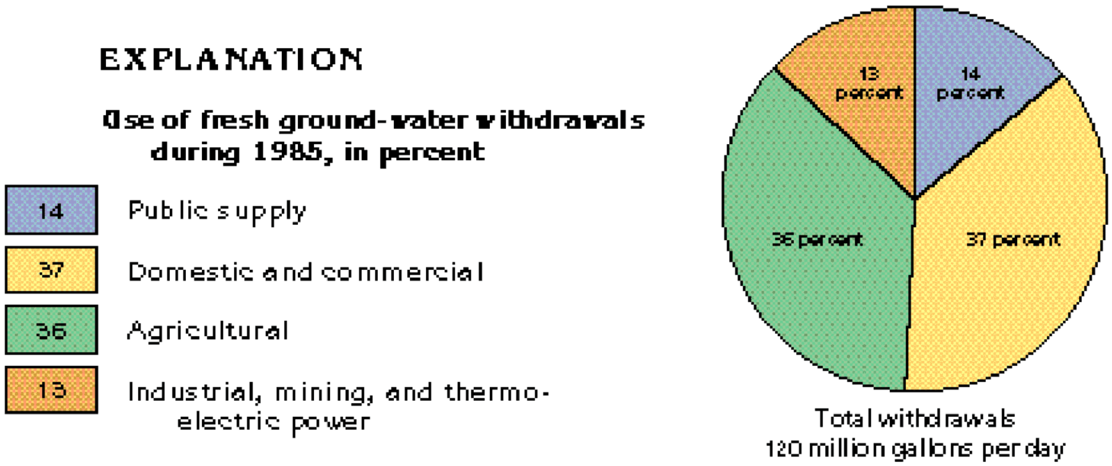


Figure 28. Most of the freshwater withdrawn from the surficial aquifer in the Northern Atlantic Coastal Plain during 1985 was used for domestic and commercial supplies and agriculture.

Modified from U.S. Geological Survey files, 1990

Figure 29. The top of the Chesapeake aquifer is more than 100 feet above sea level in central Virginia and slopes gently to depths of more than 300 feet below sea level along the Outer Banks of North Carolina. The ability of the aquifer to transmit water is greatest in coastal areas of New Jersey, Delaware, Maryland, and North Carolina.

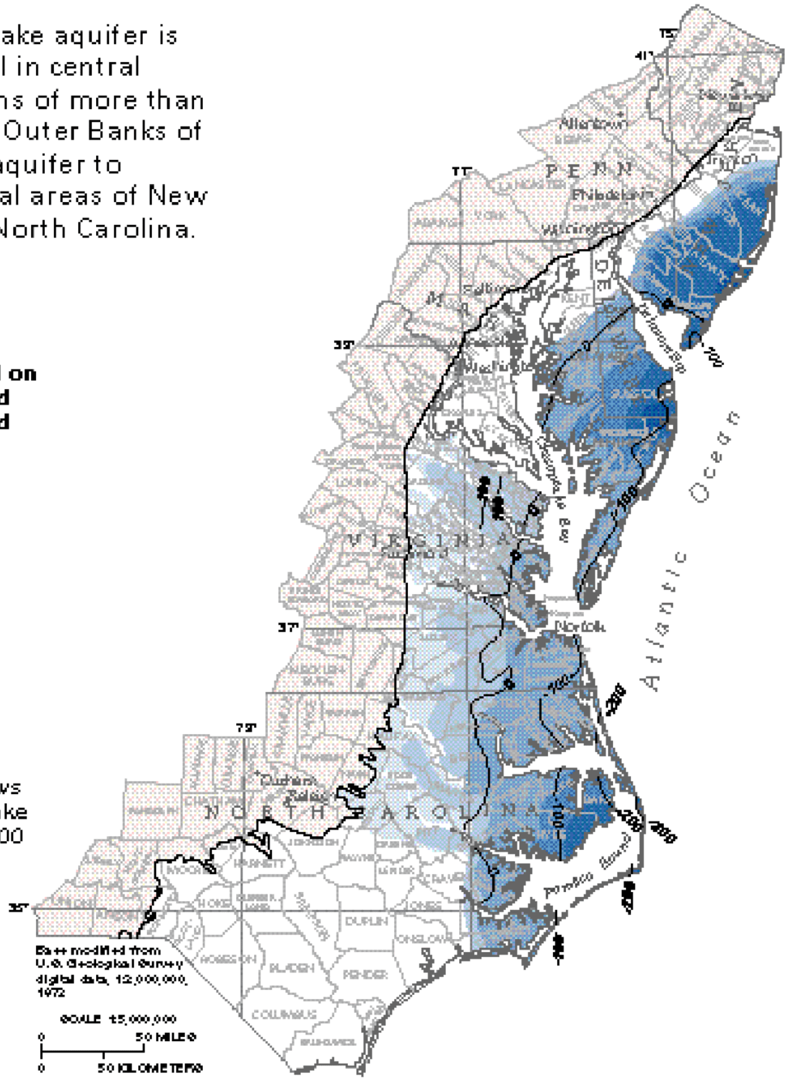
EXPLANATION

Estimated transmissivity of Chesapeake aquifer based on aquifer tests, geology, and simulation, in feet squared per day

500
1,000
5,000
10,000
20,000

Chesapeake aquifer absent

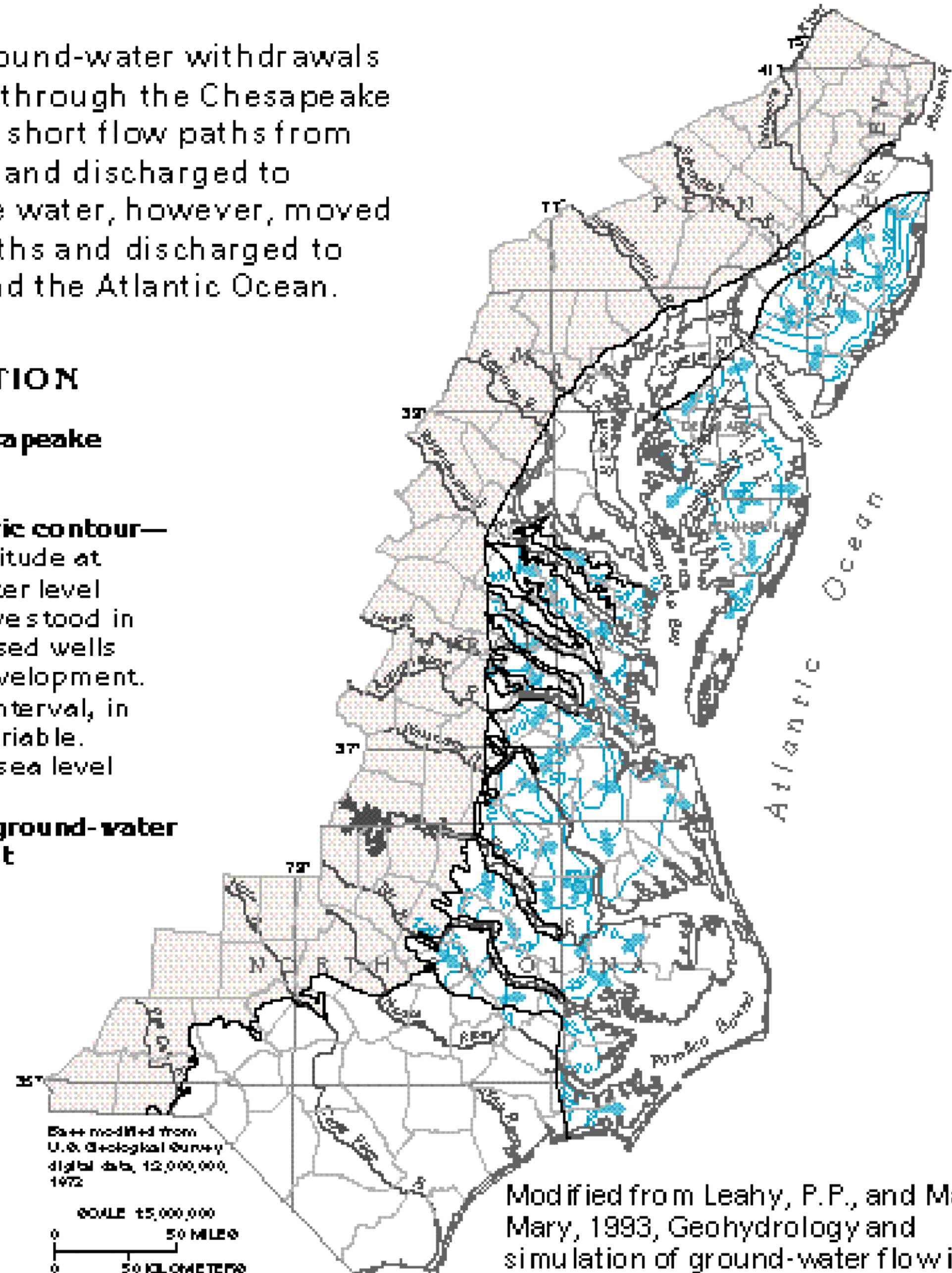
—100— **Top-of-aquifer contour**—Shows altitude of top of Chesapeake aquifer. Contour interval 100 feet. Datum is sea level



Modified from:

Meisler, Harold, 1989, The occurrence and geochemistry of salty ground water in the Northern Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 1404–D, 51 p.
Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.
Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.
Winner, M.D., Jr., and Coble, R.W., 1996, Hydrogeologic framework of the North Carolina Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–I.

Figure 30. Before ground-water withdrawals began, water moved through the Chesapeake aquifer mostly along short flow paths from high to low altitudes and discharged to streams. Some of the water, however, moved along longer flow paths and discharged to estuaries, sounds, and the Atlantic Ocean.

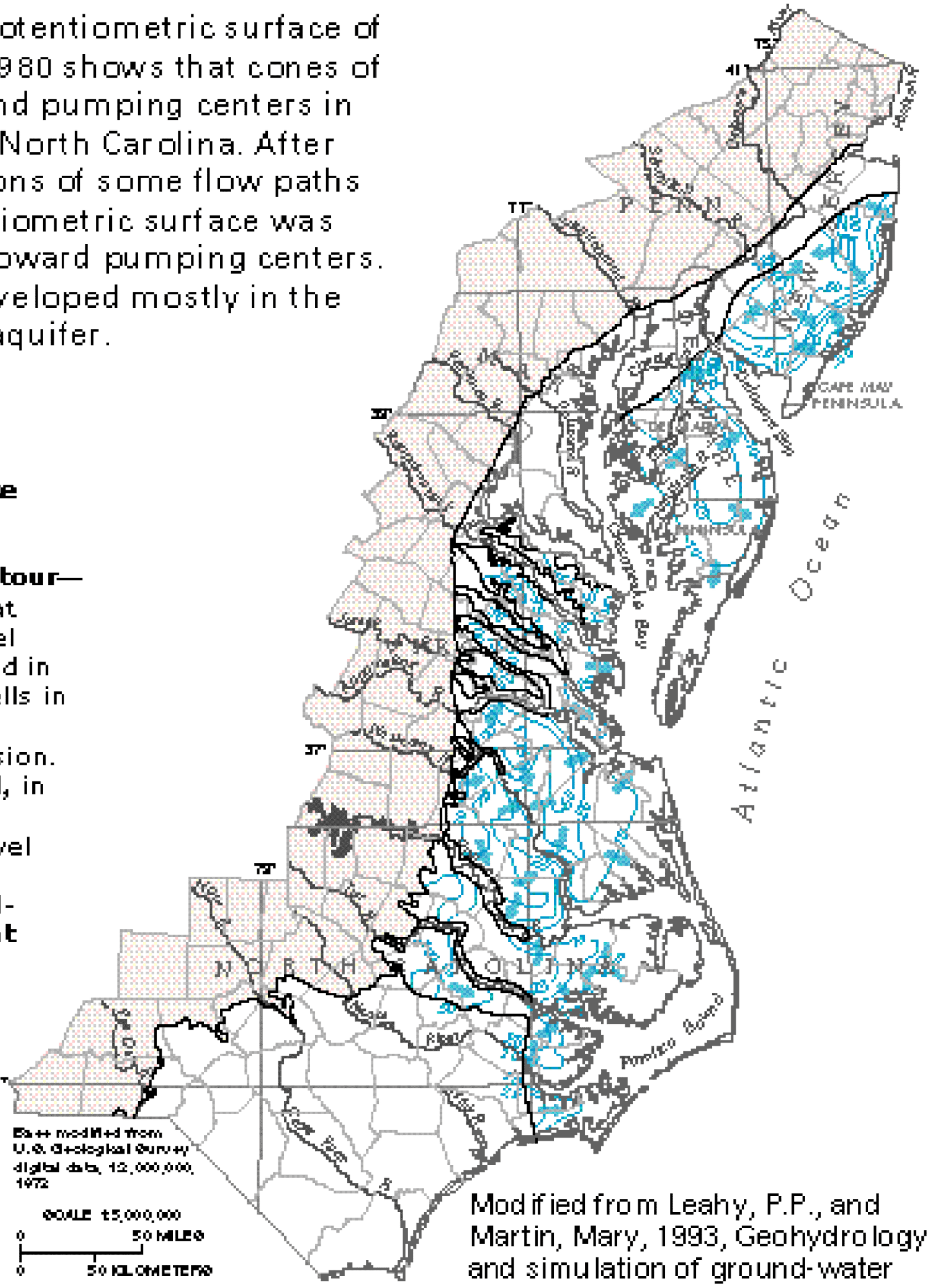


Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Figure 31. The composite potentiometric surface of the Chesapeake aquifer in 1980 shows that cones of depression developed around pumping centers in New Jersey, Delaware, and North Carolina. After pumping began, the directions of some flow paths were reversed as the potentiometric surface was lowered and water moved toward pumping centers. The cones of depression developed mostly in the lower, confined part of the aquifer.

EXPLANATION

- **Limit of Chesapeake aquifer**
- **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells in 1980. Hachures indicate depression. Contour interval, in feet, is variable. Datum is sea level
- **Direction of ground-water movement**



Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Figure 32. The hydrochemical facies of water in the Chesapeake aquifer change progressively seaward from a variable-composition facies to a sodium chloride facies. Dissolved-solids concentrations in the water increase in a seaward direction.

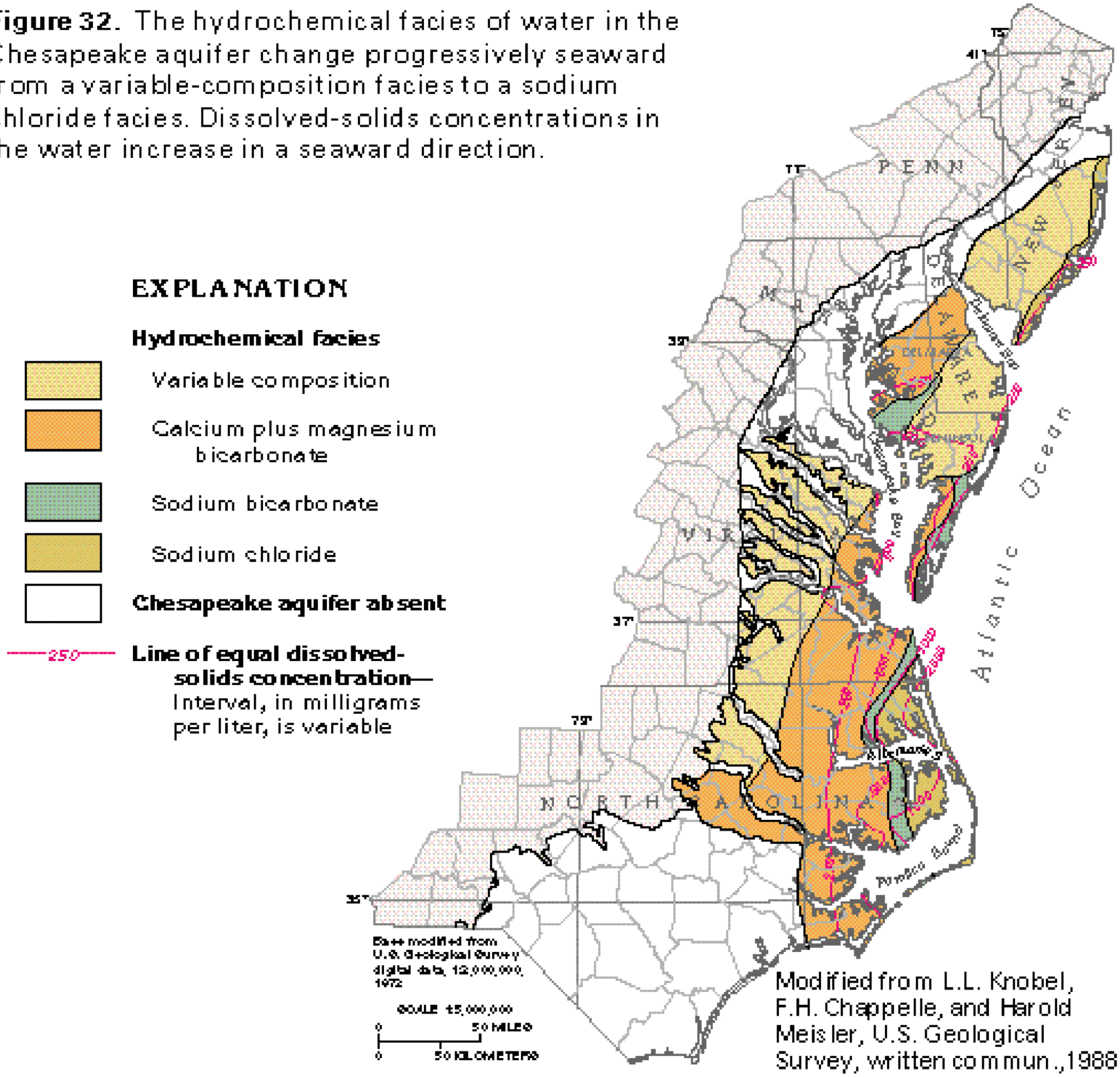
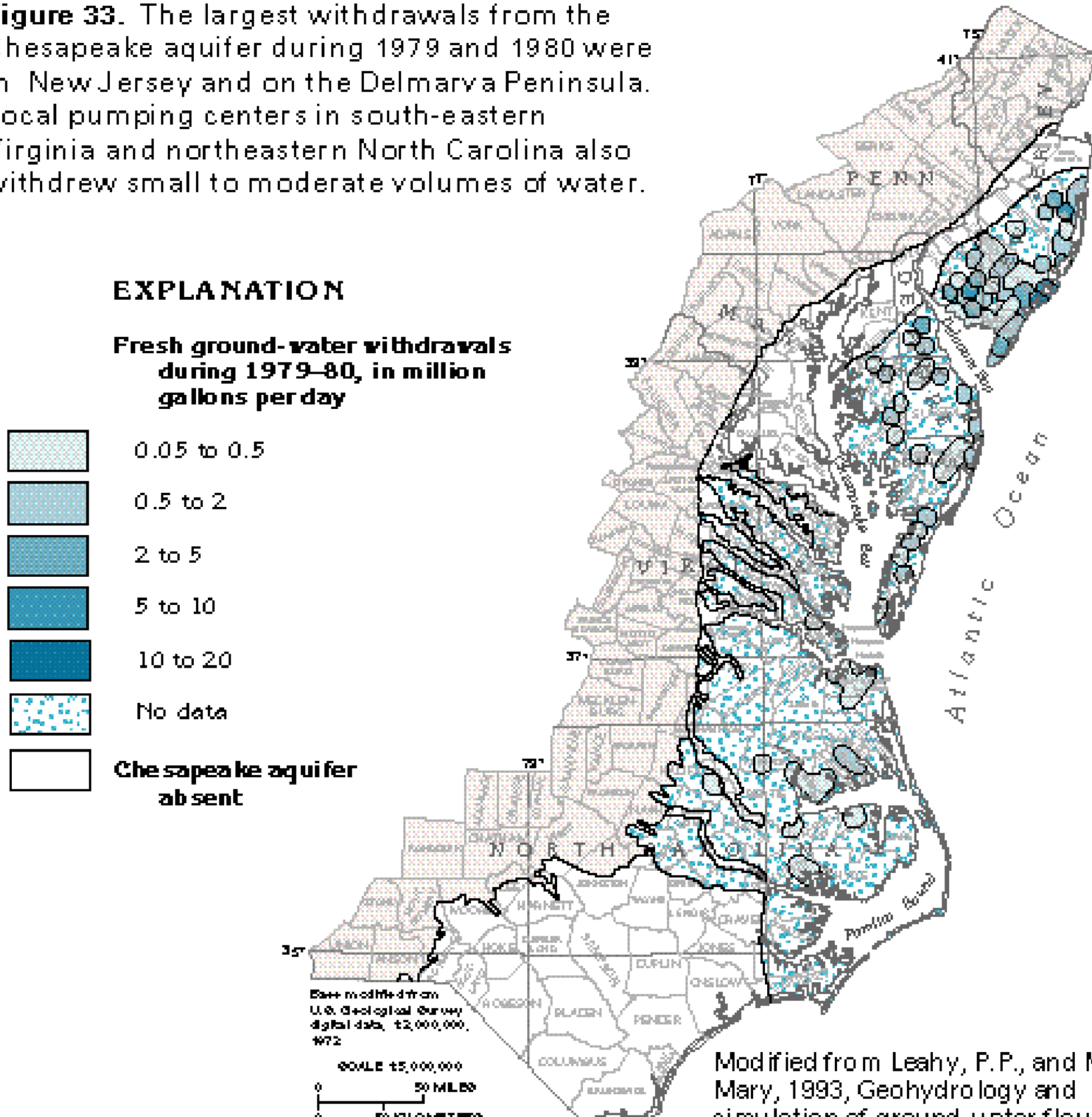


Figure 33. The largest withdrawals from the Chesapeake aquifer during 1979 and 1980 were in New Jersey and on the Delmarva Peninsula. Local pumping centers in south-eastern Virginia and northeastern North Carolina also withdrew small to moderate volumes of water.



Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

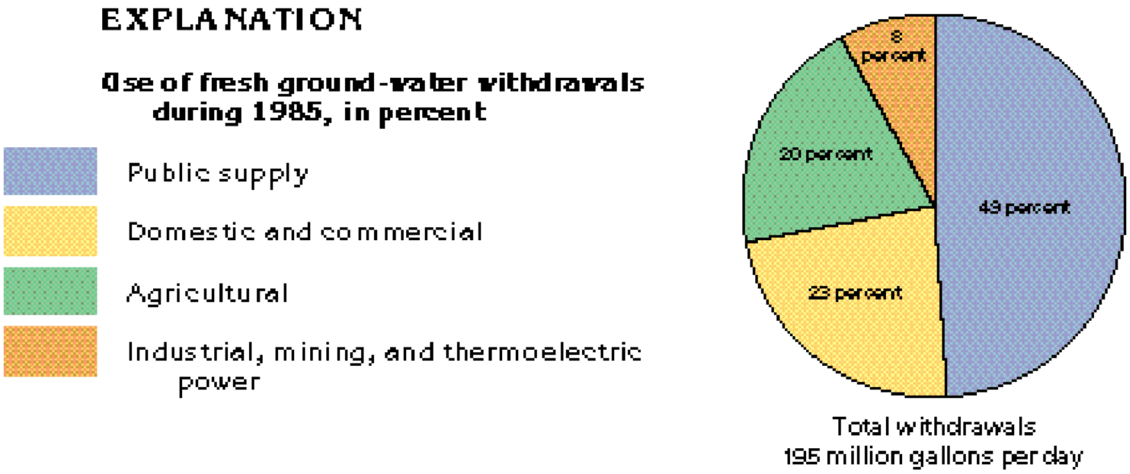
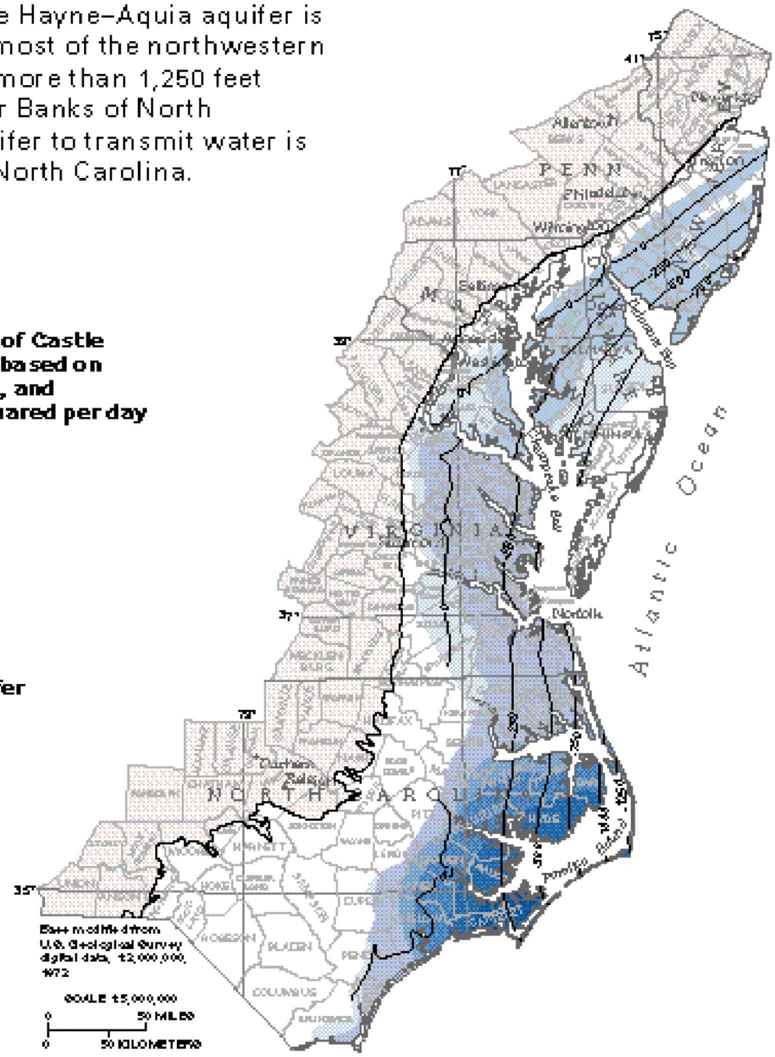


Figure 34. Most of the freshwater withdrawn from the Chesapeake aquifer during 1985 was used for public supply and domestic and commercial purposes.

Modified from U.S. Geological Survey files, 1990

Figure 35. The top of the Castle Hayne–Aquia aquifer is slightly above sea level along most of the northwestern boundary of the aquifer but is more than 1,250 feet below sea level along the Outer Banks of North Carolina. The ability of the aquifer to transmit water is greatest in the coastal area of North Carolina.



EXPLANATION

Estimated transmissivity of Castle Hayne–Aquia aquifer based on aquifer tests, geology, and simulation, in feet squared per day

1,000
10,000
20,000
50,000
100,000

Castle Hayne–Aquia aquifer absent

—250— **Top-of-aquifer contour**—Shows altitude of top of Castle Hayne–Aquia aquifer. Contour interval 250 feet. Datum is sea level

Modified from:

Meisler, Harold, 1989, The occurrence and geochemistry of salty ground water in the Northern Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 1404–D, 51 p.

Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 36. Glauconitic sand in New Jersey is typical of the Castle Hayne–Aquia aquifer north of North Carolina. The small dark grains are pellets of glauconite, which naturally softens ground water by the exchange of sodium ions on the surface of the mineral grains for hardness-producing calcium ions in the water.

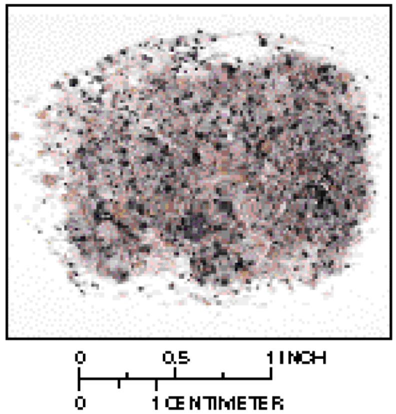
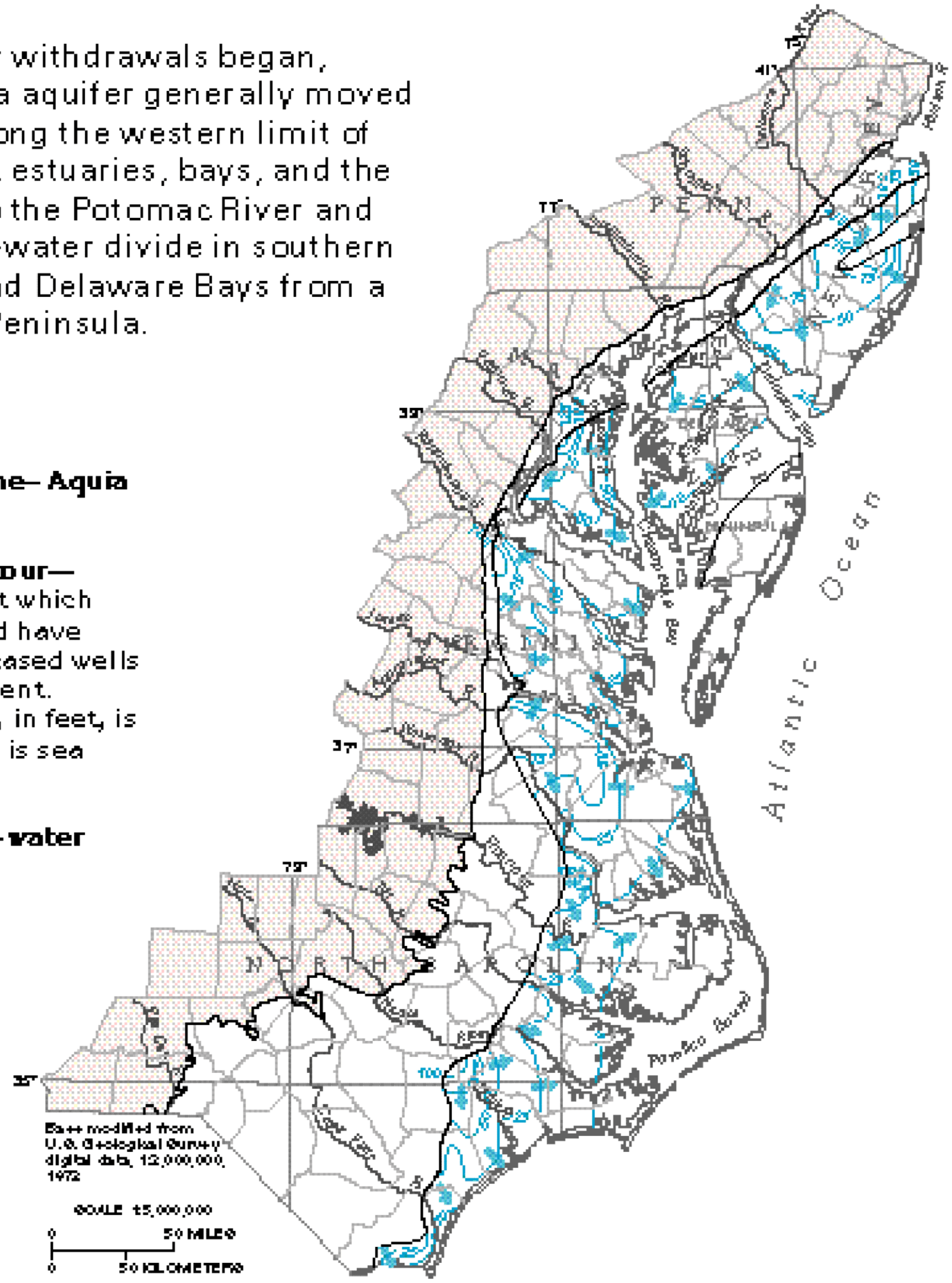


Figure 37. Before ground-water withdrawals began, water in the Castle Hayne–Aquia aquifer generally moved from areas of higher altitude along the western limit of the aquifer toward major rivers, estuaries, bays, and the Atlantic Ocean. Water moved to the Potomac River and Chesapeake Bay from a ground-water divide in southern Maryland and to Chesapeake and Delaware Bays from a similar divide in the Delmarva Peninsula.



EXPLANATION

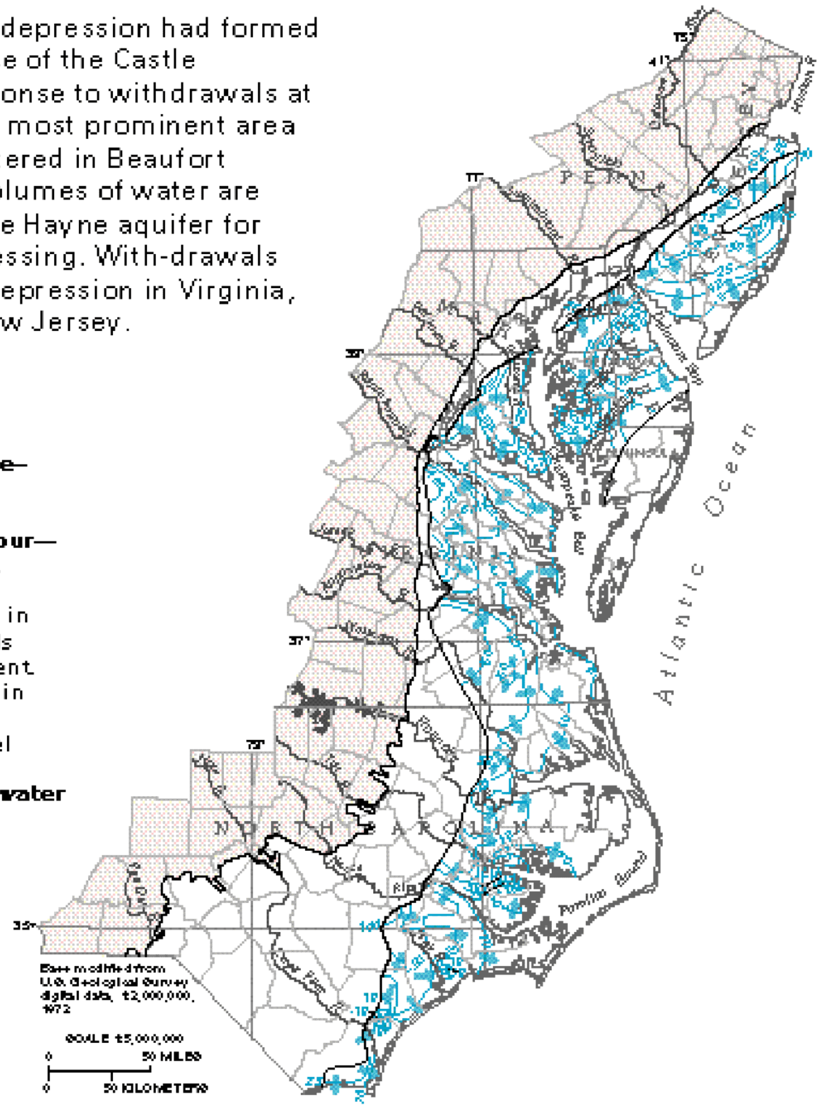
Limit of Castle Hayne–Aquia aquifer

Potentiometric contour—Shows altitude at which water level would have stood in tightly cased wells before development. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 38. In 1980, cones of depression had formed on the potentiometric surface of the Castle Hayne–Aquia aquifer in response to withdrawals at major pumping centers. The most prominent area of water-level decline is centered in Beaufort County, N.C., where large volumes of water are pumped from the local Castle Hayne aquifer for phosphate mining and processing. With-drawals also have created cones of depression in Virginia, Maryland, Delaware, and New Jersey.



EXPLANATION

Limit of Castle Hayne–Aquia aquifer

Potentiometric contour—Shows altitude at which water level would have stood in tightly cased wells before development. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Modified from:

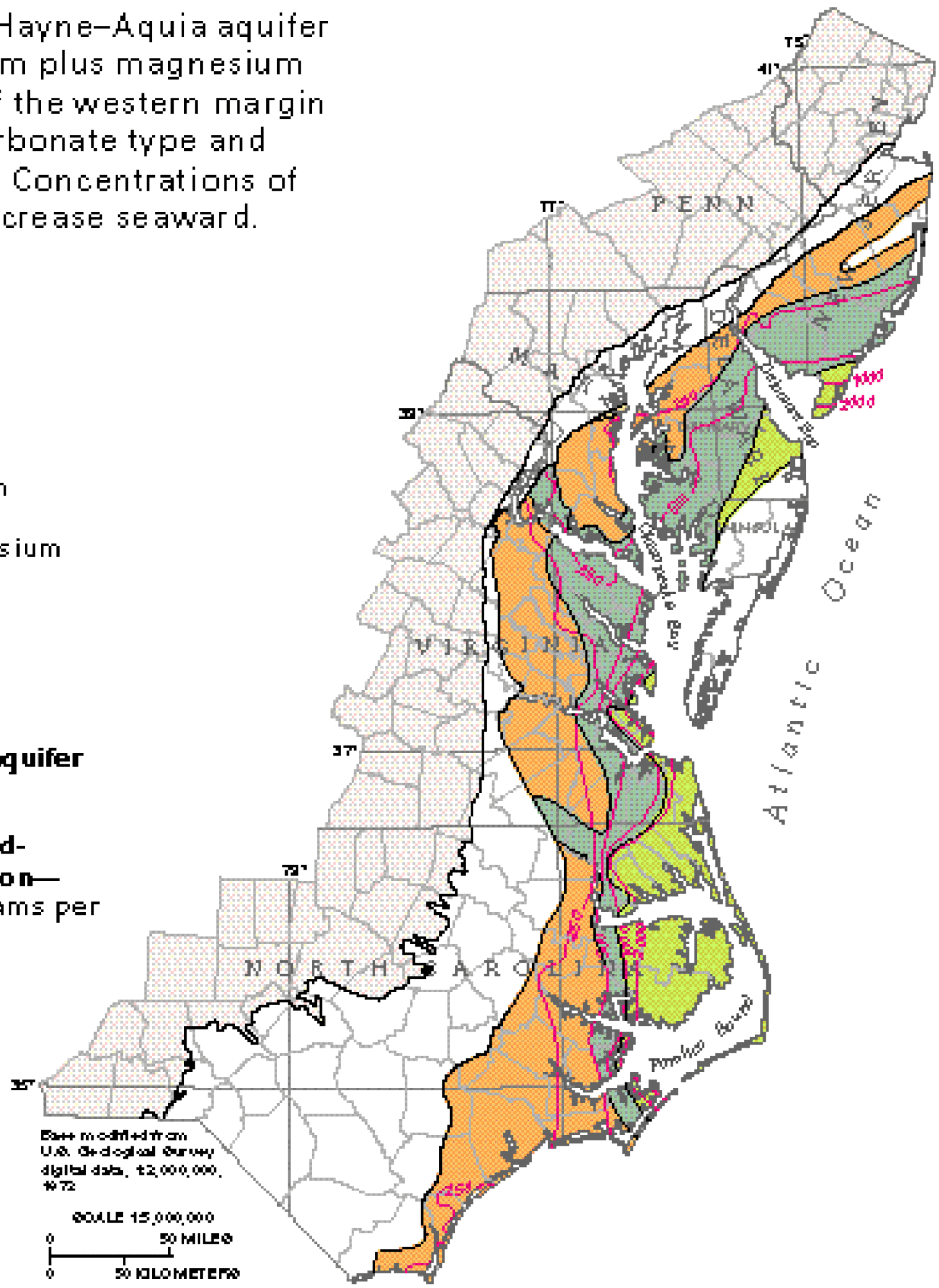
Martin, Mary, 1990, Ground-water flow in the New Jersey Coastal Plain: U.S. Geological Survey Open-File Report 87–528, 182 p.

Harsh, J.F., and Laczniak, R.J., 1990, Conceptualization and analysis of ground-water flow system in the Coastal Plain of Virginia and adjacent parts of Maryland and North Carolina: U.S. Geological Survey Professional Paper 1404–F, 100 p.

Giese, G.L., Eimers, J.L., and Coble, R.W., 1991, Simulation of ground-water flow in the Coastal Plain aquifer system of North Carolina: U.S. Geological Survey Open-File Report 90–372, 178 p.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 39. Water in the Castle Hayne–Aquia aquifer changes seaward from a calcium plus magnesium bicarbonate type along most of the western margin of the aquifer to a sodium bicarbonate type and then to a sodium chloride type. Concentrations of dissolved solids in the water increase seaward.



EXPLANATION

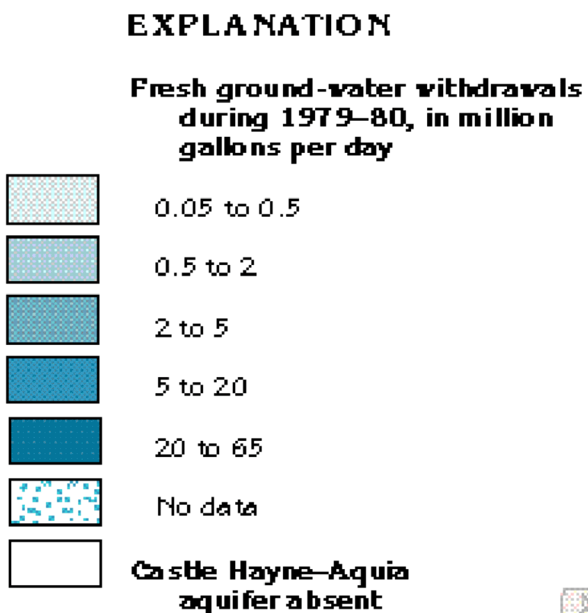
Hydrochemical facies

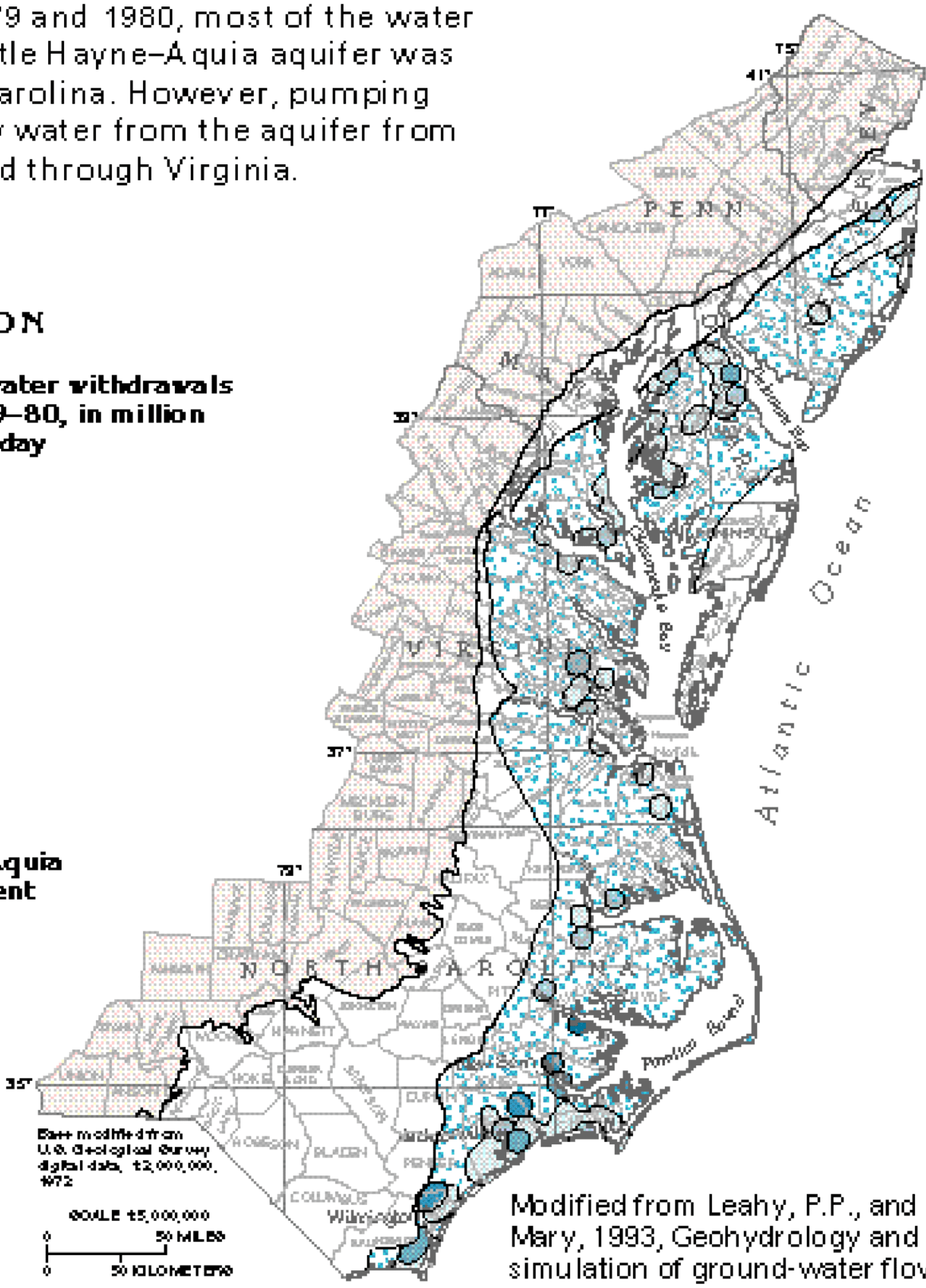
- Variable composition
- Calcium plus magnesium bicarbonate
- Sodium bicarbonate
- Sodium chloride
- **Castle Hayne–Aquia aquifer absent**

—250— **Line of equal dissolved-solids concentration—** Interval, in milligrams per liter, is variable

Modified from L.L. Knobel, F.M. Chappelle, and Harold Meisler, U.S. Geological Survey, written commun., 1988

Figure 40. During 1979 and 1980, most of the water pumped from the Castle Hayne–Aquia aquifer was withdrawn in North Carolina. However, pumping centers also withdrew water from the aquifer from New Jersey southward through Virginia.





Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

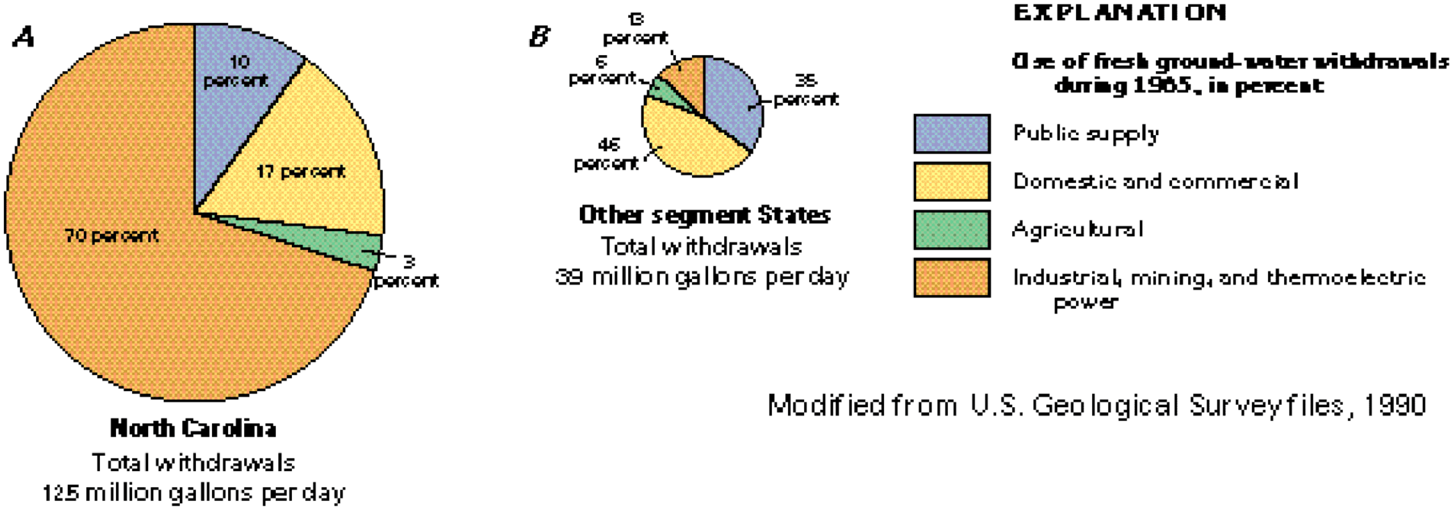
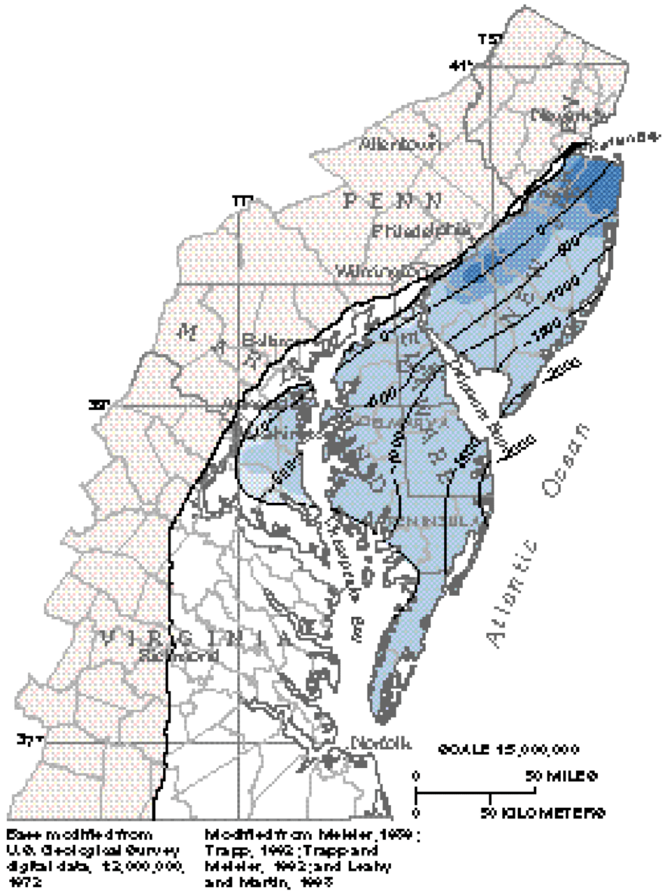


Figure 41. Most of the freshwater withdrawn from the Castle Hayne–Aquia aquifer in the North Carolina Coastal Plain during 1985 was used for industrial, mining, and thermoelectric power purposes (A); most of this water was pumped for mining use. In contrast, most of the freshwater withdrawn from the aquifer in Virginia and northward during the same period was used for public supply and domestic and com- mercial uses (B).



EXPLANATION

Estimated transmissivity of Severn–Magothy aquifer based on aquifer tests, geology, and simulation, in feet squared per day

1,000

5,000

10,000

Severn–Magothy aquifer absent

— 500 — **Top-of-aquifer contour—** Shows altitude of top of Severn–Magothy aquifer. Contour interval 500 feet. Datum is sea level

Figure 42. The top of the Severn–Magothy aquifer ranges from slightly above sea level near its northwestern limit to more than 2,000 feet below sea level along the coast. The aquifer is most transmissive in local areas of New Jersey and least transmissive near its western and southwestern limits.

Modified from:

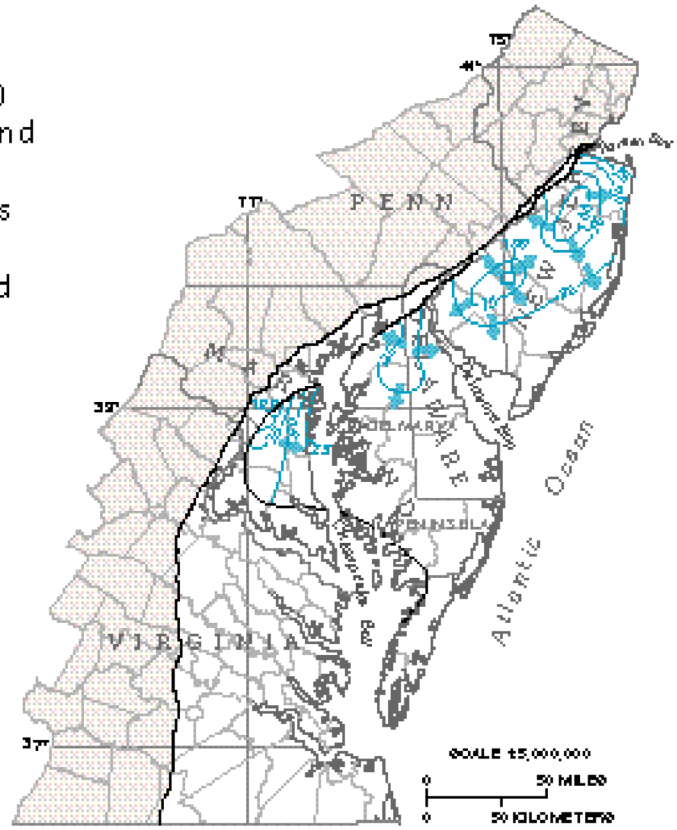
Meisler, Harold, 1989, The occurrence and geochemistry of salty ground water in the Northern Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 1404–D, 51 p.

Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 43. Before ground-water withdrawals began, water levels in the upper part of the Severn–Magothy aquifer were more than 100 feet above sea level in parts of New Jersey and Maryland; water levels on the Delmarva Peninsula were considerably lower. Flow was mostly toward discharge areas such as Chesapeake, Delaware, and Raritan Bays, and toward the Atlantic Ocean.



EXPLANATION

Limit of Severn–Magothy aquifer

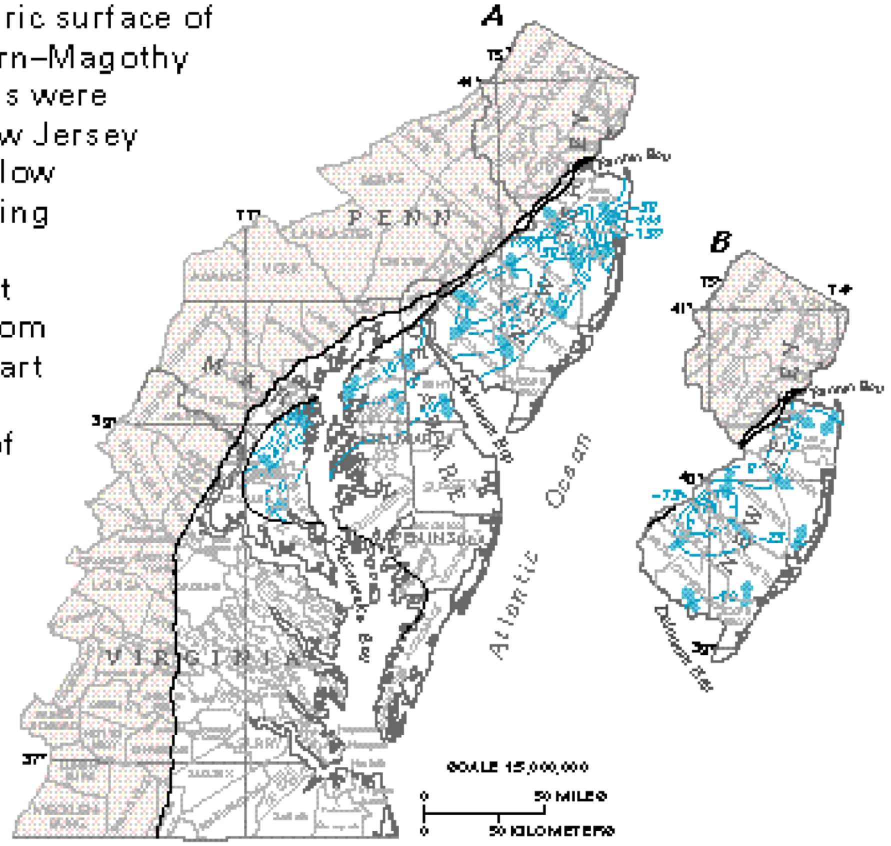
50 **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells before development. Contour interval 25 feet. Datum is sea level

Direction of ground-water movement

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 44. In 1980, the potentiometric surface of the upper part of the regional Severn–Magothy aquifer showed that hydraulic heads were lowered greatly in northeastern New Jersey by ground-water withdrawals and flow directions shifted toward the pumping centers (A). Hydraulic heads were lowered below sea level throughout most of the aquifer. Withdrawals from the lower (local Magothy aquifer) part of the regional aquifer in Salem County, N.J., created a deep cone of depression into which water moved from all directions (B).



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

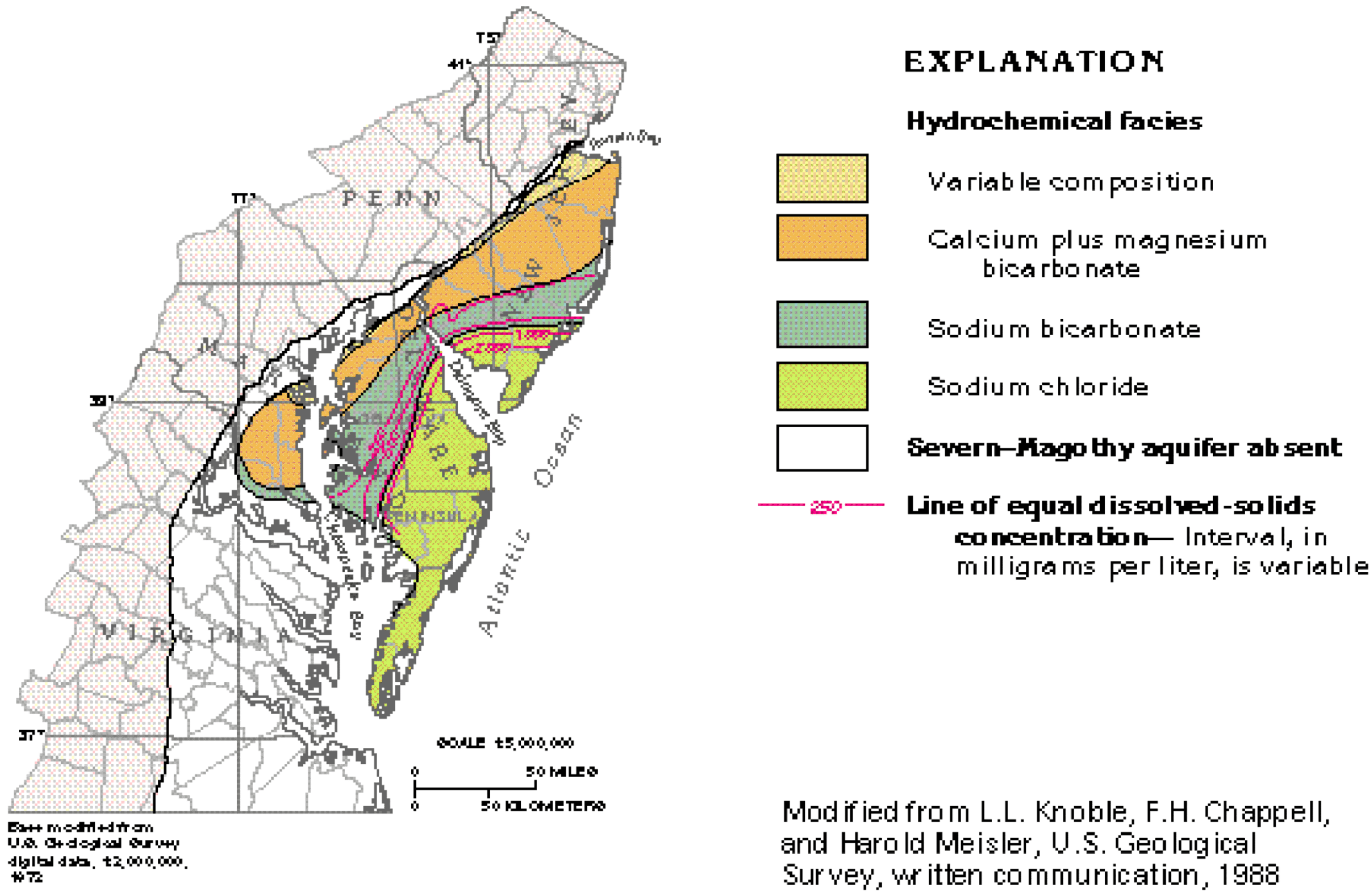
Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

EXPLANATION

Limit of Severn–Magothy aquifer

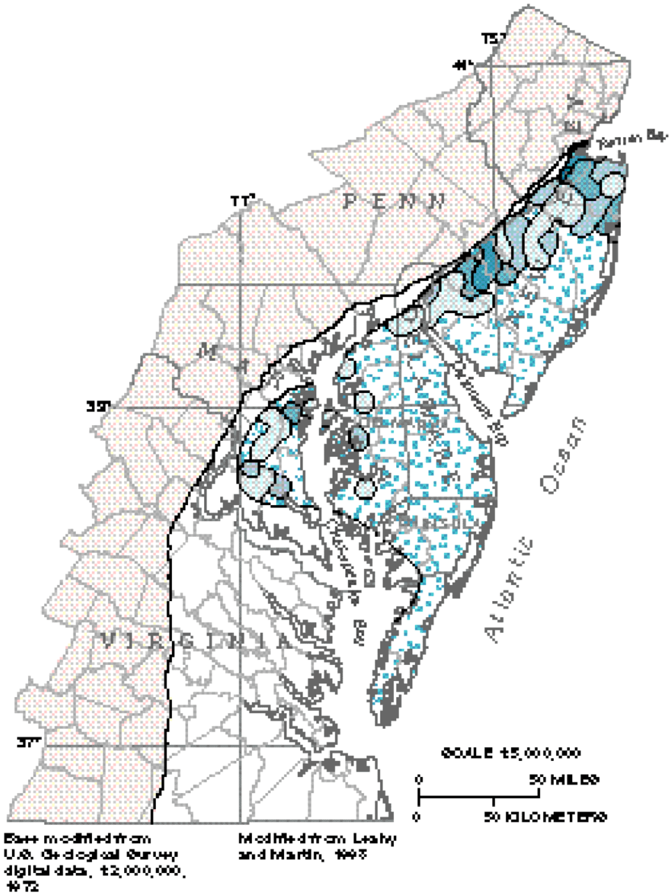
50 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells in 1980. Hachures indicate depression. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement



Modified from L.L. Knoble, F.H. Chappell, and Harold Meisler, U.S. Geological Survey, written communication, 1988

Figure 45. Water in about one-third of the Severn–Magothy aquifer is characterized by large dissolved-solids concentrations and is a sodium chloride type.



EXPLANATION

Fresh ground-water withdrawals during 1979–80, in million gallons per day

- 0.05 to 0.5
- 0.5 to 2
- 2 to 5
- 5 to 10
- 10 to 20
- No data
- **Severn–Magothy aquifer absent**

Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 46. Most of the withdrawals from the Severn–Magothy aquifer during 1979 and 1980 were along the inner margin of the New Jersey Coastal Plain.

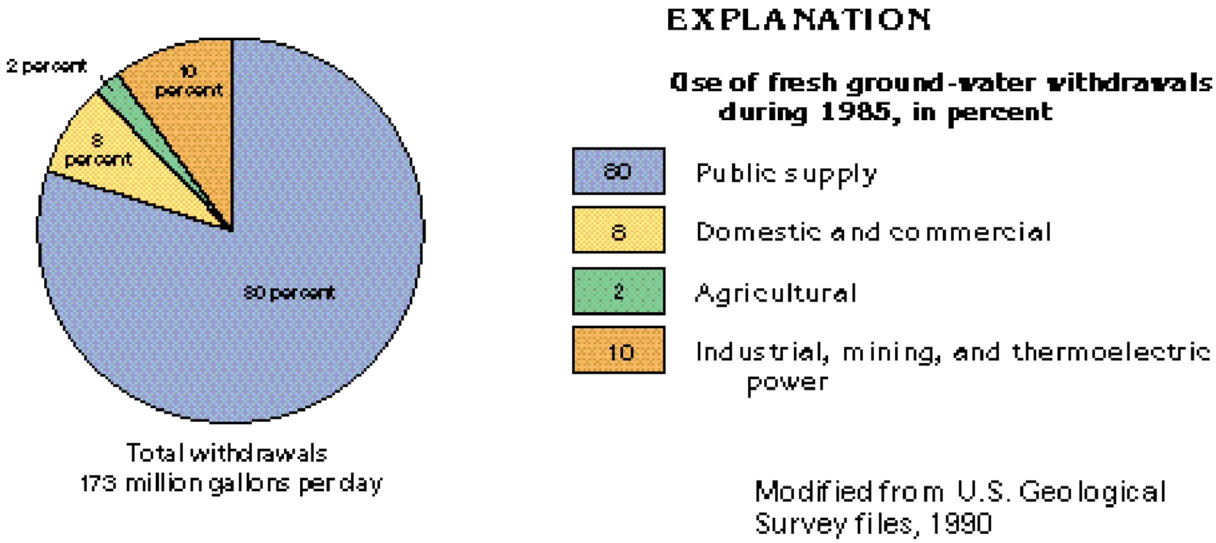


Figure 47. Most of the freshwater withdrawn from the Severn–Magothy aquifer during 1985 was used for public supply.

EXPLANATION

Estimated transmissivity of Peedee–upper Cape Fear aquifer based on aquifer tests, geology, and simulation, in feet squared per day

1,000

5,000

10,000

No data

Peedee–upper Cape Fear aquifer absent

Approximate updip limit of water containing 10,000 milligrams per liter dissolved chloride

—500— **Top-of-aquifer contour**— Shows altitude of top of Peedee–upper Cape Fear aquifer. Contour interval 500 feet. Datum is sea level

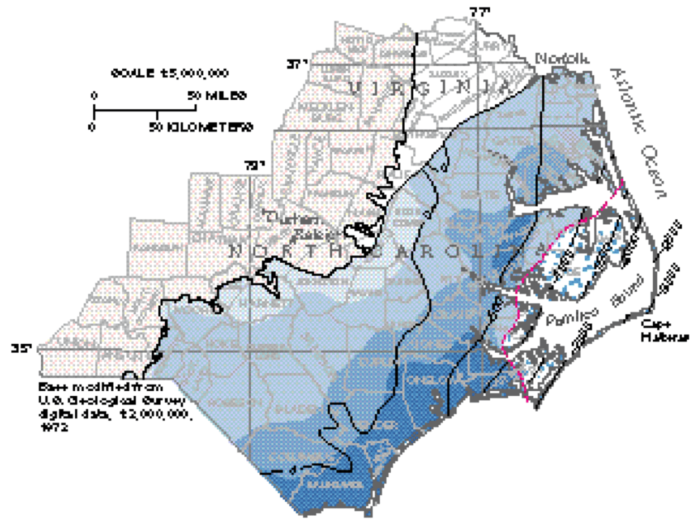


Figure 48. The top of the Peedee–upper Cape Fear aquifer is deeper than 3,000 feet below sea level at Cape Hatteras in eastern-most North Carolina but is above sea level in much of the western part of the State. The aquifer is most transmissive in the south-eastern coastal area of North Carolina, but some of the water in its deep parts contains objectionable concentrations of chloride.

Modified from:

Meisler, Harold, 1989, The occurrence and geochemistry of salty ground water in the Northern Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 1404–D, 51 p.

Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404–G, 59 p.

Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p. Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404–A, 33 p.

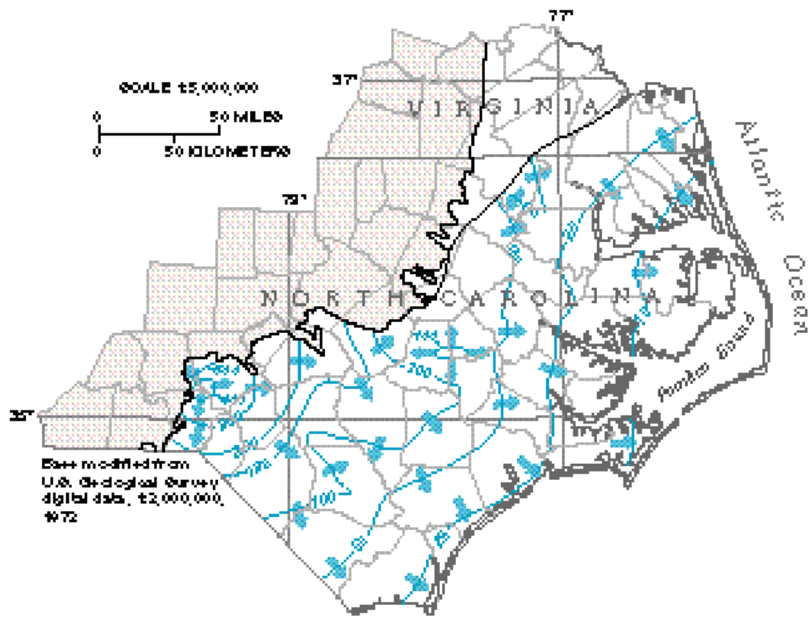
Figure 49. Before development began, regional movement of ground water in the Peedee–upper Cape Fear aquifer was toward the Atlantic Ocean, sounds, and estuaries. Some water moved locally to discharge to major streams. The regional direction of movement was eastward and southeastward.

EXPLANATION

Limit of Peedee–upper Cape Fear aquifer

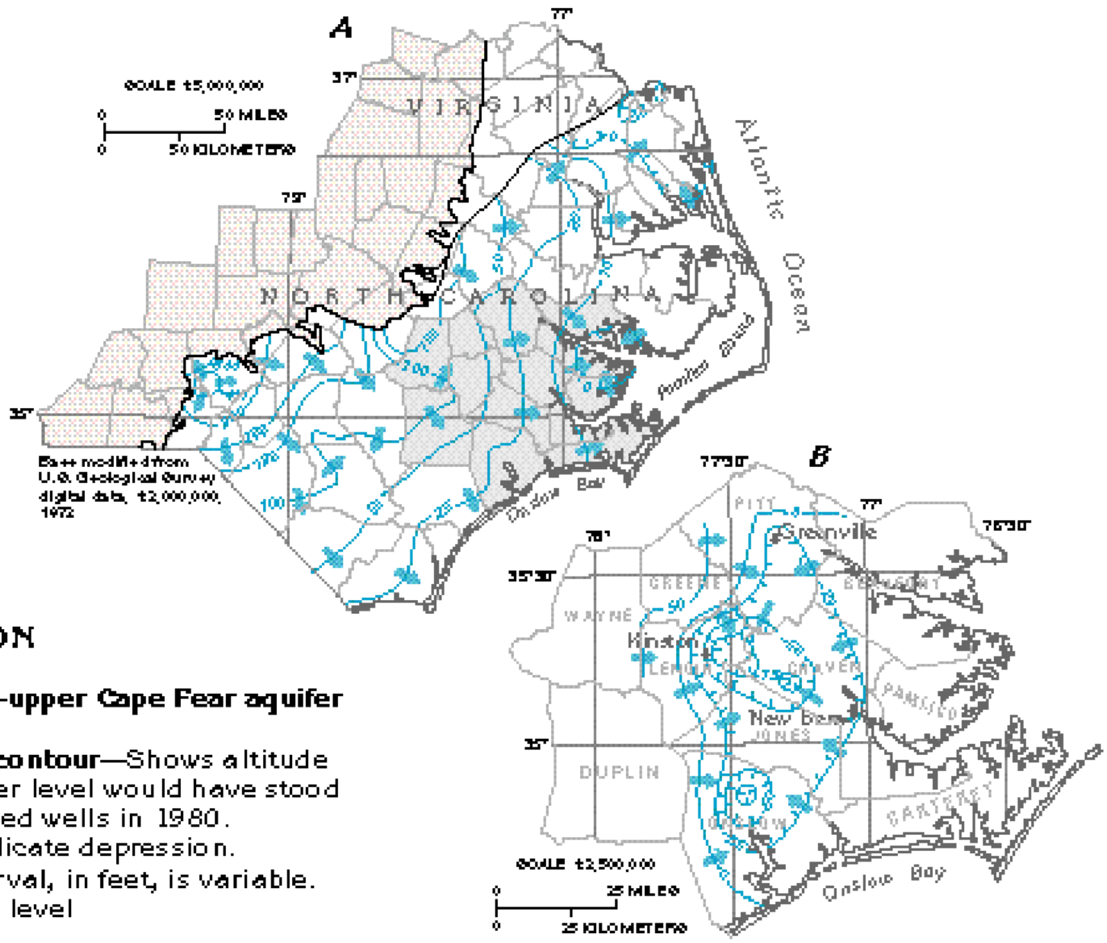
Potentiometric contour—Shows altitude at which water level would have stood in tightly cased wells before development. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement



Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Figure 50. In 1980, cones of depression had developed on the potentiometric surface of the regional Peedee–upper Cape Fear aquifer as a result of large ground-water withdrawals; the larger cones are in southeastern Virginia and eastern North Carolina (A). A substantial cone of depression from Pitt to Onslow Counties, N.C. is developed in the middle part (local Black Creek aquifer) of the regional aquifer, but is not evident on the potentiometric surface of the upper part of the regional aquifer (B).



EXPLANATION

Limit of Peedee–upper Cape Fear aquifer

50 **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells in 1980. Hachures indicate depression. Contour interval, in feet, is variable. Datum is sea level

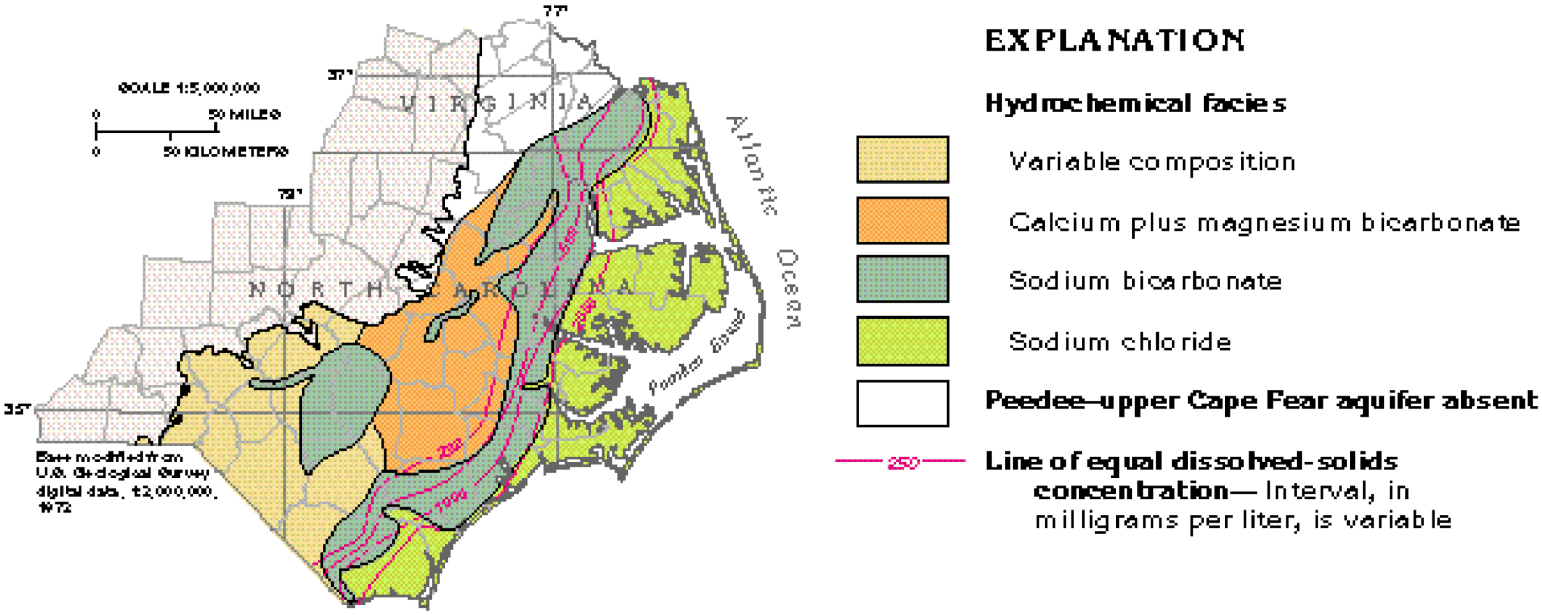
Direction of ground-water movement

Modified from:

Eimers, J.L., Lyke, W.L., and Brockman, A.R., 1990, Simulation of ground-water flow in aquifers in Cretaceous rocks in the central Coastal Plain, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 89–4153, 101 p.

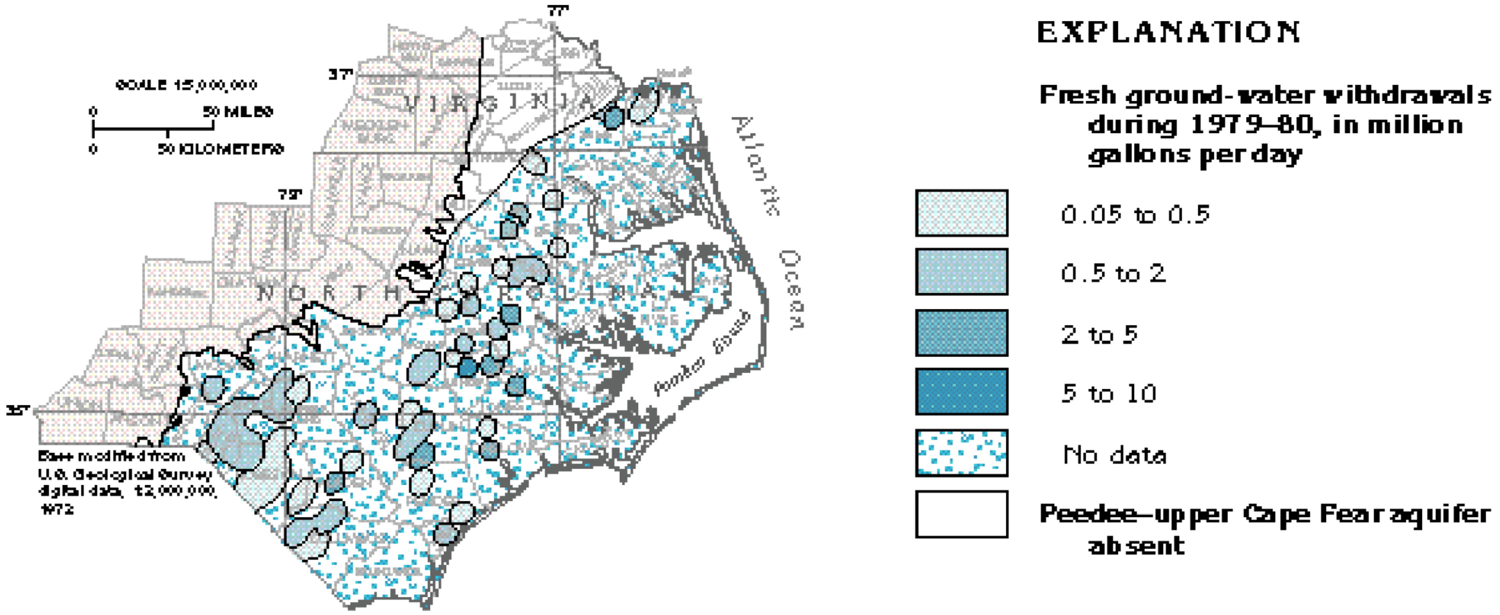
Giese, G.L., Eimers, J.L., and Coble, R.W., 1991, Simulation of ground-water flow in the Coastal Plain aquifer system of North Carolina: U.S. Geological Survey Open-File Report 90–372, 178 p.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.



Modified from L.L. Knoble, F.H. Chappell, and Harold Meisler, U.S. Geological Survey, written communication, 1988

Figure 51. The hydrochemical facies of water in the Peedee–upper Cape Fear aquifer changes seaward from a variable-composi-tion type to a calcium plus magnesium bicarbonate type, then to a sodium bicarbonate type, and finally to a sodium chloride type. Concentrations of dissolved solids in the water are less than 250 milligrams per liter in much of the aquifer but rapidly increase seaward.



Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 52. Most withdrawals from the Peedee–upper Cape Fear aquifer during 1979 and 1980 were in a wide band that extends over about the western one-half of the aquifer.

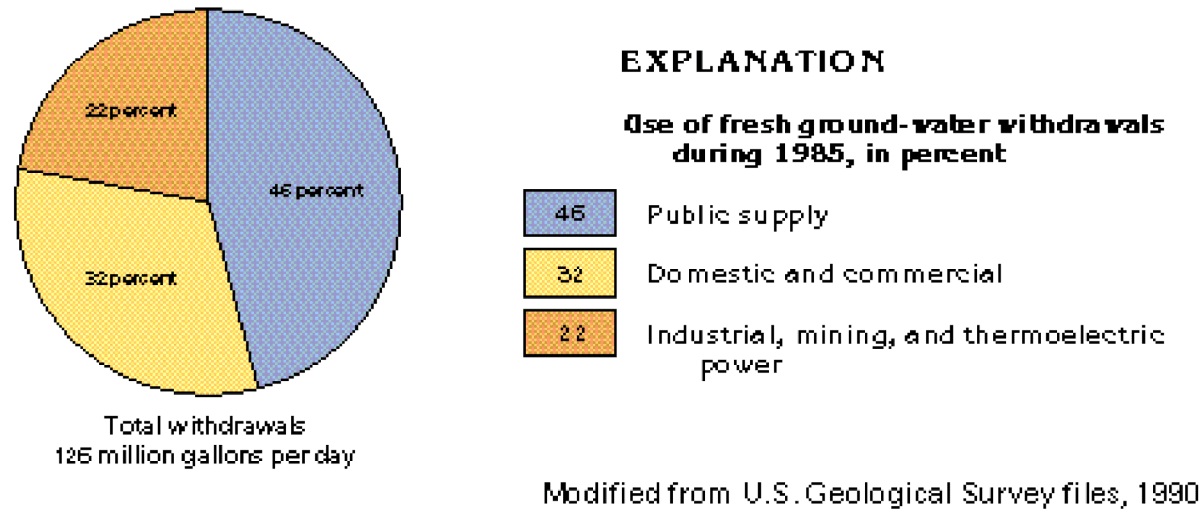


Figure 53. The largest withdrawals of freshwater from the Peedee–upper Cape Fear aquifer during 1985 were for public supply. The second largest withdrawals were for domestic and commercial uses.

Figure 54. The top of the Potomac aquifer is above sea level along its western and northwestern limit from northernmost North Carolina to New Jersey but slopes to more than 2,500 feet below sea level along the coast of New Jersey and to more than 4,500 feet below sea level near Cape Hatteras in easternmost North Carolina. The transmissivity of the aquifer is highest near Chesapeake Bay and in central New Jersey.

EXPLANATION

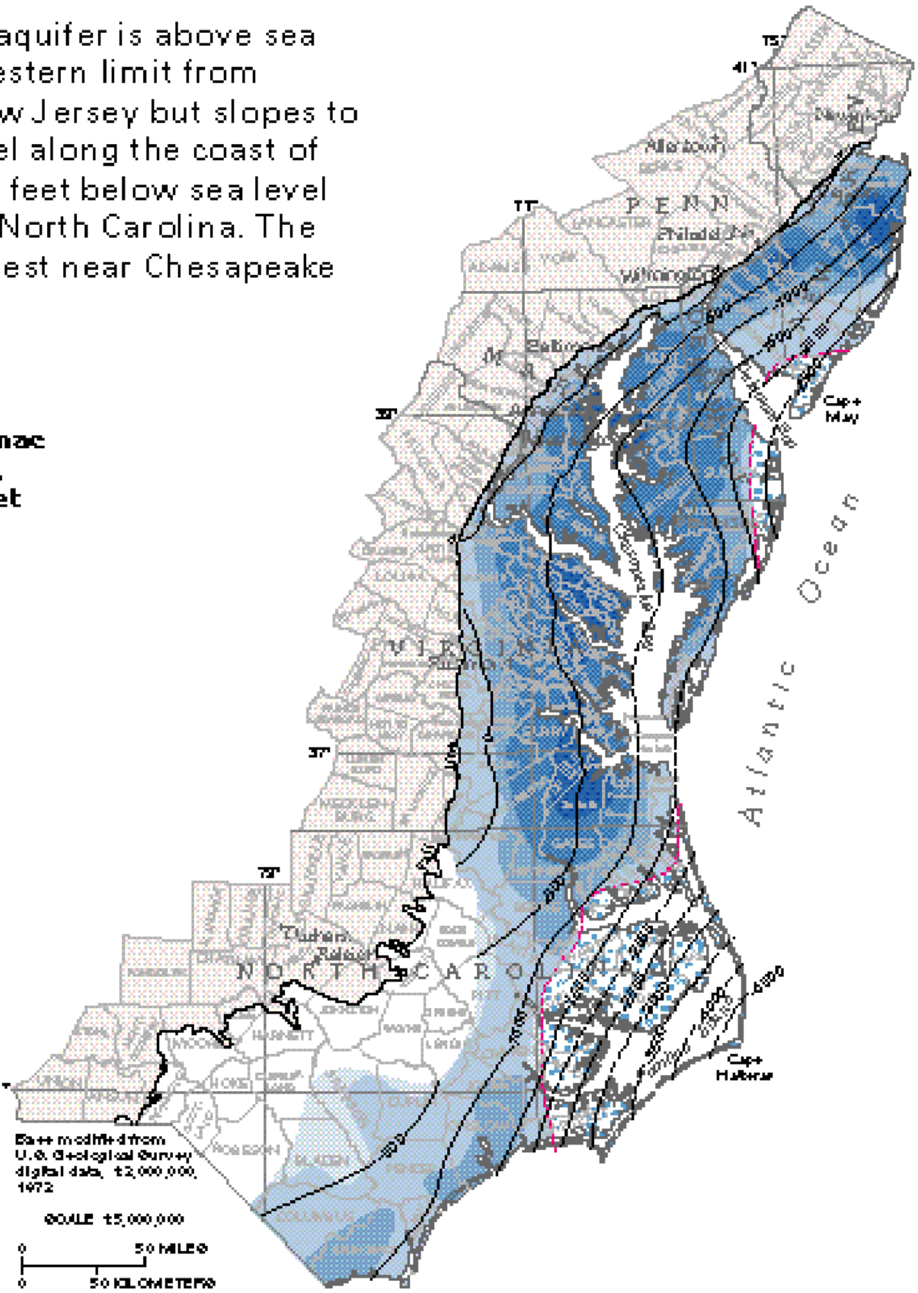
Estimated transmissivity of Potomac aquifer based on aquifer tests, geology, and simulation, in feet squared per day

1,000
5,000
10,000
20,000
No data

Potomac aquifer absent

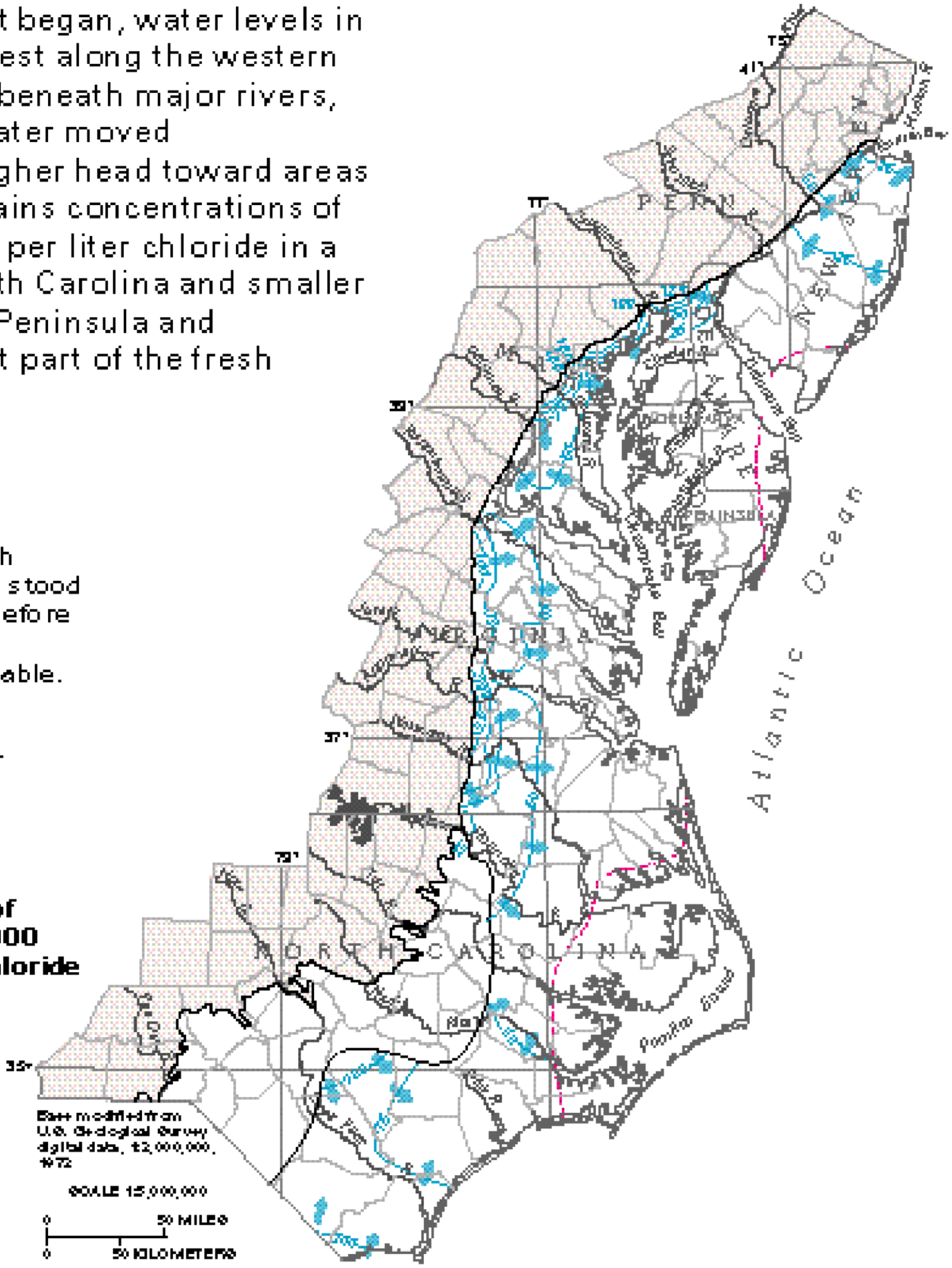
Approximate updip limit of water containing 10,000 milligrams per liter dissolved chloride

—500— **Top-of-aquifer contour**—Shows altitude of top of Potomac aquifer. Dashed where approximately located. Contour interval 500 feet. Datum is sea level



Modified from:
Meisler, Harold, 1989, The occurrence and geochemistry of salty ground water in the Northern Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 1404-D, 51 p.
Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.
Trapp, Henry, Jr., and Meisler, Harold, 1992, The regional aquifer system underlying the Northern Atlantic Coastal Plain in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York—Summary: U.S. Geological Survey Professional Paper 1404-A, 33 p.
Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Figure 55. Before development began, water levels in the Potomac aquifer were highest along the western limit of the aquifer and lowest beneath major rivers, bays, and estuaries. Ground water moved downgradient from areas of higher head toward areas of lower head. Water that contains concentrations of greater than 10,000 milligrams per liter chloride in a wide area of the aquifer in North Carolina and smaller areas in the eastern Delmarva Peninsula and southeastern New Jersey is not part of the fresh ground-water flow system.



EXPLANATION

Potentiometric contour—Shows altitude at which water level would have stood in tightly cased wells before development. Contour interval, in feet, is variable. Datum is sea level

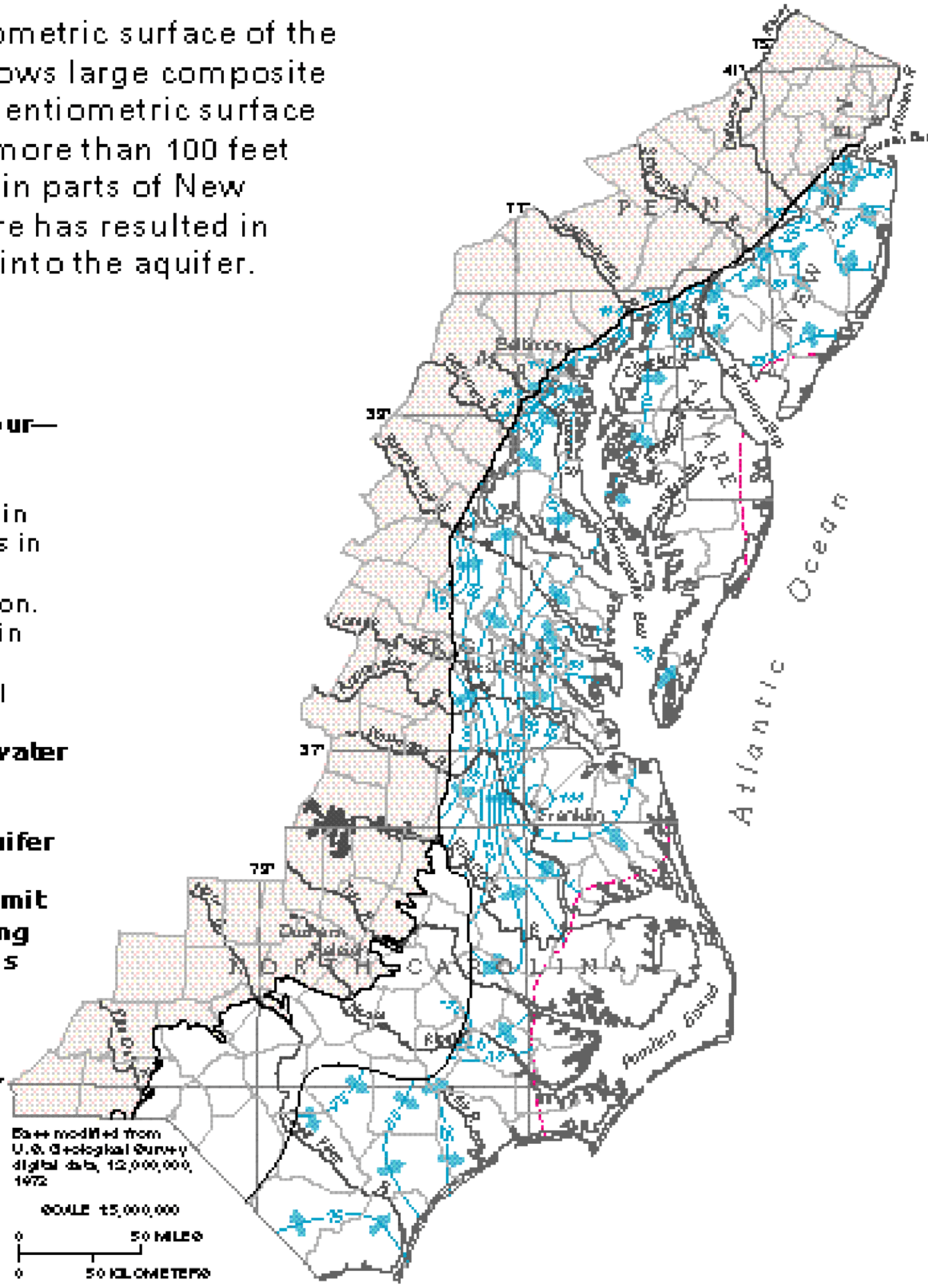
Direction of ground-water movement

Limit of Potomac aquifer

Approximate updip limit of water containing 10,000 milligrams per liter chloride

Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 56. The 1980 potentiometric surface of the regional Potomac aquifer shows large composite cones of depression. The potentiometric surface has been lowered locally to more than 100 feet below sea level. The decline in parts of New Jersey and northern Delaware has resulted in the intrusion of saline water into the aquifer.



EXPLANATION

—50— **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells in 1980. Hachures indicate depression. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Limit of Potomac aquifer

Approximate updip limit of water containing 10,000 milligrams per liter chloride

Modified from:
Harsh, J.F., and Laczniak, R.J., 1990, Conceptualization and analysis of ground-water flowsystem in the Coastal Plain of Virginia and adjacent parts of Maryland and North Carolina: U.S. Geological Survey Professional Paper 1404–F, 100 p.
Martin, Mary, 1990, Ground-water flow in the New Jersey Coastal Plain: U.S. Geological Survey Open-File Report 87–528, 182 p.
Giese, G.L., Eimers, J.L., and Coble, R.W., 1991, Simulation of ground-water flow in the Coastal Plain aquifer system of North Carolina: U.S. Geological Survey Open-File Report 90–372, 178 p.
Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404–K, 81 p.

Figure 57. Water of the variable-composition hydrochemical facies in the Potomac aquifer is only in small areas along the northern part of the outcrop of the aquifer. The sodium chloride facies is more than one-half of the aquifer and is the result of mixing of saline water with freshwater in downdip areas.

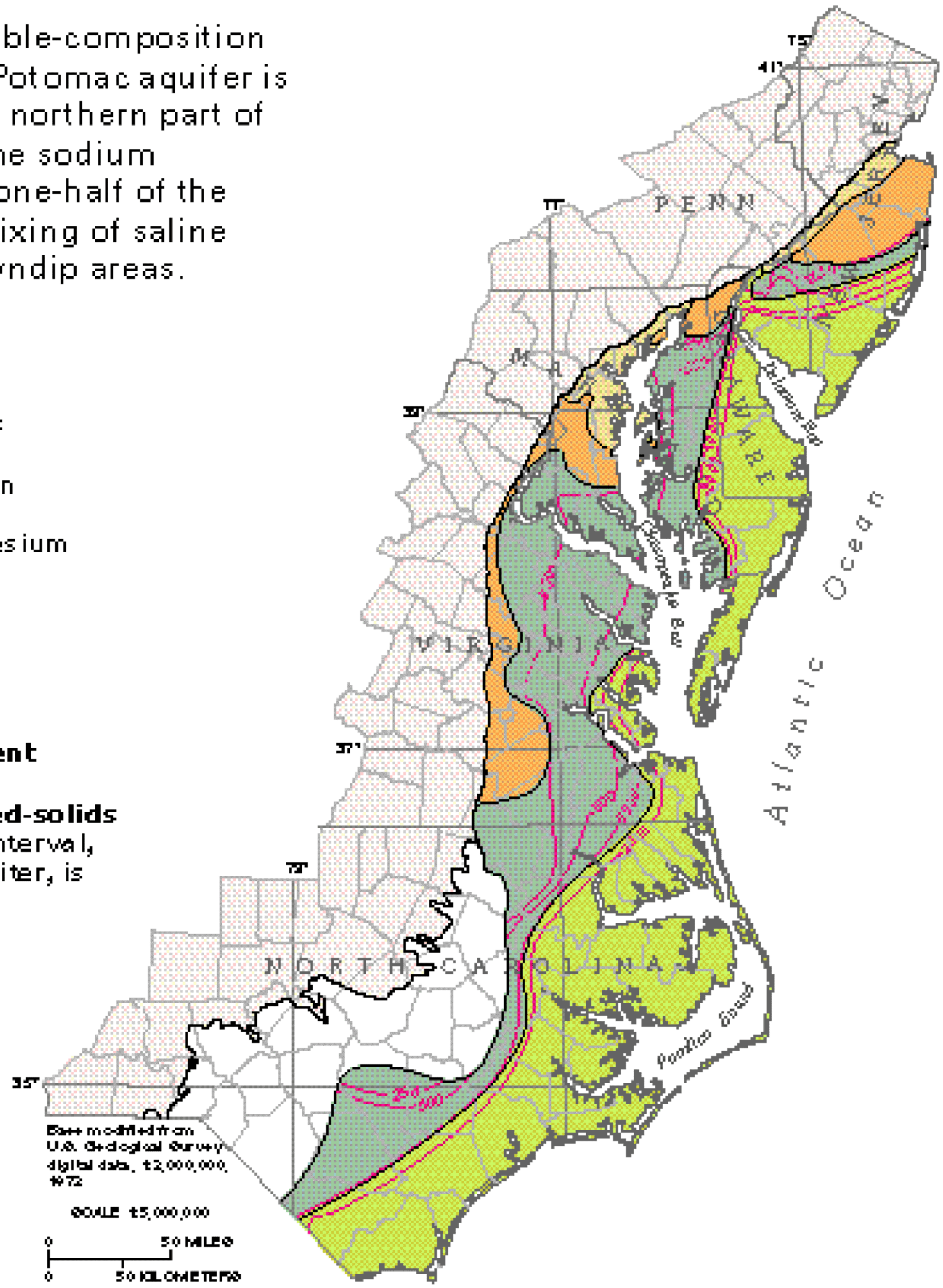
EXPLANATION

Hydrochemical facies

- Variable composition
- Calcium plus magnesium bicarbonate
- Sodium bicarbonate
- Sodium chloride

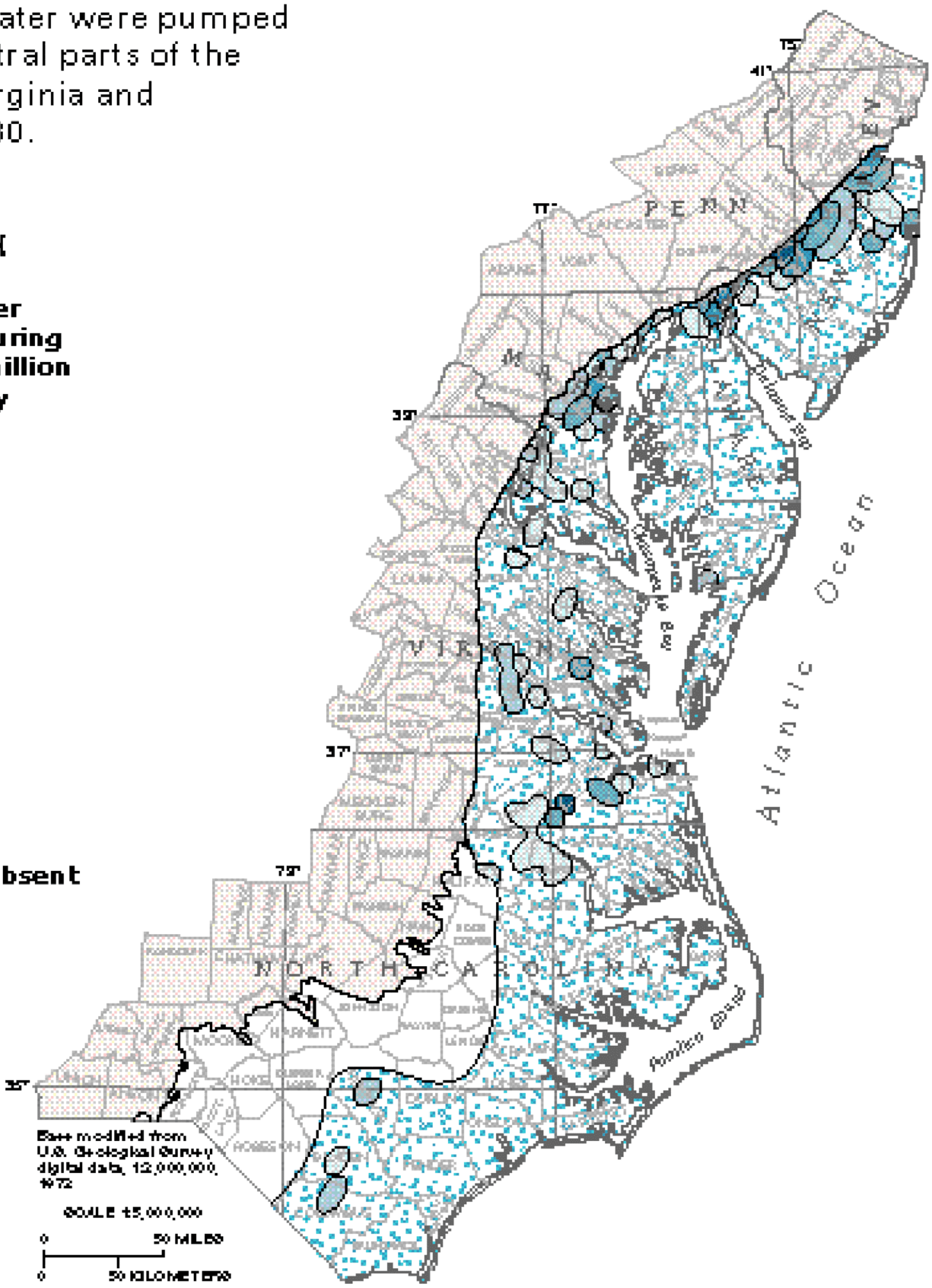
Potomac aquifer absent

—250— **Line of equal dissolved-solids concentration**— Interval, in milligrams per liter, is variable



Modified from L.L. Knobel, F.H. Chappelle, and Harold Meisler, U.S. Geological Survey, written commun., 1988

Figure 58. Large volumes of water were pumped from the westernmost and central parts of the regional Potomac aquifer in Virginia and northward during 1979 and 1980.



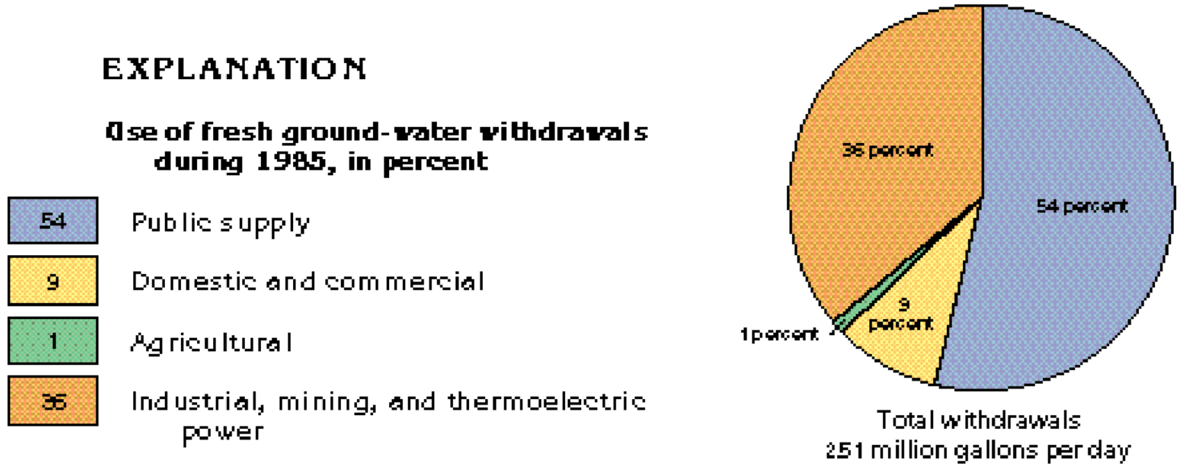
EXPLANATION

Fresh ground-water withdrawals during 1979–80, in million gallons per day

- 0.05 to 0.5
- 0.5 to 2
- 2 to 5
- 5 to 10
- 10 to 20
- 20 to 40
- No data
- **Potomac aquifer absent**

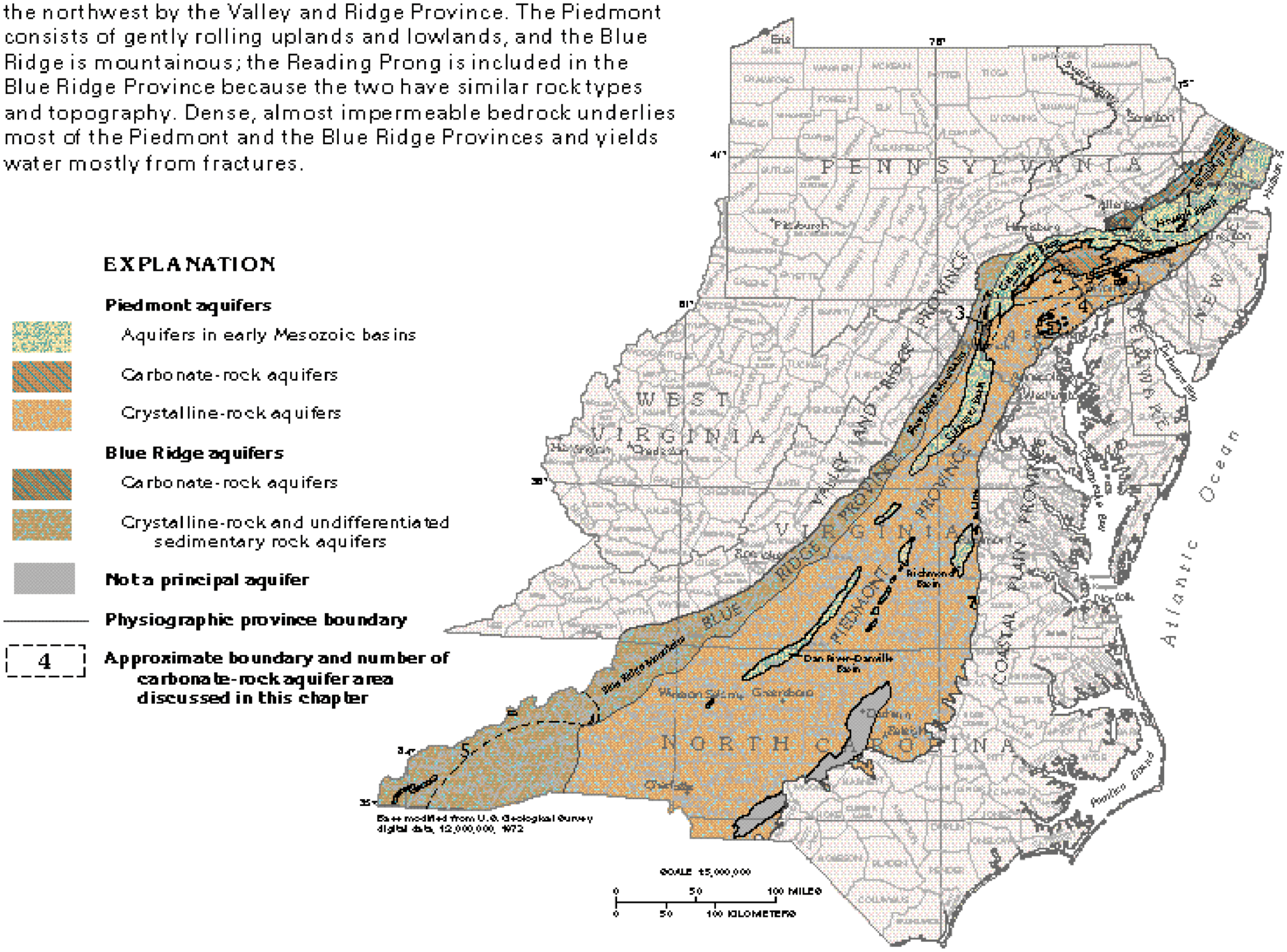
Modified from Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Figure 59. More than one-half of the freshwater withdrawn from the regional Potomac aquifer during 1985 was used for public supply. Large amounts of water also were withdrawn for industrial, mining, and thermoelectric power uses.



Modified from U.S. Geological Survey files, 1990

Figure 60. The Piedmont and the Blue Ridge Provinces are bounded on the southeast by the Coastal Plain Province and on the northwest by the Valley and Ridge Province. The Piedmont consists of gently rolling uplands and lowlands, and the Blue Ridge is mountainous; the Reading Prong is included in the Blue Ridge Province because the two have similar rock types and topography. Dense, almost impermeable bedrock underlies most of the Piedmont and the Blue Ridge Provinces and yields water mostly from fractures.



Modified from:

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.

Johnson, M.E., 1950, Geologic map of New Jersey: New Jersey Geological Survey, scale 1:250,000, 1 sheet.

Calver, J.L., and others, compilers, 1963, Geologic map of Virginia: Virginia Department of Conservation and Economic Development, Division of Mineral Resources, scale 1:500,000, 1 sheet.

Cleaves, E.T., Edwards, Jonathan, Jr., and Glaser, J.D., compilers, 1968, Geologic map of Maryland: Maryland Geological Survey, scale 1:250,000, 1 sheet.

Berg, T.M., and others, comp., 1980, Geologic map of Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, scale 1:250,000, 3 sheets.

Brown, P.M., and Parker, J.M., III, compilers, 1985, Geologic map of North Carolina: North Carolina Department of Natural Resources and Community Development, Division of Land Resources, scale 1:500,000, 1 sheet.

Figure 61. Rugged mountains characterize the Blue Ridge Province, whereas the topography of the Piedmont Province is mostly low, rolling hills. In this view from Chimney Rock in the Blue Ridge of North Carolina, low hills of the Piedmont Province below extend to the horizon where an erosional remnant of resistant rock forms a foothill.

Photo from: North Carolina Department of Travel and Tourism

Figure 62. This view shows part of the early Mesozoic Newark Basin in New Jersey and Pennsylvania. The low-lying, gently undulating land surface, which developed on sedimentary rocks, surrounds a diabase ridge that is being quarried.

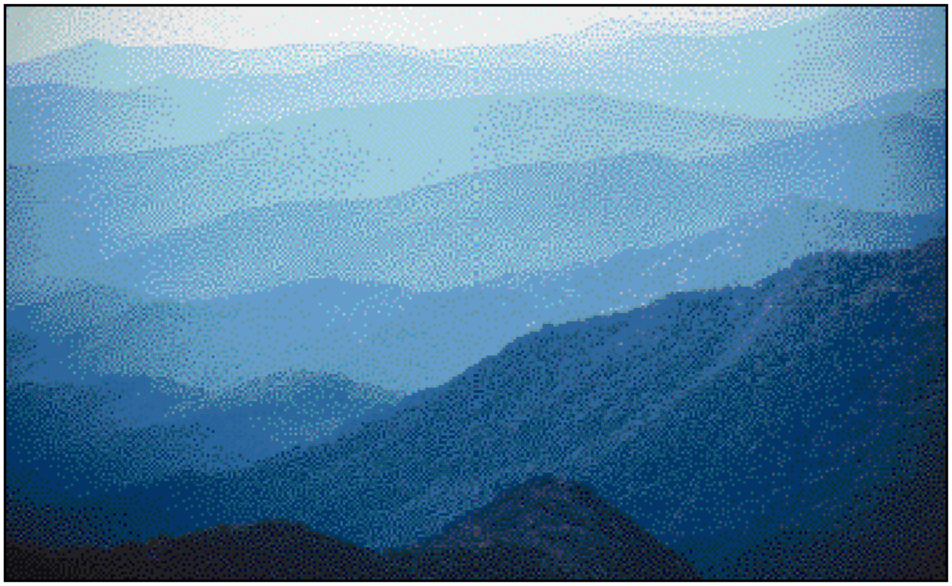
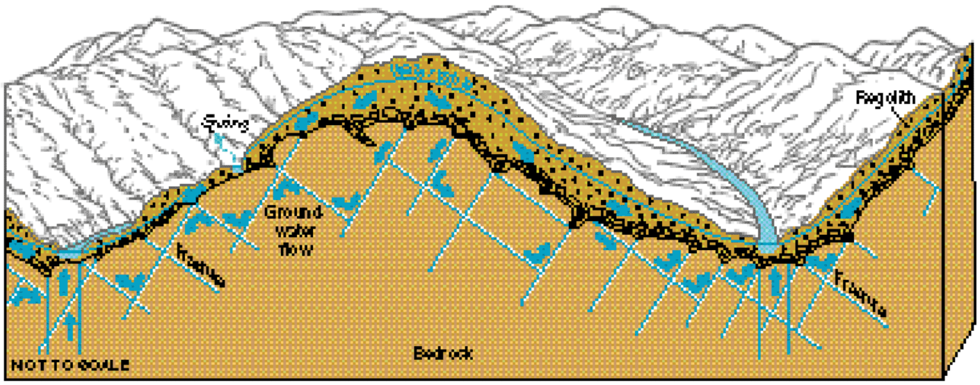


Photo from: North Carolina Department of Travel and Tourism

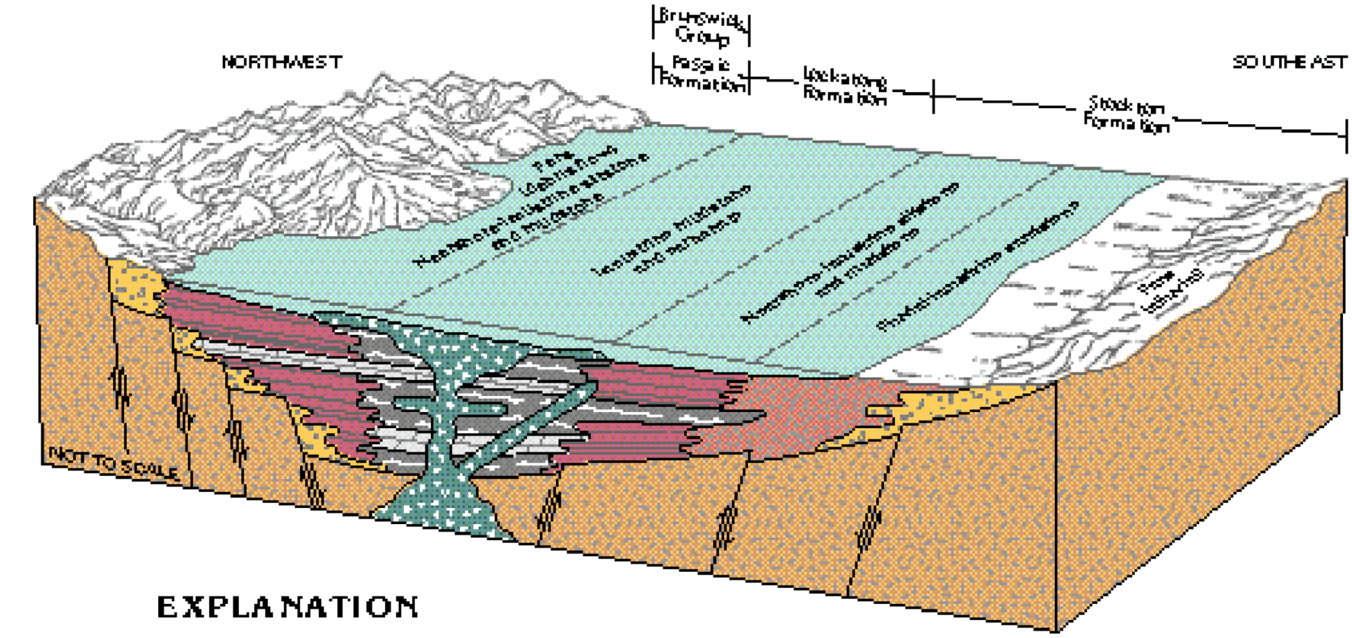
Figure 63. The Blue Ridge Province is characterized by steep, rugged, high mountains whose densely forested slopes are cut by numerous stream valleys. This photograph shows part of the mountains in North Carolina where the Blue Ridge Province is 70 miles wide.

Figure 64. Ground water percolates downward through the regolith, which is a layer of weathered rock, alluvium, colluvium, and soil, to fractures in the underlying bedrock. The water moves from highland recharge areas to discharge areas, such as springs and streams, at lower altitudes.



Modified from Heath, R.C., 1980, Basic elements of ground-water hydrology with reference to conditions in North Carolina: U.S. Geological Survey Water-Resources Investigations Open-File Report 80–44, 86 p.

Figure 65. The early Mesozoic basins are bounded by faults and are filled with thick sequences of sedimentary rocks of fluvial and alluvial origin, as in this interpretive diagram of part of the Newark Basin. Siltstone, mudstone, and local beds of dolomite and coal (not shown) were deposited in lakes and marshy areas within the basins as they filled. Basaltic lava flows are interbed-ded with the sedimentary rocks, which were intruded by diabase sills and dikes.



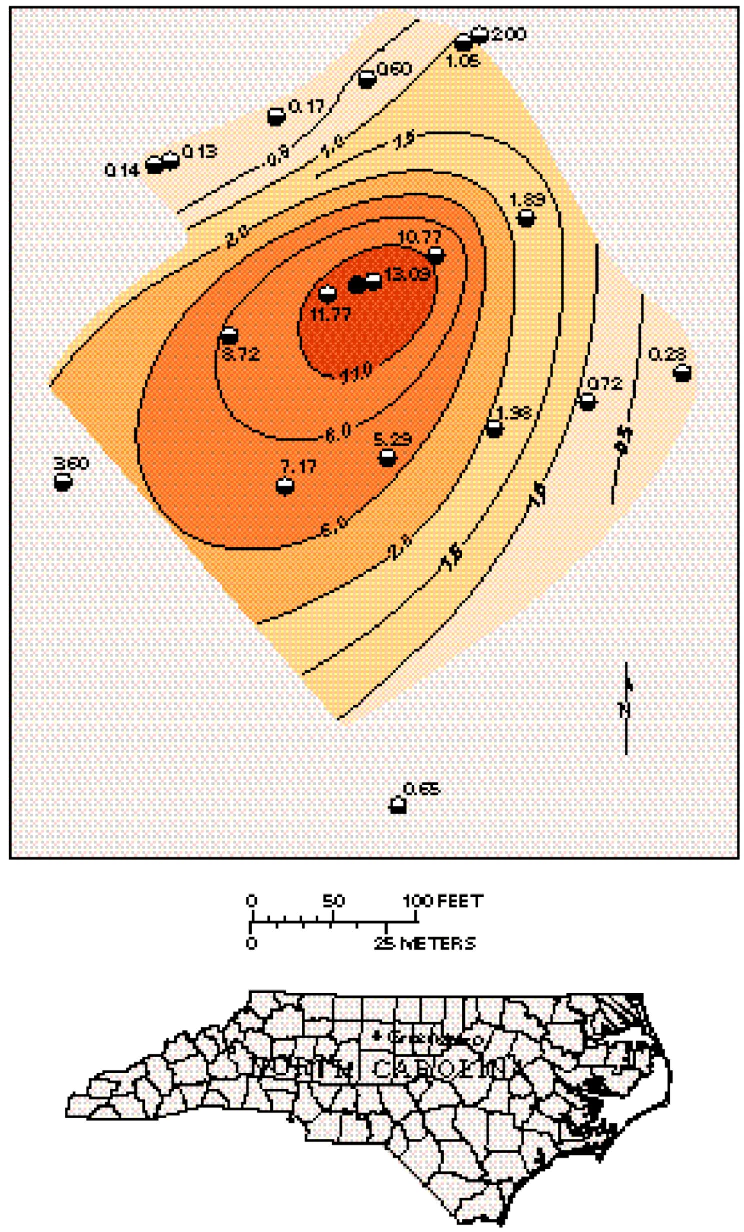
EXPLANATION

- **Conglomerate**
- **Sandstone**
- **Siltstone**
- **Mudstone**
- **Dolomite**
- **Diabase and basalt**
- **Crystalline rocks**
- **Fault**—Arrows show relative direction of movement

Modified from Turner-Peterson, C.E., and Smoot, J.P., 1985, New thoughts on facies relationships in the Triassic Stockton and Lockatong Formations, Pennsylvania and New Jersey, pt. 3 of Robinson, G.R., Jr., and Froelich, A.J., eds., 1985, Proceedings of the 2nd U.S. Geological Survey Workshop on the early Mesozoic basins of the United States: U.S. Geological Survey Circular 946, p. 10–17.

Figure 66. Steeply dipping basalt (on right) and siltstone of the Passaic Formation, cream colored where it was baked by the molten basalt, are typical lower Mesozoic rocks from the Newark Basin in Hunterdon County, N.J. The layers were horizontal at the time the rocks were formed; later, the rocks were tilted and now dip to the right, or northeast. The basalt is intensely fractured because the exposed rocks are near a fault.

Figure 67. Following an aquifer test, contours of equal water-level decline are elongated to the northeast and paral- lel to the direction of fractures in crystalline bedrock. The permea- bility of the rock is greatest in the direction of elongation; this condition of nonuniform permeability is called anisotropy.



EXPLANATION

Water-level decline, in feet

1.0
2
5
11

—1.0— **Line of equal water-level decline**—Interval, in feet, is variable.

Production well

0.65 **Observation well**—Number is water-level decline, in feet

Modified from Daniel, C.C., III, and Sharpless, N.B., 1983, Ground-water supply potential and procedures for well-site selection in the upper Cape Fear River Basin, North Carolina: North Carolina Department of Natural Resources and Community Development, 73 p.

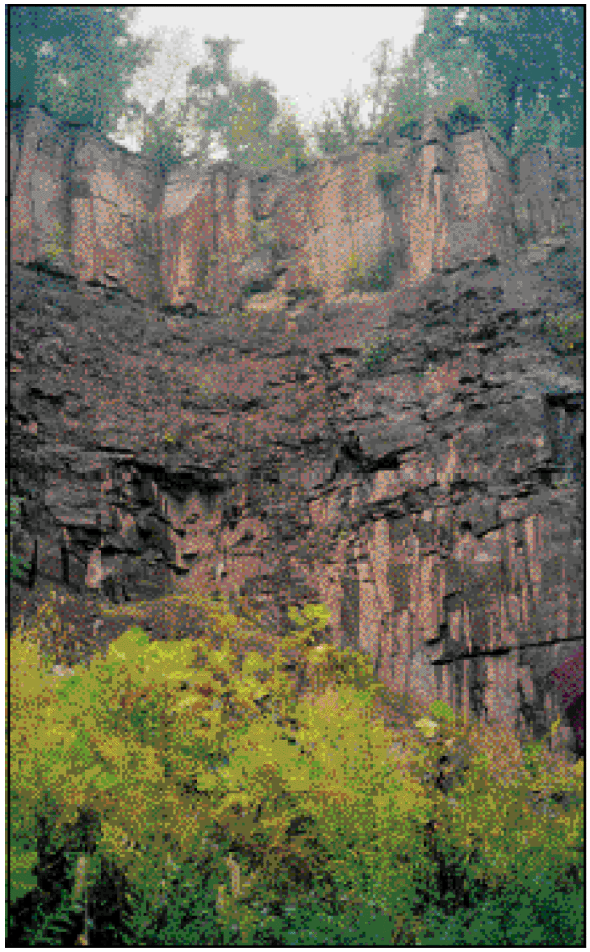
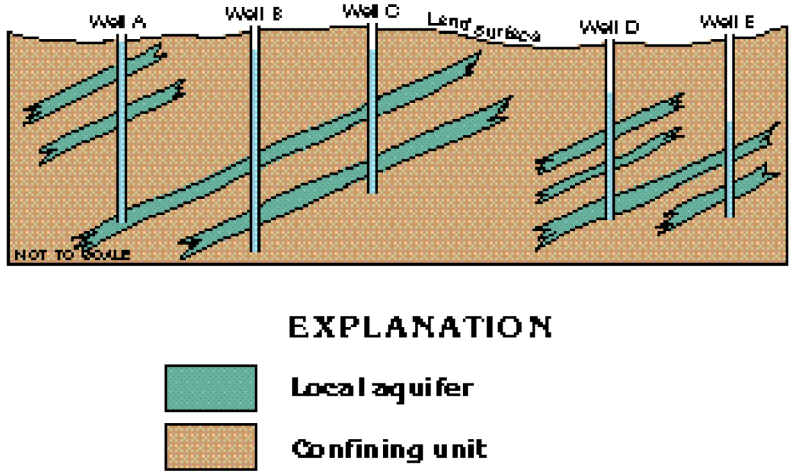


Figure 68. Massive sandstones of the Stockton Formation are exposed in the Newark Basin near Stockton, N.J. Vertical joints and bedding planes in the sandstone beds above and below the dark shale confining unit act as channels for the movement of the water that is visible as dark stains on the quarry face.

Figure 69. Wells aligned in the direction of dip in an early Mesozoic basin might not be completed in the same local aquifers, depending on the angle of dip of the aquifers and the positioning of the wells. Under these conditions, wells can be located so that the pumping of one well has a minimal effect on other wells.



Modified from Vecchioli, John, Carswell, L.D., and Kasabach, H.F., 1969, Occurrence and movement of ground water in the Brunswick Shale at a site near Trenton, New Jersey—Geological Survey research 1969: U.S. Geological Survey Professional Paper 650-B, p. B154-B157.

Figure 70. Crystalline bedrock commonly is overlain by regolith, which is a blanket of weathered rock, alluvium, colluvium, and soil. Most of the ground water is stored in the regolith, but some percolates downward to fill fractures in the less porous bedrock.

EXPLANATION

Direction of ground-water movement

Modified from Heath, R.C., 1980, Basic elements of ground-water hydrology with reference to conditions in North Carolina: U.S. Geological Survey Water-Resources Investigations Open-File Report 80–44, 86 p.

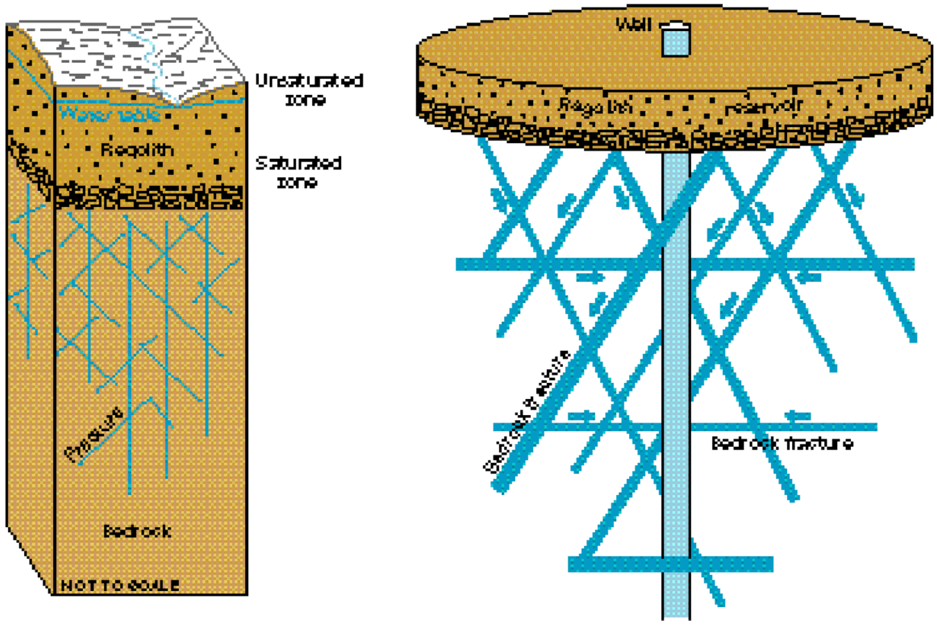
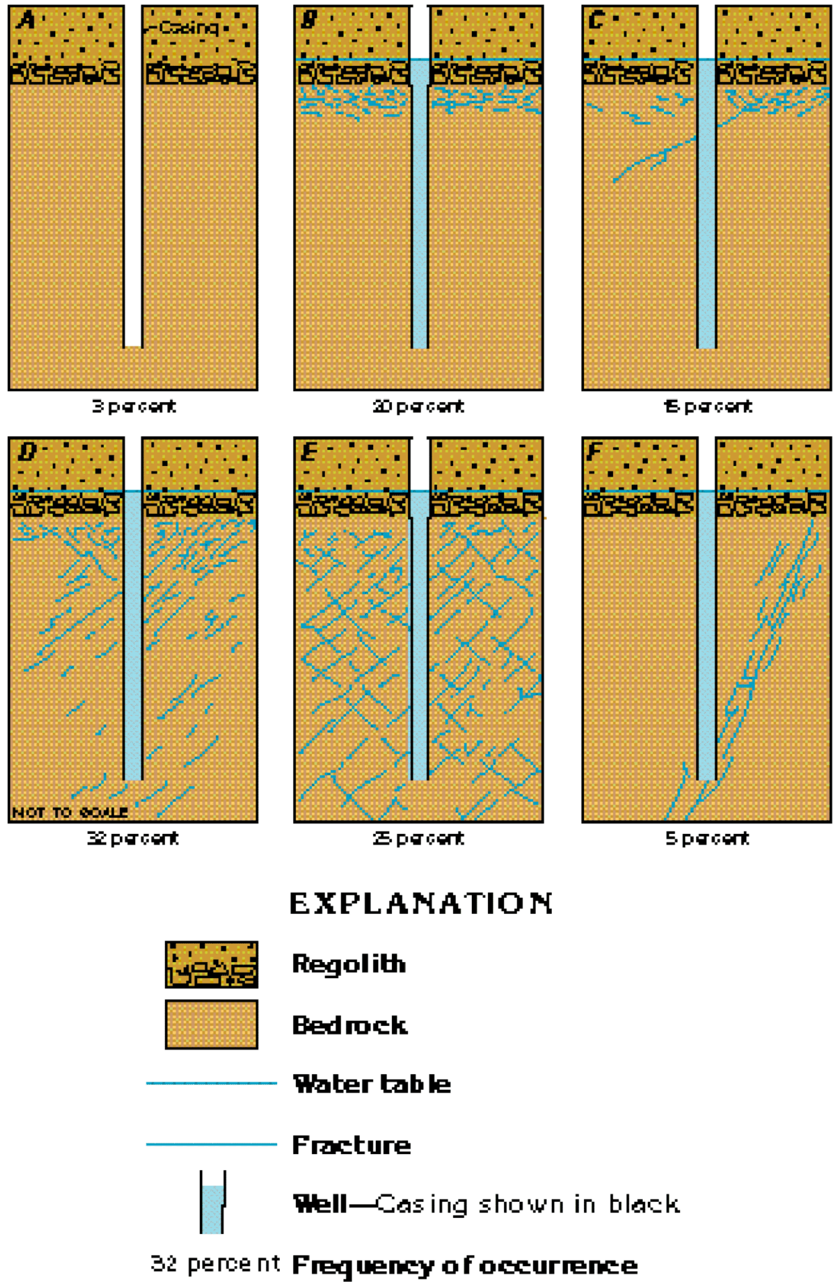
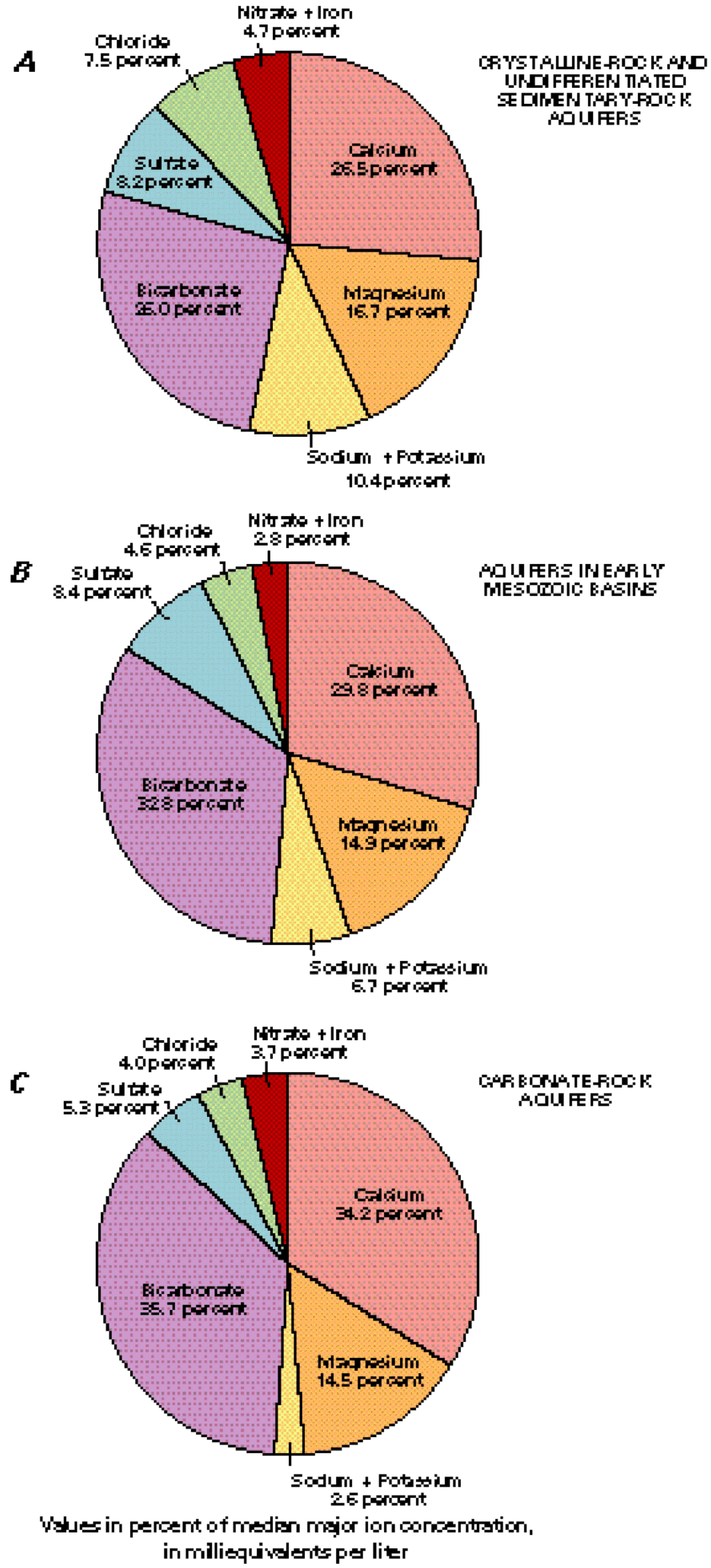


Figure 71. The distribution and interconnection of fractures influence the effective porosity of crystalline rocks under at least six types of conditions. The approximate frequency of occurrence of the different types in North Carolina is shown as a percentage. Wells that pen- etrate no fractures below the casing (A) will probably be dry. Wells that encounter a few fractures (B and C) might briefly yield as much as 20 gallons per minute until the fractures are drained, when the yield suddenly declines. Wells that penetrate several fractures (D) or a large number of interconnected fractures (E) are likely to have the highest sustained yields. Wells that penetrate only a single large fracture (F) will have low sustained yields.



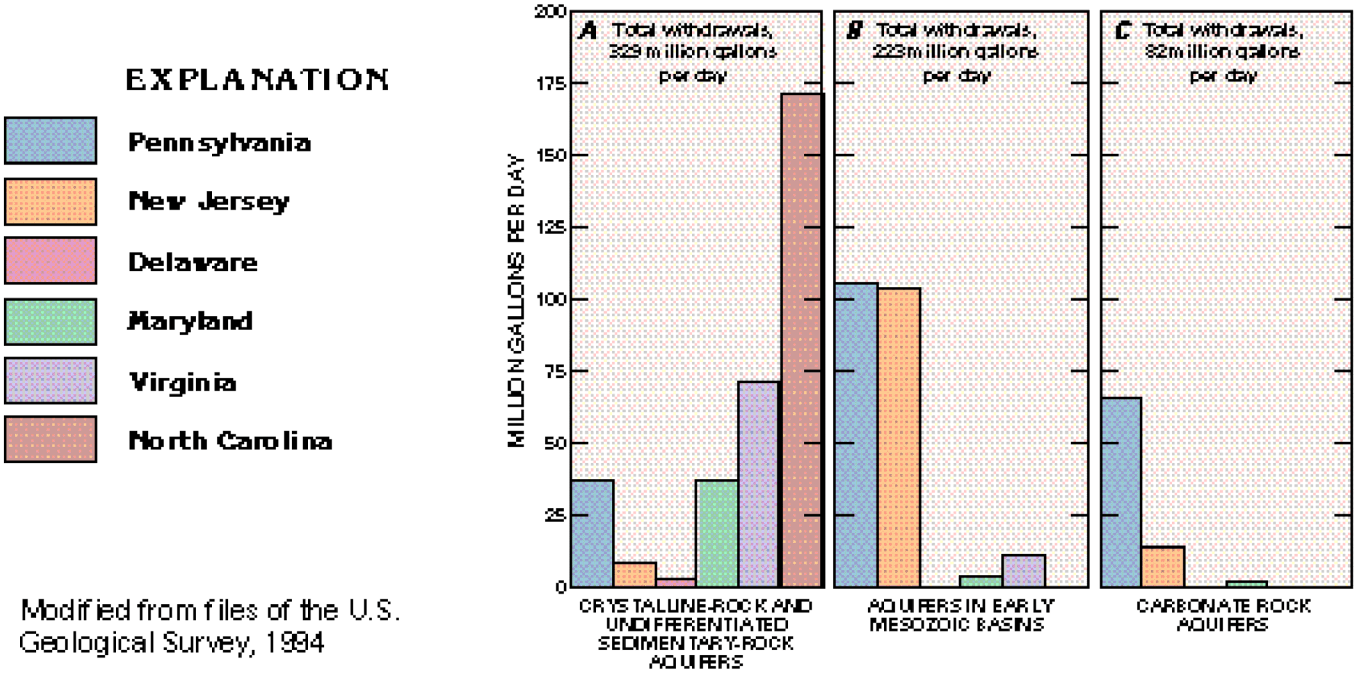
Modified from LeGrand, H.E., 1967, Ground water of the Piedmont and Blue Ridge Provinces in the southeastern States: U.S. Geological Survey Circular 538, 11 p.

Figure 72. Waters from the three aquifer types of the Piedmont and Blue Ridge Provinces have similar chemical compositions—all are calcium plus magnesium bicarbonate (A) or calcium bicarbonate (B and C) types. Nitrate concentrations in all three types of aquifers reflect contamination by fertilizers, animal wastes, or sewage.



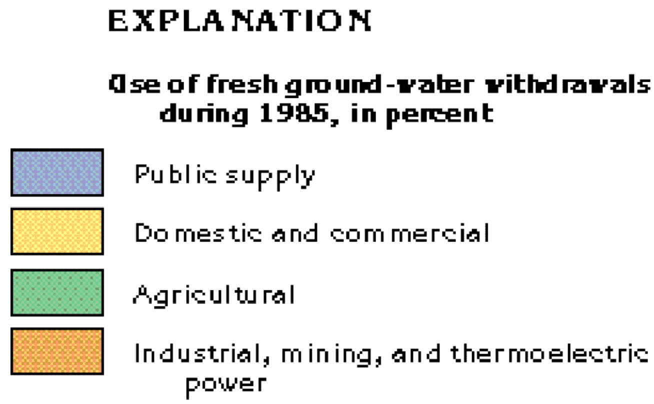
Modified from files of the U.S. Geological Survey

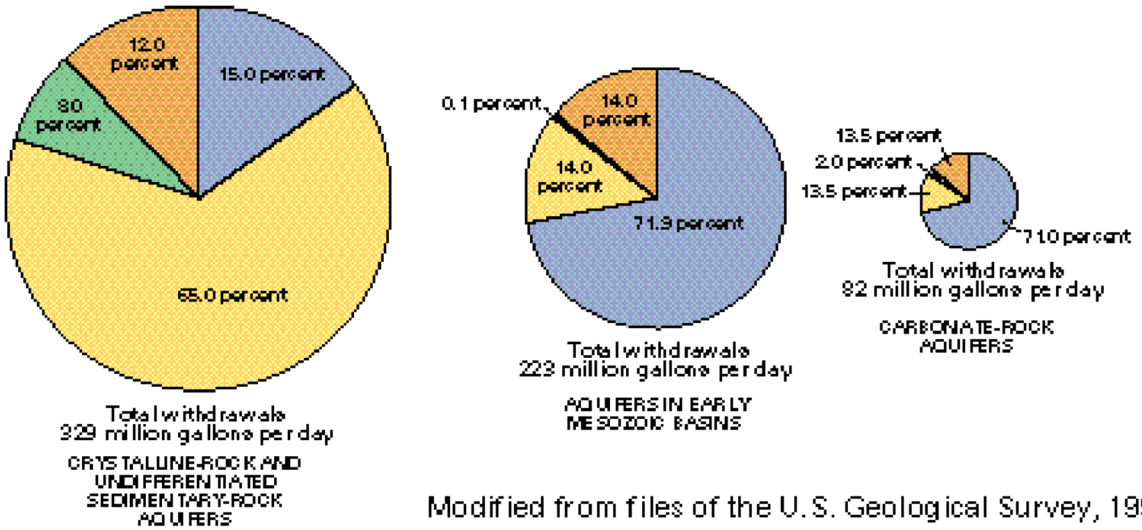
Figure 73. During 1985, the crystalline-rock and undifferentiated sedimentary-rock aquifers (A) were the largest sources of ground water in the Piedmont and the Blue Ridge Provinces and mostly were used in North Carolina and Virginia. Aquifers in early Mesozoic basins (B) also were important sources of supply in Pennsylvania and New Jersey. Carbonate-rock aquifers (C) mostly were used for supply in Pennsylvania.



Modified from files of the U.S. Geological Survey, 1994

Figure 74. Most of the freshwater withdrawn from the crystalline-rock and undifferentiated sedimentary-rock aquifers during 1985 was used for domestic and commercial supplies. Most of the water pumped from the aquifers in early Mesozoic basins and the carbonate-rock aquifers was used for public supply.





Modified from files of the U.S. Geological Survey, 1990

Figure 75. The most important aquifers in the Valley and Ridge Province are northeast- to east-trending carbonate rocks. Undifferentiated sedimentary-rock aquifers that consist mostly of sandstone and yield moderate volumes of water separate the bodies of carbonate rocks. Coal-bearing beds are prominent in parts of the province in Pennsylvania and in a local area in southwestern Virginia.

EXPLANATION

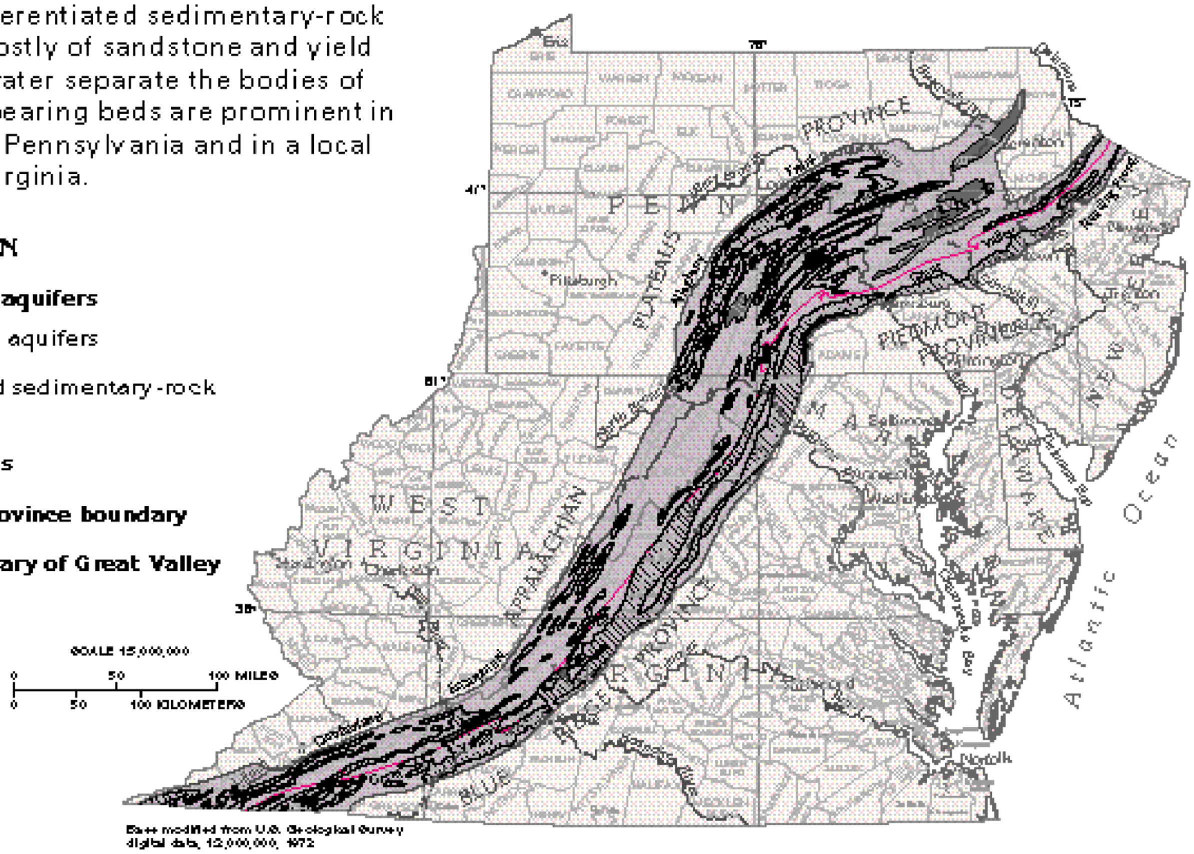
Valley and Ridge aquifers

- Carbonate-rock aquifers
- Undifferentiated sedimentary-rock aquifers

Coal-bearing beds

Physiographic province boundary

Northwest boundary of Great Valley



Modified from:
Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.
Calver, J.L., and others, compilers, 1963, Geologic map of Virginia: Virginia Department of Conservation and Economic Development, Division of Mineral Resources, scale 1:500,000, 1 sheet.
Cardwell, D.H., Erwin, R.B., and Woodward, H.P., compilers, 1968, Geologic map of West Virginia: West Virginia Geologic and Economic Survey, scale 1:250,000, 2 sheets.
Cleaves, E.T., Edwards, Jonathan, Jr., and Glaser, J.D., compilers, 1968, Geologic map of Maryland: Maryland Geological Survey, scale 1:250,000, 1 sheet.
Berg, T.M., and others, comp., 1980, Geologic map of Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, scale 1:250,000, 3 sheets.

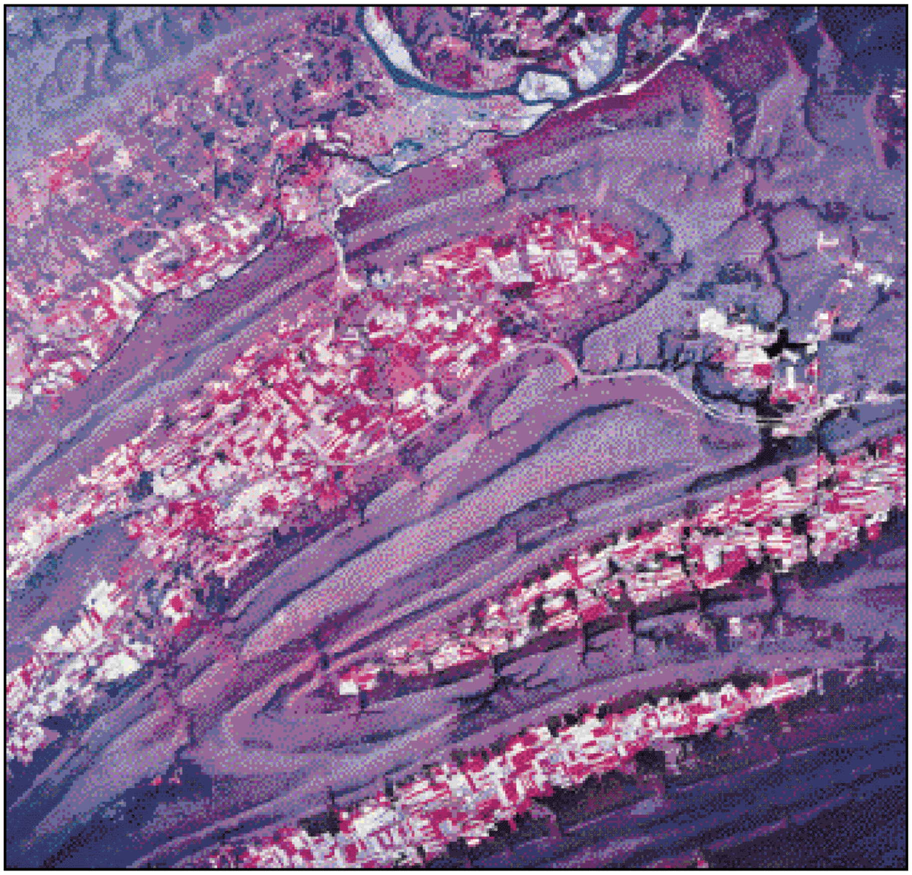
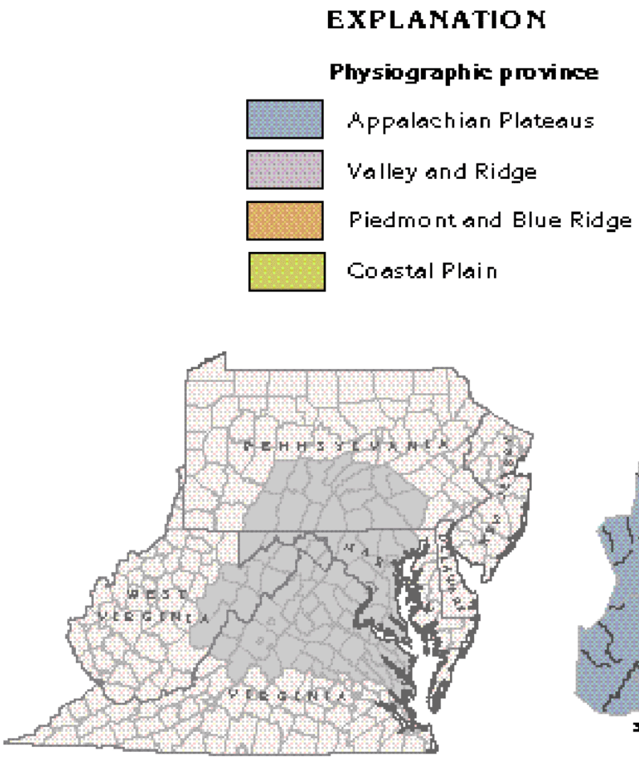
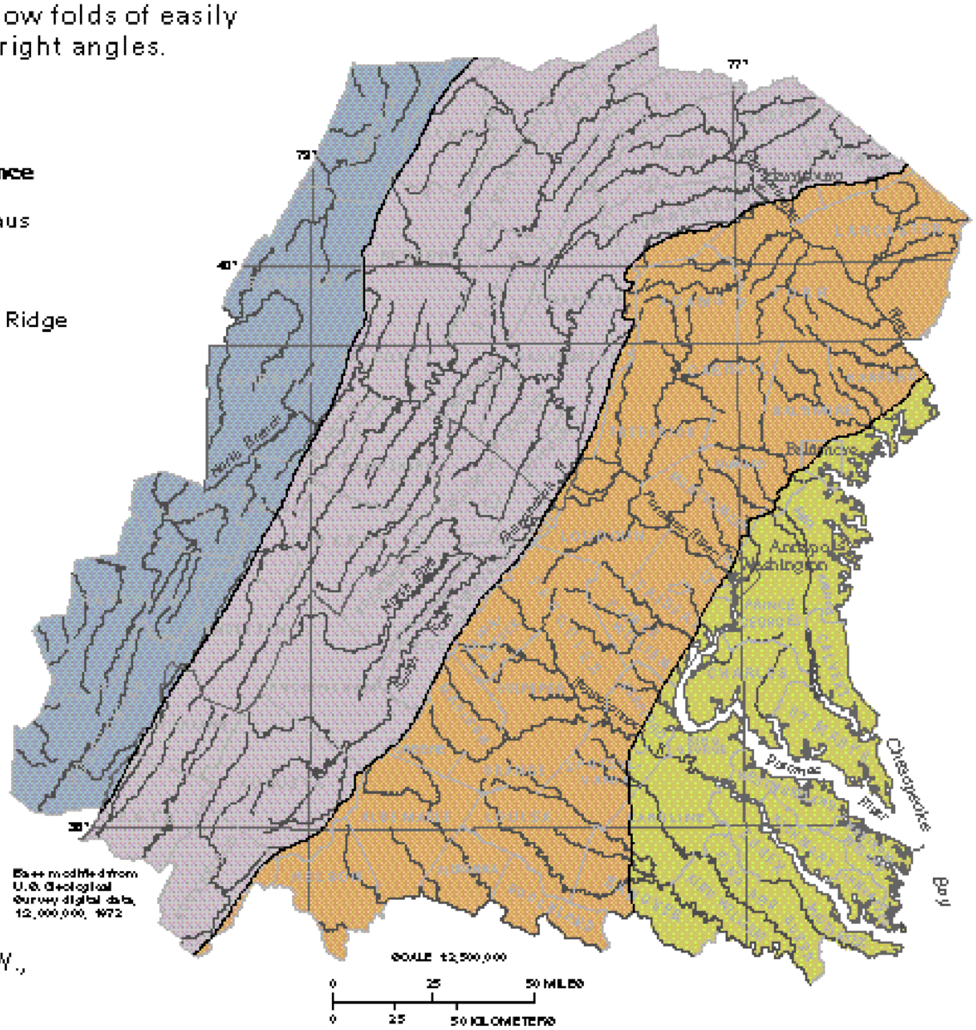


Figure 76. The Valley and Ridge Province also is called the Folded Appalachians because folded sedimentary strata dominate the topography. This photograph is a false-color satellite view of folds in the northern part of the Valley and Ridge Province near Lock Haven, Pa. The multicolored patchwork pattern is cultivated land bounded by sinuous bands of wooded mountains that developed on folded, resistant rocks, which appear dark in the photograph. The Allegheny Front is the area of rugged topography in the upper left corner of the image.

Figure 77. The trellis drainage pattern of the upper Potomac River and its tributaries is typical of the Valley and Ridge Province. The rectangular pattern results from the intersection of superimposed streams that cut across geologic structures and subsequent tributary streams that follow folds of easily eroded rocks. The streams meet nearly at right angles.



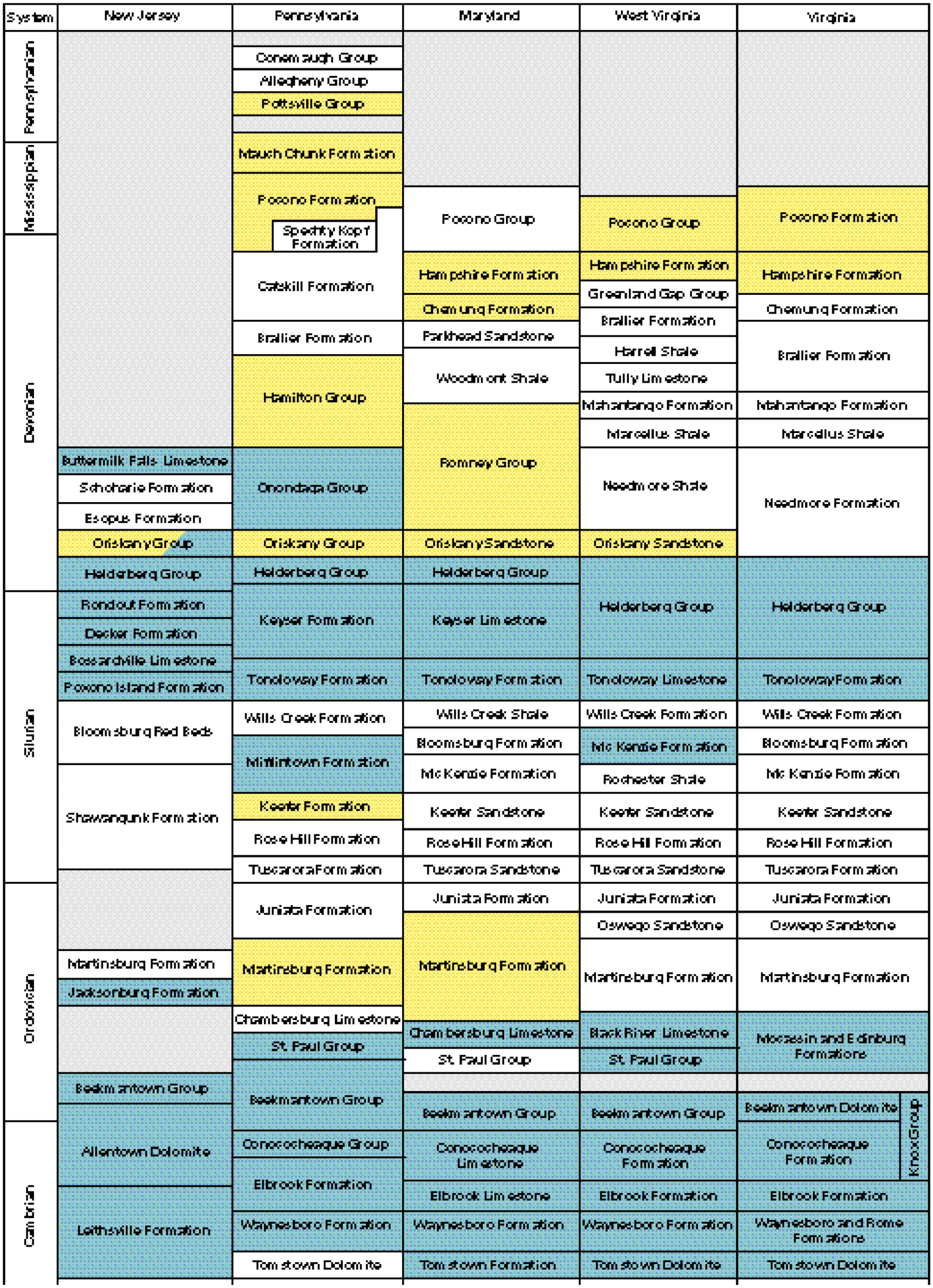


Modified from Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.

Figure 78. A water gap is a deep pass in a mountain ridge through which a stream flows. An example is the Delaware Water Gap, where the Delaware River has cut through massive conglomerate and sandstone beds of Kittatinny Mountain viewed here from the south.

Figure 79. A wind gap, such as the one cut through Blue Mountain, north of Wind Gap, Pa., is a water gap that was abandoned by the stream that formed it.

Figure 80. A large number of geologic formations are in the Valley and Ridge Province. The carbonate-rock formations that are productive aquifers are shown in blue, and productive sandstone aquifers are shown in yellow. The gray areas represent missing rocks.



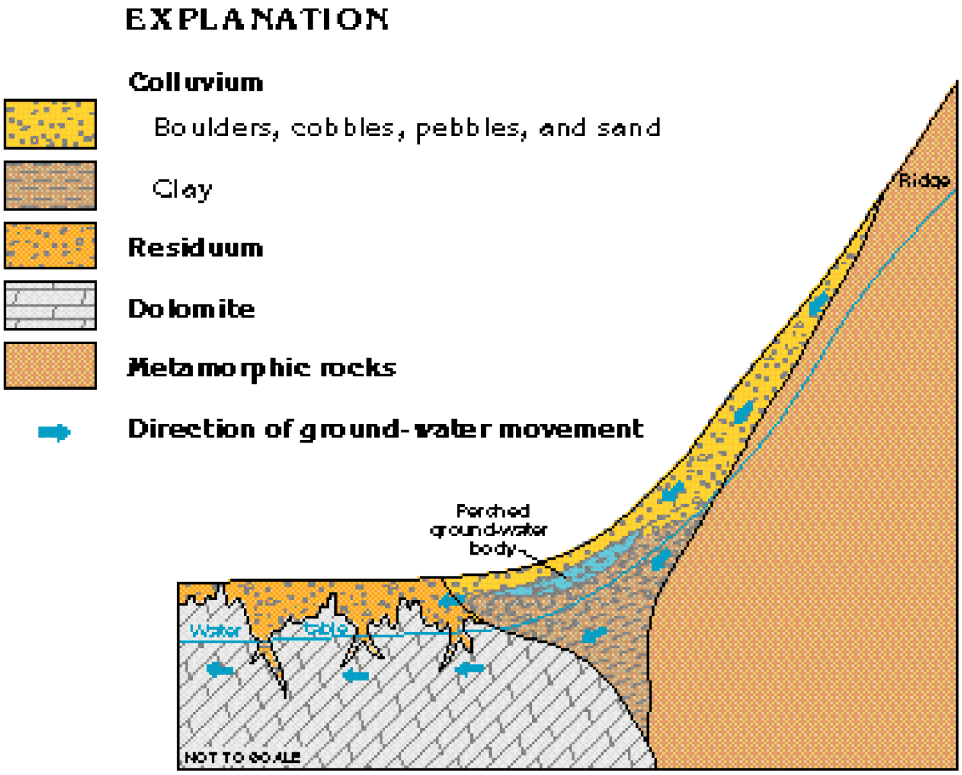
8					Formations
		Tomstown Dolomite	Tomstown Formation	Tomstown Dolomite	Tomstown Dolomite
	Hardyston Quartzite	Chilhowee Group	Chilhowee Group equivalents	Chilhowee Group	Chilhowee Group

Modified from:

Patchen, D.G., and others, 1985a, Correlation of stratigraphic units of North America (COSUNA) Project, southern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

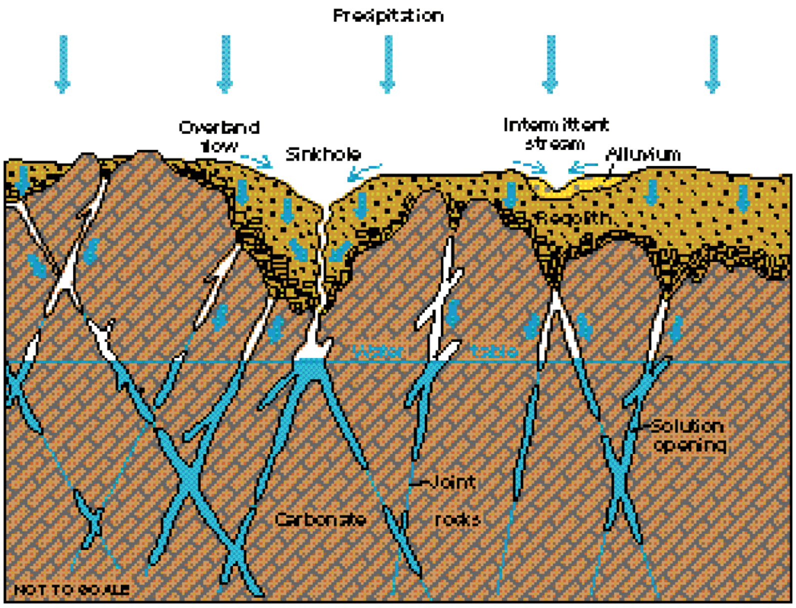
______1985b, Correlation of stratigraphic units of North America (COSUNA) Project, northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Figure 81. Thick wedges of colluvium on the lower flanks of ridges store large quantities of water that subsequently move into aquifers in the valleys. The colluvium commonly contains perched bodies of ground water that are separated from the main water table by clay confining units.



Modified from Nutter, L.J., 1974a, Hydrogeology of Antietam Creek Basin: U.S. Geological Survey Journal of Research, v. 2, no. 2, p. 249–252.

Figure 81. Thick wedges of colluvium on the lower flanks of ridges store large quantities of water that subsequently move into aquifers in the valleys. The colluvium commonly contains perched bodies of ground water that are separated from the main water table by clay confining units.



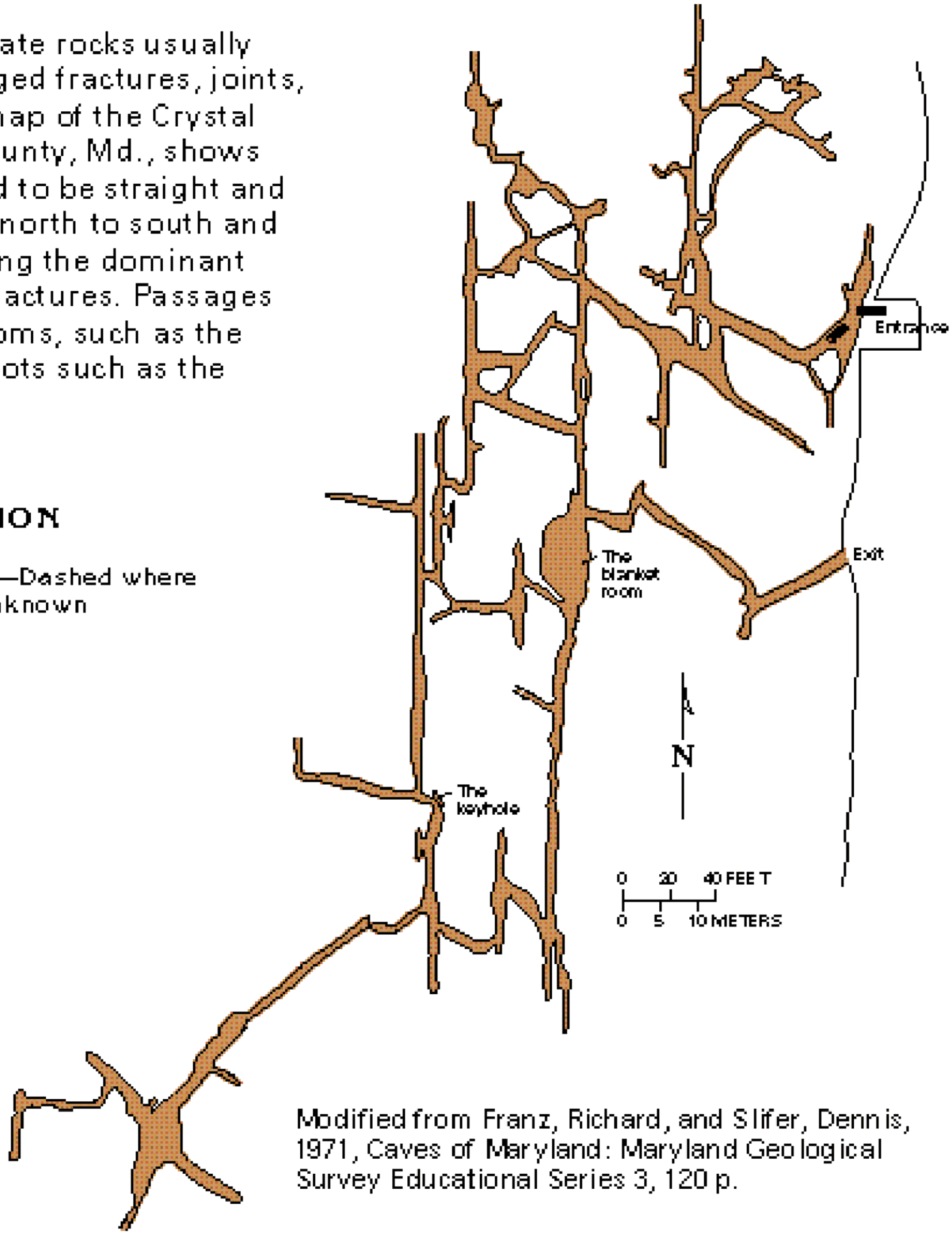
Modified from Nutter, L.J., 1973, Hydrogeology of the carbonate rocks, Frederick and Hagerstown Valleys: Maryland Geological Survey Report of Investigations 9, 70 p.

Figure 83. Caves in carbonate rocks usually originate as solution-enlarged fractures, joints, and bedding planes. This map of the Crystal Grottoes in Washington County, Md., shows that the cave passages tend to be straight and are aligned predominately north to south and northwest to southeast along the dominant directions of intersecting fractures. Passages range in size from large rooms, such as the Blanket Room, to narrow slots such as the Keyhole.

EXPLANATION

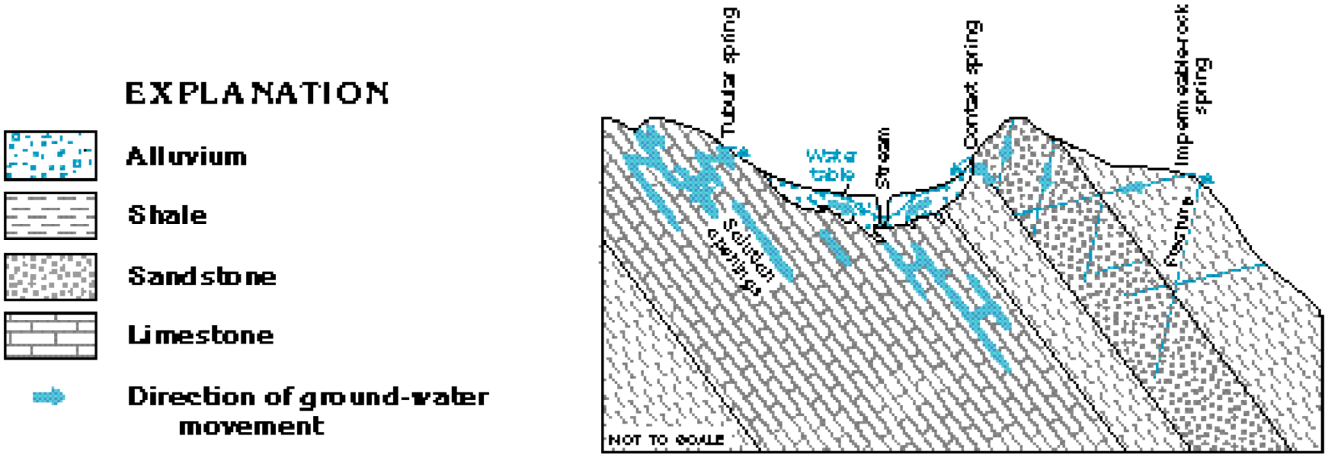
Cave passage—Dashed where location unknown

Escarpment



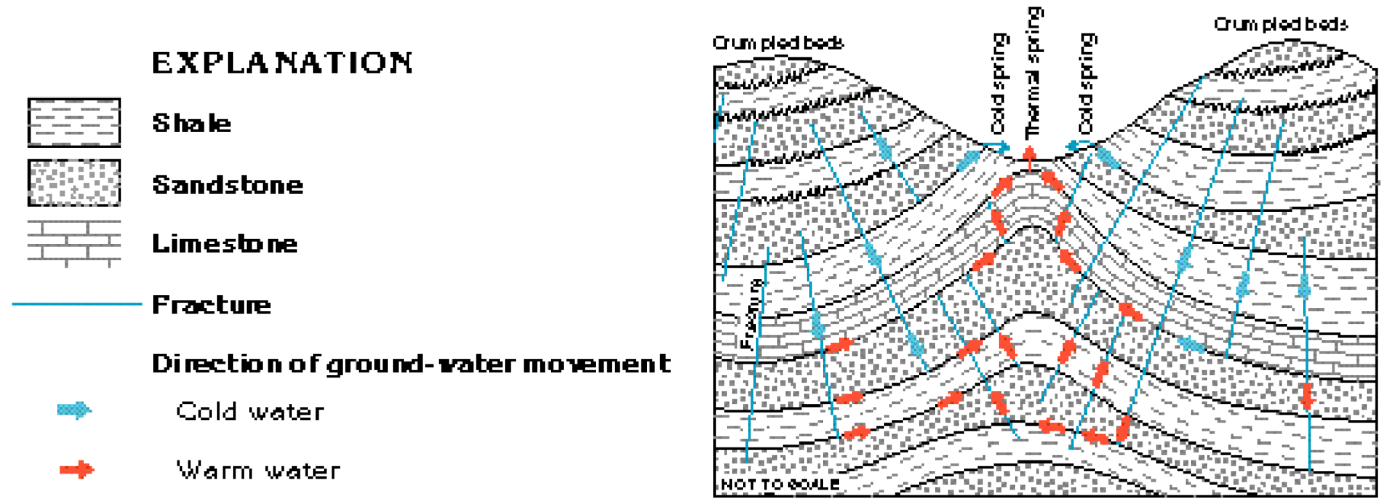
Modified from Franz, Richard, and Slifer, Dennis, 1971, Caves of Maryland: Maryland Geological Survey Educational Series 3, 120 p.

Figure 84. Tubular springs, contact springs, and impermeable-rock springs are common in the Valley and Ridge Province, but only the tubular springs yield large quantities of water.



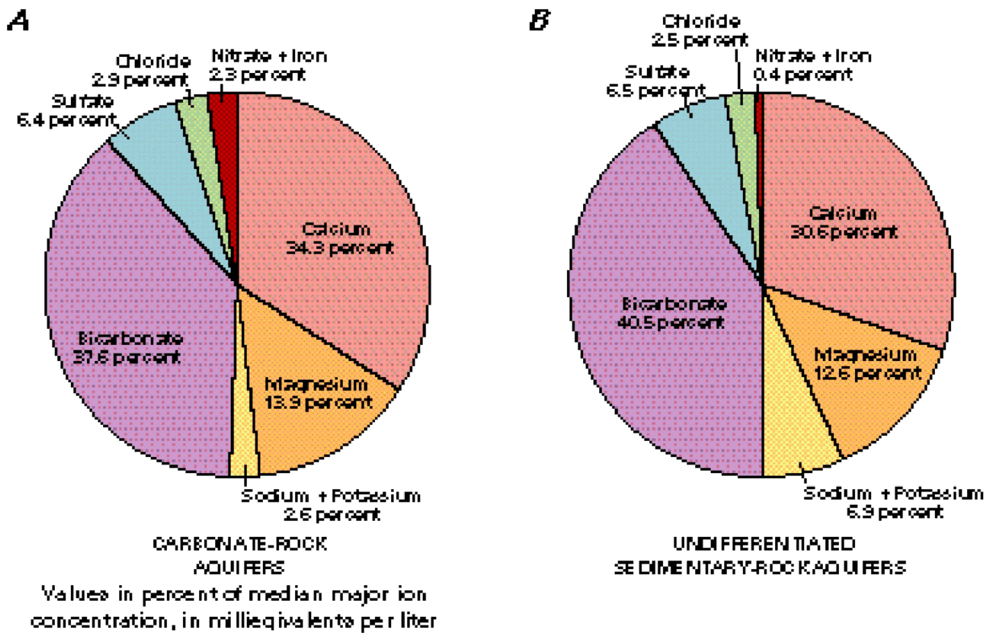
Modified from Brahana, J.V., Mulderink, Dolores, Macy, JoAnn, and Bradley, M.W., 1986, Preliminary delineation and description of the regional aquifers of Tennessee—The East Tennessee aquifer system: U.S. Geological Survey Water-Resources Investigations Report 82–4091, 30 p.

Figure 85. Water that issues from thermal springs has circulated along deep flow paths that channeled the water to depths where it became heated by the normal increase in temperature with depth in the Earth's crust. Most of the thermal springs issue near the axes of anticlines, but some issue along fault zones. Deep, connected fractures, such as these in Warm Springs Valley, Va., provide conduits that can channel the water to great depths.



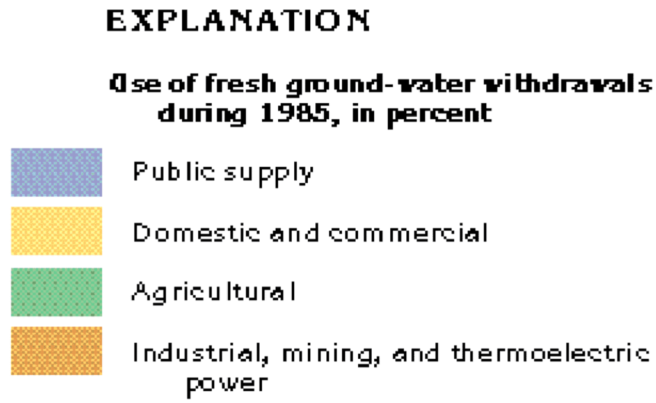
Modified from Hobba, W.A., Jr., Fisher, D.W., Pierson, F.J., Jr., and Chemerys, J.C., 1979, Hydrology and geochemistry of thermal springs of the Appalachians; Geohydrology of geothermal systems: U.S. Geological Survey Professional Paper 1044-E, 36 p.

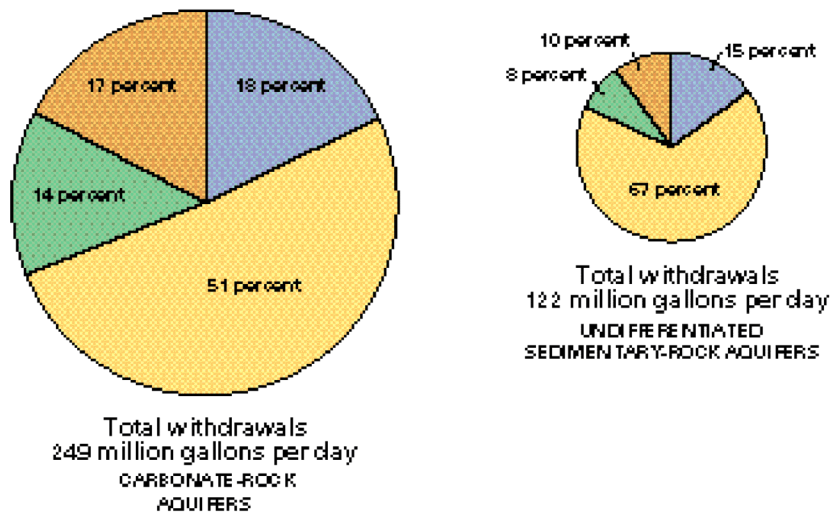
Figure 86. Waters from the carbonate-rock aquifers (A) of the Valley and Ridge Province contain only slightly larger concentrations of calcium, magnesium, and bicarbonate than those from undifferentiated sedimentary-rock aquifers (B). The presence of nitrate in water from the carbonate-rock aquifers is an indication that the water has been contaminated by fertilizers, animal wastes, or sewage.



Modified from the files of the U.S. Geological Survey

Figure 87. Slightly more than one-half of the total freshwater withdrawn from the carbonate-rock aquifers in the Valley and Ridge Province during 1985 was used for domestic and commercial purposes; about two-thirds of the water withdrawn from undifferentiated sedimentary-rock aquifers was pumped for the same uses. The remainder of the water withdrawn was used nearly equally for public supply, agricultural, and industrial, mining, and thermoelectric power purposes.





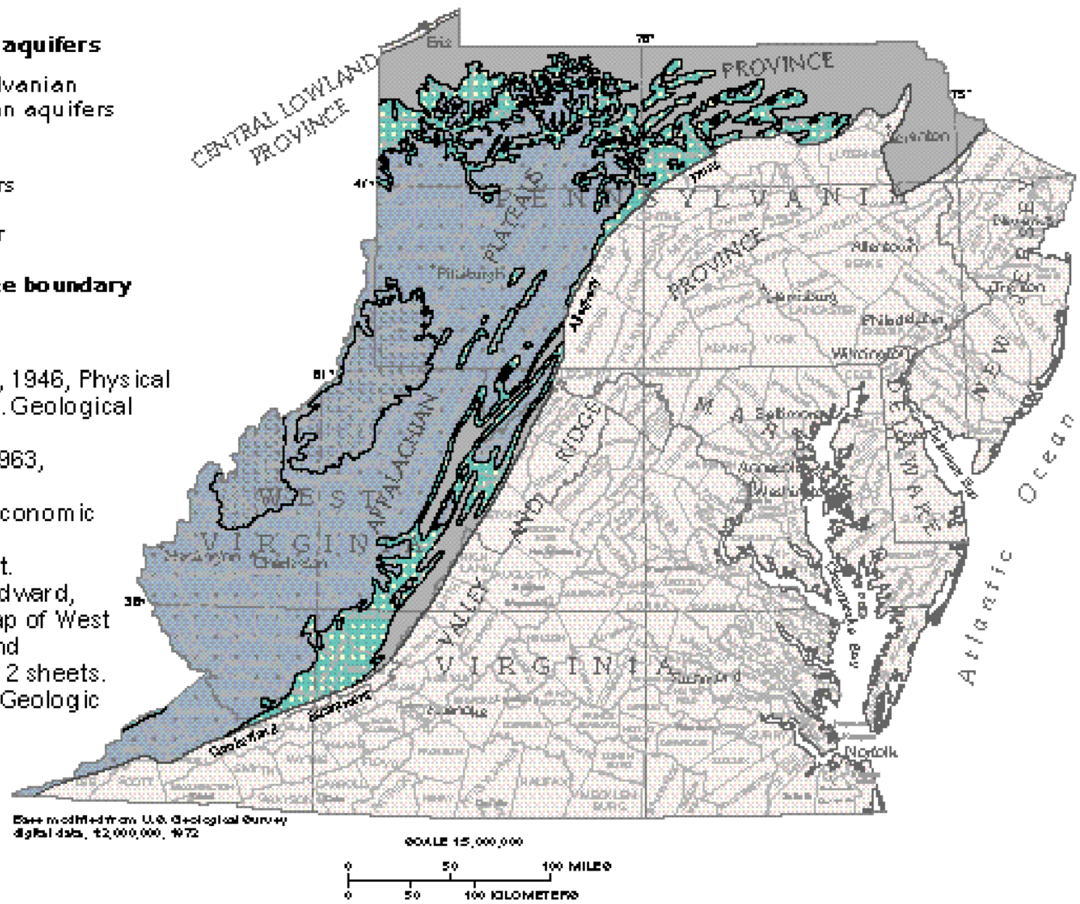
Modified from U.S. Geological Survey files, 1990

Figure 88. Consolidated sedimentary rocks of Permian, Pennsylvanian, and Mississippian ages, chiefly sandstone, compose the aquifers of the Appalachian Plateaus Province in Segment 11.

EXPLANATION

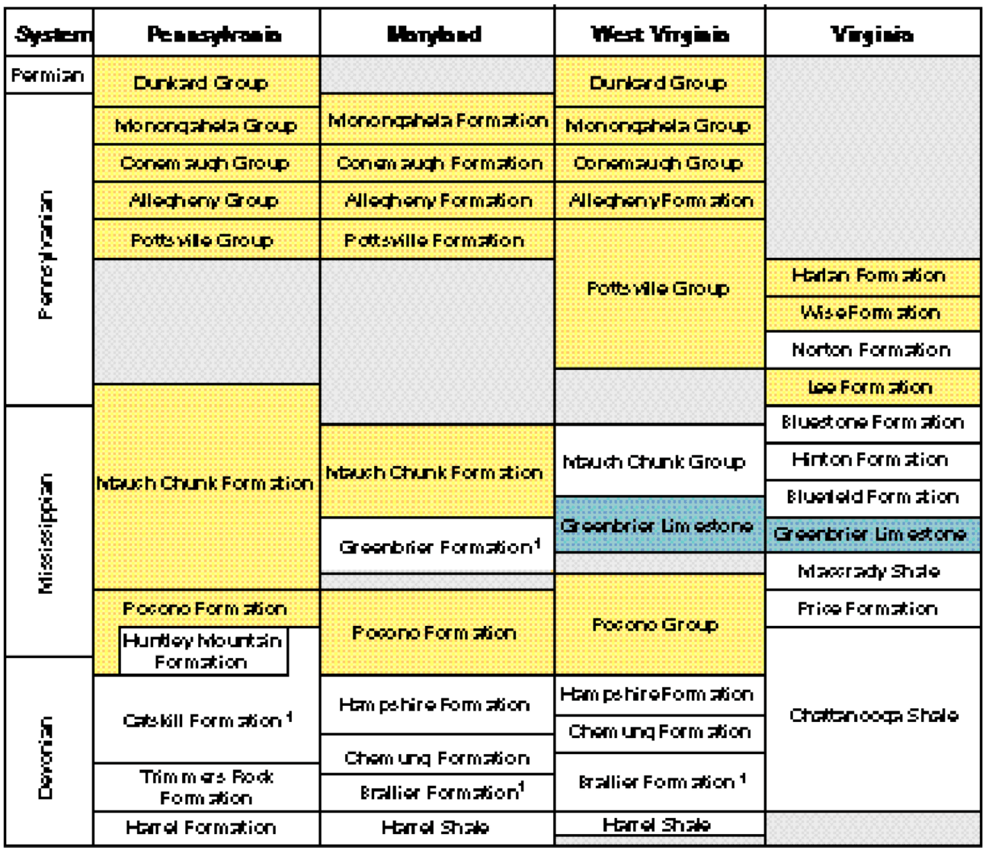
Appalachian Plateaus aquifers

- Permian and Pennsylvanian aquifers—Permian aquifers patterned
- Mississippian aquifers
- **Not a principal aquifer**
- **Physiographic province boundary**



Modified from:
Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.
Calver, J.L., and others, compilers, 1963, Geologic map of Virginia: Virginia Department of Conservation and Economic Development, Division of Mineral Resources, scale 1:500,000, 1 sheet.
Cardwell, D.H., Erwin, R.B., and Woodward, H.P., compilers, 1968, Geologic map of West Virginia: West Virginia Geologic and Economic Survey, scale 1:250,000, 2 sheets.
Berg, T.M., and others, comp., 1980, Geologic map of Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, 4th ser., scale 1:250,000, 3 sheets.

Figure 89. The principal aquifers in the Appalachian Plateaus Province in Segment 11 are sandstones in the geologic units shown in yellow and limestone shown in blue. Where fractured, rocks of the Greenbrier, the Catskill, and the Brallier Formations locally yield water. The gray areas represent missing rocks.



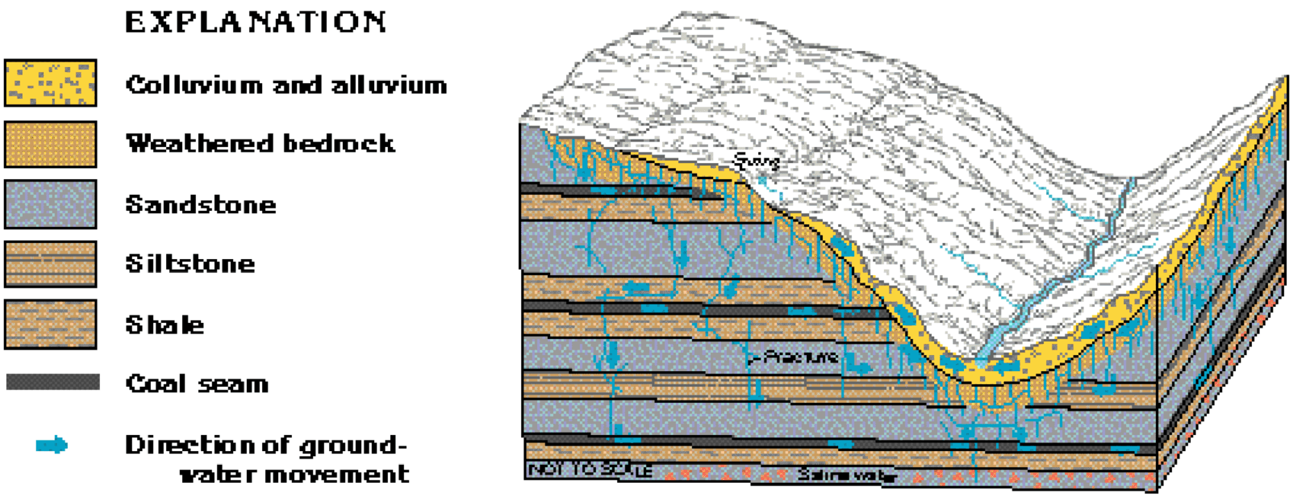
[1] Locally water-yielding

Modified from:

Patchen, D.G., and others, 1985a, Correlation of stratigraphic units of North America (COSUNA) Project, southern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

______1985b, Correlation of stratigraphic units of North America (COSUNA) Project, northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Figure 90. Topography and shallow fracture systems determine ground-water movement in the aquifers of the Appalachian Plateaus. Water infiltrates weathered bedrock and moves mostly through near-surface fractures; some water moves in a steplike fashion vertically along deeper fractures and horizontally through fractured sandstone or coal beds. Because of the absence of deep ground-water circulation and regional flow systems, saline water is at shallow depths.

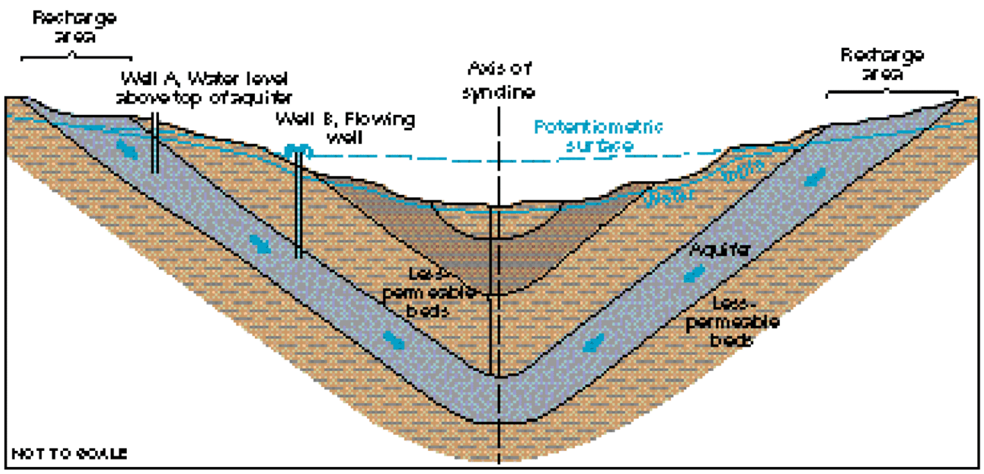


Modified from Harlow, G.E., Jr., and LeCain, G.D., 1993, Hydraulic characteristics of, and ground-water flow in, coal-bearing rocks of southwestern Virginia: U.S. Geological Survey Water-Supply Paper 2388, 36 p.

Figure 91. Flowing wells are common in synclinal valleys of the Appalachian Plateaus. The water in the aquifer is confined by less-permeable material, is under pressure, and rises above the top of the aquifer (well A). Wells at lower altitudes might flow at the land surface (well B).

EXPLANATION

- Sandstone
- Siltstone
- Shale
- Direction of ground-water movement



Modified from Baldwin, H.L., and McGuinness, C.L., 1963, A primer on ground water: U.S. Geological Survey, 26 p.

Figure 92. Stress relief occurs when compressional stress is partly removed by erosion of overlying rocks; this results in the formation of predictable fracture patterns in valleys. The fractures are generally horizontal under valley floors and vertical along valley walls. The interconnected fracture system greatly increases the permeability of the rocks, especially in the valleys.

EXPLANATION

Colluvium and alluvium

Sandstone

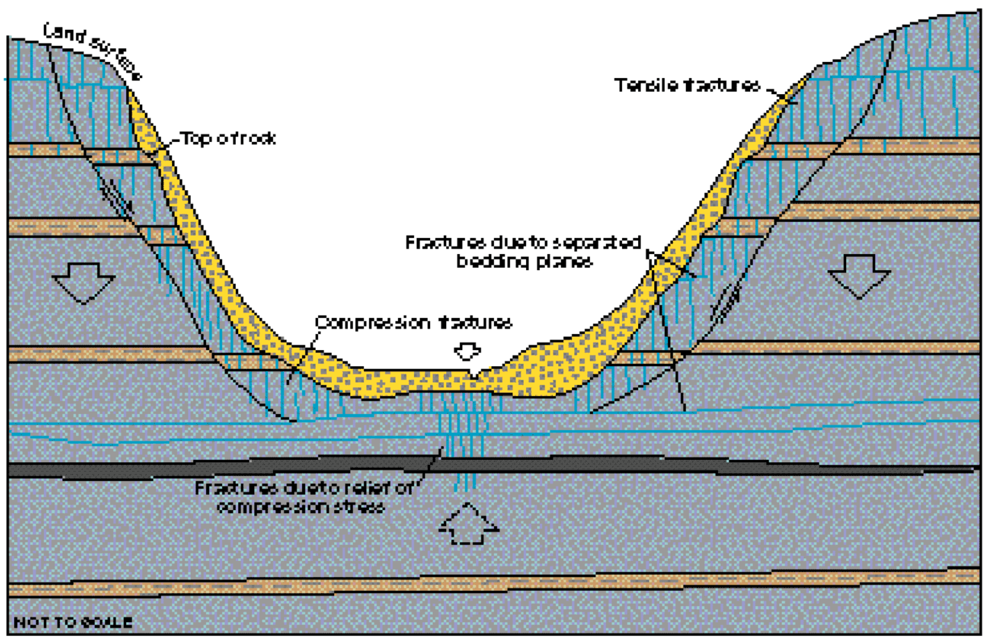
Shale

Coal seam

Compressional stress—Proportional to size of arrow

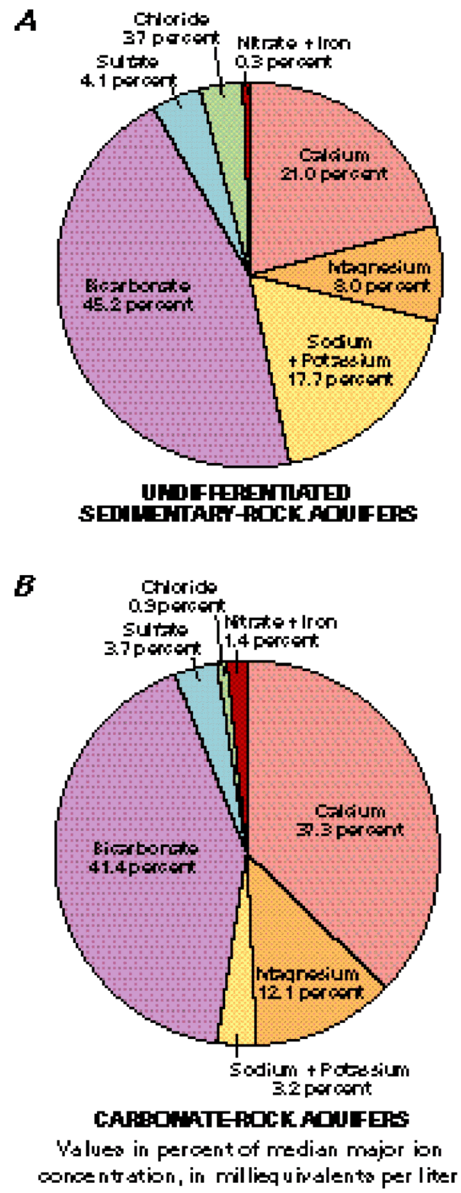
Resultant stress

Plane of slumping—Arrows show relative movement



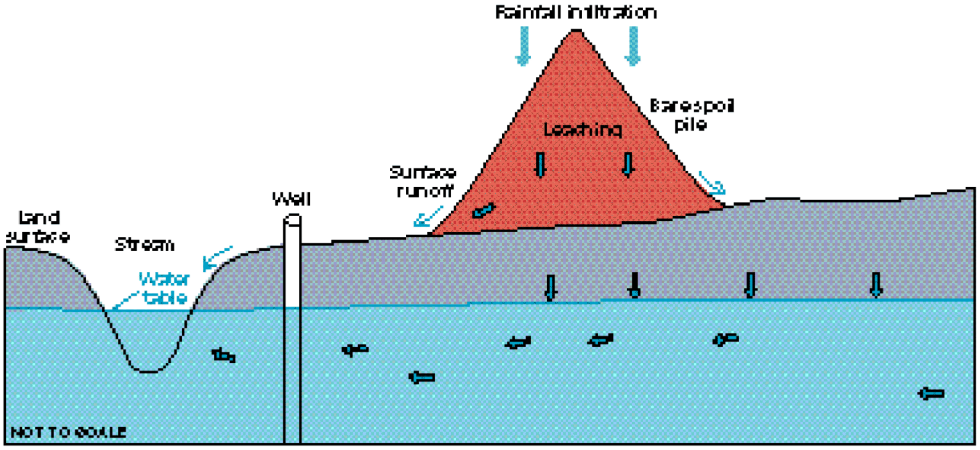
Modified from: Wyrick, G.G., and Borchers, J.W., 1981, Hydrologic effects of stress-relief fracturing in an Appalachian valley: U.S. Geological Survey Water-Supply Paper 2177, 51 p.

Figure 93. Water from undifferentiated sedimentary-rock aquifers, chiefly sandstone and shale, of the Appalachian Plateaus Province (A) contains smaller concentrations of calcium and mag-nesium than water from carbonate-rock aquifers (B). Nitrate in greater than trace concentrations in that from the carbonate-rock aquifers is an indication of contamination by fertilizers, animal wastes, or sewage.



Modified from the files of the U.S. Geological Survey

Figure 94. Coal mining generates large quantities of waste material called spoil, which commonly contains sulfate minerals. The spoil is mounded in large piles on the land surface where it is exposed to decomposition by the action of air, water, and bacteria. Weathering products include sulfuric acid, ferrous iron, manganese, and trace metals, which, when leached by precipitation, can infiltrate the ground and contaminate aquifers.

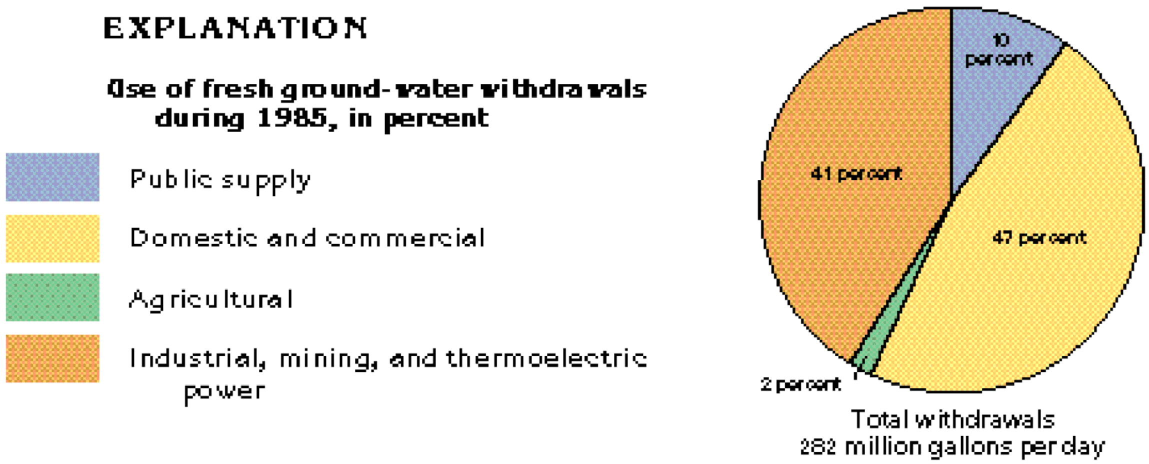


Modified from Kiesler, Jay, Quinones, Ferdinand, Mull, D.S., and York, K.L., 1983, Hydrology of Area 13, eastern coal province, Kentucky, Virginia, and West Virginia [Big Sandy River, Levisa Fork, Tug Fork, Blaine Creek]: U.S. Geological Survey Water-Resources Investigations Open-File Report 82–505, 112 p.

Figure 95. Drainage from an abandoned underground coal mine in western Pennsylvania is discolored by large concentrations of iron and other metals and is strongly acidic. The mine drainage pictured is at the land surface, where it pollutes streams, but some also enters and contaminates ground water.

Photo from Roth and others, 1981

Figure 96. Most of the freshwater withdrawn from the consolidated sedimentary-rock aquifers in the Appalachian Plateaus Province during 1985 was used for domestic and commercial supplies and for industrial, mining, and thermo electric power purposes.



Modified from U.S. Geological Survey files, 1990