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ANALYSIS OF RECORDS AND VARIABLES

A substantial part of the differences between median specific-capacity values for the five hydrogeologic terranes (fig. 8) is due to variables other than hydrogeologic terrane. Casing diameter, primary use of the water, and topographic setting influence the specific-capacity values of wells completed in the various hydrogeologic terranes. For example, when specific-capacity values for wells in the limestone hydrogeologic terrane were grouped sequentially, first by categories of the variable casing diameter, then by categories of primary use of the water, and last by categories of topographic setting (fig. 11), substantial differences became apparent. For the limestone hydrogeologic terrane, wells with casing diameters of less than 7 in. generally have smaller specific capacity than wells with casing diameters of greater than 9 in. Wells used for domestic supply typically have smaller specific capacity than wells used for public or industrial supply, and wells located on hills have smaller specific capacity than wells located in valleys (fig. 11). These categories have similar relations to specific-capacity values for wells completed in the four other hydrogeologic terranes.

To further examine the apparent differences in specific-capacity values among the categories of the variables casing diameter, primary use of the water, and topographic setting, a nonparametric statistical procedure, Tukey's honestly significant difference test (SAS Institute, Inc., 1985, p. 473), was employed. Tukey's test was used to determine if the apparent differences in median values among these categories were statistically significant from each other. The Tukey test involves the null hypothesis that no real differences in median values of specific capacity exist among wells in the various categories. An alpha level, or level of probability, is used in the test to represent the maximum probability of rejecting the null hypothesis when it is actually true. Tukey tests performed at a probability (alpha level) of 0.05 indicated a statistically significant difference between the median values of specific capacity for the following seven pairs of categories within the three variables {where (less than 7 in.)/(7 to 9 in. inclusive) is an example of a single pair} (fig. 11):

Seven pairs of categories within three variables:
- Casing diameter:
  - (less than 7 in.)/(7 to 9 in. inclusive)
  - (less than 7 in.)/(greater than 9 in.),
  - (7 to 9 in. inclusive)/(greater than 9 in.),
- Primary use of the water:
  - (domestic)/(commercial),
  - (domestic)/(public supply and industrial),
  - (commercial)/(public supply and industrial)
- Topographic setting:
  - (hill)/(valley)

Differences among the hydrogeologic terranes in regard to the percentage of wells in each category of the three variables tend to bias the median values of specific capacity and complicate the determination of significant differences in water-yielding properties among the hydrogeologic terranes. For example, the alluvium hydrogeologic terrane has a larger percentage of wells with casing diameters of greater than 9 in. than does the dolomite hydrogeologic terrane (fig. 8). This difference between the two hydrogeologic terranes tends to exaggerate the apparent difference between their median values of specific capacity. Testing for significant differences in water-yielding properties between the alluvium and dolomite hydrogeologic terranes may not be possible without accounting for differences between data sets in regard to casing diameter.

A method for reducing the influence of casing diameter, primary use of the water, and topographic setting on specific capacity is to subdivide the data base into homogeneous data sets in which the wells have the same characteristics with respect to these three variables. Two homogeneous data sets were constructed for each hydrogeologic terrane—the most-productive wells and the least-productive wells (fig. 12). The homogeneous data set that represented the most-productive wells consisted only of wells with casing diameters of greater than or equal to 7 in., used for either public or industrial supply, and located in valleys. The homogeneous data set that represented the least-productive wells consisted only of wells with casing diameters of less than 7 in., used for domestic supply, and located on hills.

Specific-capacity values for these two homogeneous data sets for each hydrogeologic terrane are significantly different according to Tukey tests—probability (alpha level) of 0.001. Subdividing the data into homogeneous sets (fig. 12) revealed some of the cause for the large range in values within each hydrogeologic terrane that results in overlapping values between terranes (fig. 8). The homogeneous data sets represent end members in a range of values wherein restrictions were made on the three variables—casing diameter, primary use of the water, topographic setting. In contrast, no restrictions were made on these variables in the undivided sets; consequently, the range in specific-capacity values for each hydrogeologic terrane was sufficiently large that real differences among terranes were obscured, and the range in values for each hydrogeologic terrane had substantial overlap with the range of other terranes (fig. 8). Subdividing the data base by the three variables allows for better estimates of the specific capacity of the hydrogeologic terranes.

Valid conclusions about significant differences in water-yielding properties can be made by comparing subdivided data sets. Concerning a comparison of median specific-capacity values for most-productive wells, Tukey test results indicated a statistically significant difference—probability (alpha level) of 0.10—between median values for the following pairs of hydrogeologic terranes:

Eight pairs of hydrogeologic terranes:
- (alluvium)/(limestone),
- (alluvium)/(argillaceous carbonate rock),
- (alluvium)/(siliciclastic rock),
- (dolomite)/(limestone),
- (dolomite)/(argillaceous carbonate rock),
- (dolomite)/(siliciclastic rock),
- (limestone)/(siliciclastic rock), and
- (argillaceous carbonate rock)/(siliciclastic rock)

Tukey test results did not indicate a statistically significant difference between median values of specific capacity for the remaining two pairs of hydrogeologic terranes at a probability (alpha level) of 0.10:

Two pairs of hydrogeologic terranes:
- (alluvium)/(dolomite), and
- (limestone)/(argillaceous carbonate rock)

In summary, Tukey test results indicated that the differences in median specific-capacity values were significant for at least 8 of the 10 pairs of hydrogeologic terranes by use of homogeneous data sets. The hydrogeologic terranes are, for the most part, significantly different in their water-yielding properties.

POTENTIAL YIELD OF WATER TO WELLS

The potential rate that water can be withdrawn from public- and industrial-supply wells can be estimated from the reported specific-capacity values of the most-productive wells (fig. 12) by assuming constant drawdowns for each hydrogeologic terrane and negligible well-entrance losses. For these wells, the median drawdowns (rounded to the nearest 10 ft) were 10 ft, alluvium; 30 ft, dolomite and limestone; 50 ft, argillaceous carbonate rock; and 90 ft, siliciclastic rock. As an example of the calculation of potential yield, the median specific capacity of the 47 most-productive wells in siliciclastic rock (fig. 12) was 1.3 (gal/min)/ft. When multiplied by 90 ft of drawdown, this specific-capacity value resulted in an estimated median potential yield of about 120 gal/min (fig. 13). Because the water-yielding properties of the rock varies, a more realistic estimate of potential yield is given by the interquartile range in specific capacity. On the basis of data for the 180 most-productive wells, the middle 50-percent range in estimated yields to these public- and industrial-supply wells was 170 to 600 gal/min, alluvium; 280 to 1,700 gal/min, dolomite; 80 to 520 gal/min, limestone; 60 to 550 gal/min, argillaceous carbonate rock; and 60 to 240 gal/min, siliciclastic rock (fig. 13).

SUMMARY

In response to concern about the adequacy of water supplies during drought, the U.S. Geological Survey began a study in 1988 of ground-water resources in parts of 11 Eastern and Southeastern States. This study, called the Appalachian Valleys–Piedmont Regional Aquifer-System Analysis, was designed to provide information on the regional hydrogeologic framework for more efficient development and management of the region's ground-water resources. This report provides information on the hydrogeologic setting of the Valley and Ridge Physiographic Province in Maryland, New Jersey, and Pennsylvania; describes and maps hydrogeologic terranes within this setting; tests these hydrogeologic terranes for significant differences in water-yielding properties; and estimates the quantity of water potentially available to public- and industrial-supply wells in these hydrogeologic terranes.

The ground-water hydrology of the study area is strongly influenced by the geology. Ground water in the consolidated rock resides in and flows through secondary openings. Flow systems tend to be limited in depth by weathering and associated enhancement of secondary permeability and limited in areal extent by faults and folds. Selected rock types can account for a substantial part of the variation in the water-yielding properties of the rock because of the unique way in which these rock types deform and weather. Structure also accounts for some of the variation because faults juxtapose rock types with different water-yielding properties and fractures and bedding-plane partings provide openings for ground water to enter, occupy, and move through. Well-sorted alluvium of glacial origin in the northern and eastern one-third of the area stores and transmits large quantities of ground water.

Hydrogeologic terranes are regionally mappable areas characterized by similar rock type and water-yielding properties; they are intended to help water users in locating and developing adequate water supplies. The five hydrogeologic terrane classes defined in the report—alluvium, dolomite, limestone, argillaceous carbonate rock, and siliciclastic rock—were based on a rationale that relates rock type to the nature of water-yielding openings and properties as indicated by the specific capacity of wells. Consolidated rock units, which were identified from State geologic maps, and the regolith were grouped into the hydrogeologic terrane classes on the basis of the predominant lithology of the geologic unit. The hydrogeologic terrane map of the study area, which was compiled from the same State geologic maps, shows the distribution of the hydrogeologic terranes. The hydrogeologic terranes coincide with the outcrop of the geologic units that have the corresponding predominant lithology. The siliciclastic rock hydrogeologic terrane covers more than one-half of the study area.

To determine if significant differences in water-yielding properties among the hydrogeologic terranes could be detected, records for wells with 6,118 reported specific-capacity values were retrieved from the Ground-Water Site Inventory data base for Maryland, New Jersey, and Pennsylvania. These records are predominantly for domestic wells on hilltops and hillsides. Building on the results of previous workers, the authors considered specific capacity as the variable that best represents the water-yielding properties of the hydrogeologic terranes in the study area and casing diameter, primary use of the water, hydrogeologic terrane, and topographic setting to be variables that influence the value of specific capacity.

Casing diameter, primary use of the water, and topographic setting influence specific-capacity values of wells completed in each hydrogeologic terrane. Homogeneous data sets, which consist of all wells that have the same characteristics with respect to casing diameter, primary use of the water, and topographic setting, however, take these three variables into account and allow valid conclusions regarding significant differences in water-yielding properties. All five hydrogeologic terranes showed differences. According to results of Tukey statistical tests at a probability (alpha level) of 0.10, eight out of ten pairs of hydrogeologic terranes had significantly different median specific-capacity values by using homogeneous data sets.

Estimates of potential yields to public- and industrial-supply wells were calculated from specific-capacity data for most-productive wells, which have casing diameters of 7 in. or more, discharge water primarily for public or industrial supply, and are in a valley. Median constant drawdowns were assumed to be between 10 and 90 ft for wells completed in each of the five hydrogeologic terranes, and well-entrance losses were assumed to be negligible. Estimated interquartile ranges in potential yields to most-productive wells in the hydrogeologic terranes, in gallons per minute, were 170 to 600, alluvium; 280 to 1,700, dolomite; 80 to 520, limestone; 60 to 550, argillaceous carbonate rock; and 60 to 240, siliciclastic rock.

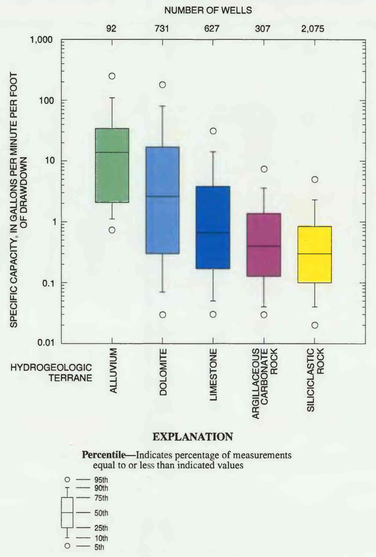

Figure 8. Boxplots showing the variation of specific-capacity values for wells grouped by hydrogeologic terranes.

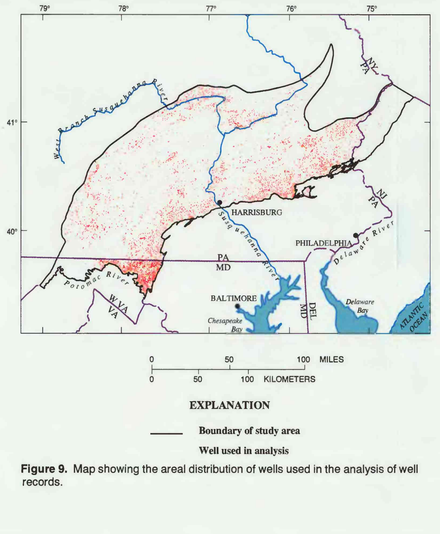

Figure 9. Map showing the areal distribution of wells used in the analysis of well records.

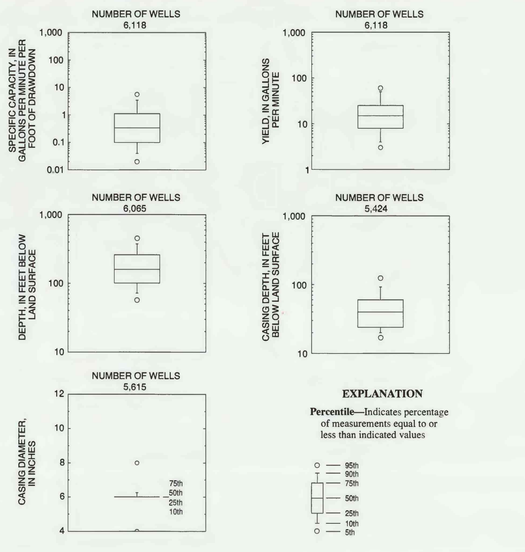

Figure 10. Boxplots showing the variation of selected hydrologic and well–construction data for wells used in analysis.

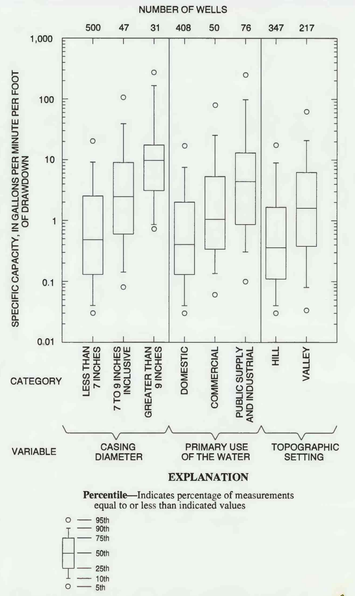

Figure 11. Boxplots showing variation of specific–capacity values for wells in the limestone hydrogeologic terrane grouped by categories of well casing diameter, primary use of the water, and topographic setting of the well.

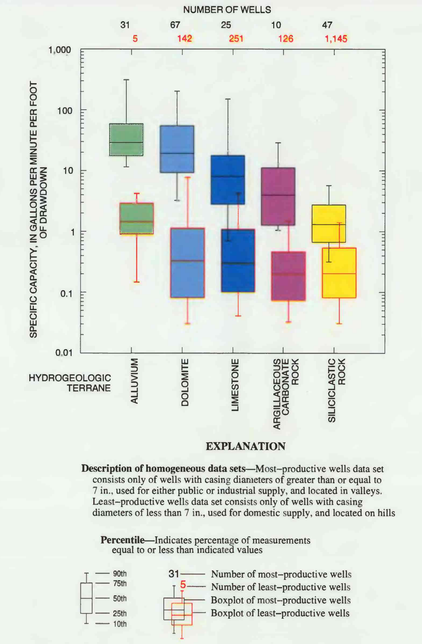

Figure 12. Boxplots showing variation of specific–capacity values for wells grouped by five hydrogeologic terranes and two homogeneous data sets (most–productive wells and least–productive wells).

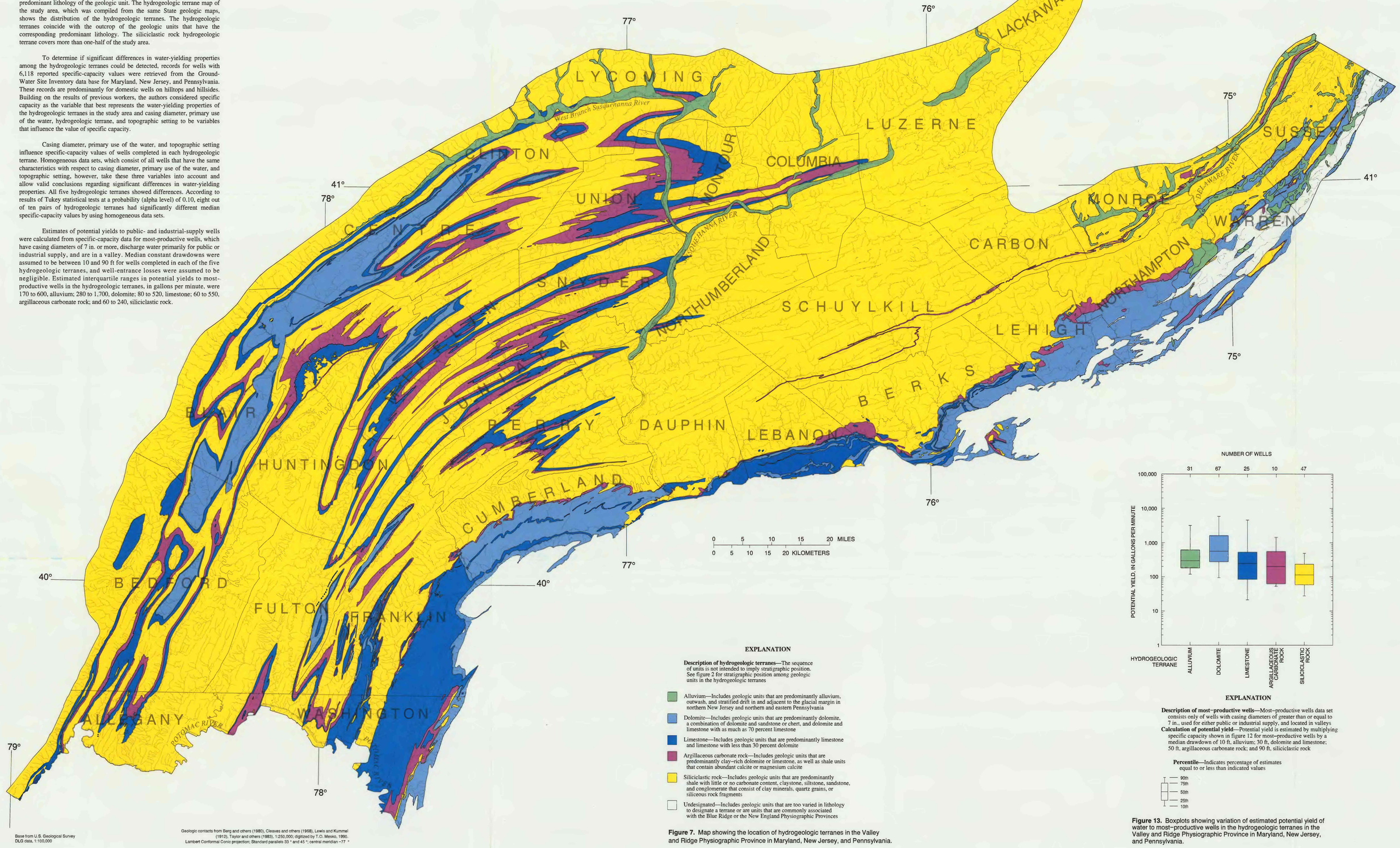

Figure 7. Map showing the location of hydrogeologic terranes in the Valley and Ridge Physiographic Province in Maryland, New Jersey, and Pennsylvania.

Figure 13. Boxplots showing variation of estimated potential yield of water to most–productive wells in the hydrogeologic terranes in the Valley and Ridge Physiographic Province in Maryland, New Jersey, and Pennsylvania.

SELECTED REFERENCES

Becher, A.E., and Root, S.I., 1981, Groundwater and geology of the Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 50, 95 p.

Becher, A.E., and Taylor, L.E., 1982, Groundwater resources in the Cumberland and contiguous valleys of Franklin County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 53, 67 p.

Berg, T.M., Edmunds, W.E., Geyer, A.R., and others, comps., 1980, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 1, 3 sheets, scale 1:250,000.

Berg, T.M., Way, J.H., and McInerney, M., 1985, South-central Pennsylvania, column 18, southeastern Pennsylvania, column 19, and eastern Pennsylvania, column 24, *in* Patchen, D.G., Avary, K.L., and Erwin, R.B., regional coords., Correlation of stratigraphic units of North America (COSUNA) project—Northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Carswell, L.D., and Lloyd, O.B., 1979, Geology and groundwater resources of Monroe County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 47, 61 p.

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

Cloos, Ernst, 1951, Stratigraphy and sedimentary rocks of Washington County, *in* The physical features of Washington County: Maryland Department of Geology, Mines and Water Resources, p. 17–94.

Colton, G.W., 1970, The Appalachian basin—Its depositional sequences and their geologic relationships, *in* Fisher, G.W., Pettijohn, F.J., Reed, J.C., and Weaver, K.N., eds., Studies of Appalachian geology—Central and southern: New York, John Wiley & Sons, p. 5–47.

Dalton, Richard, and Markawicz, F.J., 1985, Northwestern New Jersey, column 25, *in* Patchen, D.G., Avary, K.L., and Erwin, R.B., regional coords., Correlation of stratigraphic units of North America (COSUNA) project—Northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Daniel, C.C., III, 1989, Statistical analysis relating well yield to construction practices and siting of wells in the Piedmont and Blue Ridge provinces of North Carolina: U.S. Geological Survey Water-Supply Paper 2341–A, 27 p.

Drake, A.A., Jr., and Lyttle, P.T., 1980, Alleghanian thrust faults in the Kittatinny Valley, New Jersey, *in* Manspeizer, Warren, ed., Field studies of New Jersey geology and guide to field trips: Newark, N.J., Rutgers University Press, p. 92–114.

Duigon, M.T., and Dine, J.R., 1991, Water resources of Washington County: Maryland Geological Survey Bulletin 36, 109 p.

Duigon, M.T., Dine, J.R., and Trumpkins, M.D., 1989, Ground-water and surface-water data for Washington County, Maryland: Maryland Geological Survey Basic Data Report 18, 273 p.

Edwards, Jonathan, Jr., 1978, Geologic map of Washington County: Maryland Geological Survey map, 1 sheet, scale 1:62,500.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill, 714 p.

Glaser, J.D., 1985, Allegany County, Maryland, column 13, *in* Patchen, D.G., Avary, K.L., and Erwin, R.B., regional coords., Correlation of stratigraphic units of North America (COSUNA) project—Northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Hack, J.T., 1965, Geomorphology of the Shenandoah Valley, Virginia and West Virginia, and origin of the residual ore deposits: U.S. Geological Survey Professional Paper 484, 84 p.

Hobson, J.P., Jr., 1963, Stratigraphy of the Beekmantown Group in southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report G37, 331 p.

Hollowell, J.R., 1971, Hydrology of the Pleistocene sediments in the Wyoming Valley, Luzerne County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 28, 77 p.

Hollowell, J.R., and Koester, H.E., 1975, Ground-water resources of Lackawanna County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 41, 106 p.

King, P.B., 1970, Epilogue, *in* Fisher, G.W., Pettijohn, F.J., Reed, J.C., and Weaver, K.N., eds., Studies of Appalachian geology—Central and southern: New York, John Wiley & Sons, 460 p.

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

Knopman, D.S., 1990, Factors related to the water-yielding potential of rocks in the Piedmont and Valley and Ridge Provinces of Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 90–4174, 52 p.

Lewis, J.V., and Kummel, H.B., 1912, Geologic map of New Jersey: New Jersey Department of Conservation and Economic Development Atlas Sheet 40, 1 sheet, scale 1:250,000. Revised by Johnson, M.E., 1950.

Lloyd, O.B., Jr., and Carswell, L.D., 1981, Groundwater resources of the Williamsport region, Lycoming County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 51, 69 p.

Lyttle, P.T., and Epstein, J.B., 1987, Geologic map of the Newark 1-degree by 2-degree quadrangle, New Jersey, Pennsylvania, and New York: U.S. Geological Survey Miscellaneous Investigations Series I–1715, 1:250,000-scale, 2 sheets.

MacLachlan, D.B., 1967, Structure and stratigraphy of the limestones and dolomites of Dauphin County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report G44, 168 p.

Meisler, Harold, and Becher, A.E., 1971, Hydrogeology of the carbonate rocks of the Lancaster 15-minute quadrangle, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 26, 149 p.

Newport, T.G., 1971, Ground-water resources of Montgomery County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 29, 83 p.

Nutter, L.J., 1973, Hydrogeology of the carbonate rocks, Frederick and Hagerstown Valleys, Maryland: Maryland Geological Survey Report of Investigations 19, 70 p.

Parizek, R.R., White, W.B., and Langmuir, Donald, 1971, Hydrogeology and geochemistry of folded and faulted carbonate rocks of the central Appalachian type and related land use problems, [field trip guidebook] for Geological Society of America annual meeting, Washington, D.C., November 1971: State College, Pennsylvania State University, 184 p.

Patchen, D.G., Avary, K.L., and Erwin, R.B., regional coords., 1985, Correlation of stratigraphic units of North America (COSUNA) project—Northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

Root, S.I., 1968, Geology and mineral resources of southeastern Franklin County, Pennsylvania: Pennsylvania Geological Survey Atlas 119cd, 118 p.

SAS Institute, Inc., 1985, SAS user's guide: Statistics (5th ed.): Carey, N.C., SAS Institute, Inc., 956 p.

Seaber P.R., and Hollyday, E.F., 1965, An appraisal of the ground-water resources of the lower Susquehanna River basin: U.S. Geological Survey open-file report, 75 p.

Seven, W.D., 1989, Surficial materials of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 64, 1 sheet, scale 1:2,000,000.

Sherwood, W.C., 1964, Structure of the Jacksonburg Formation in Northampton and Lehigh Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report G45, 64 p.

Siddiqui, S.H., and Parizek, R.R., 1971, Hydrogeologic factors influencing well yields in folded and faulted carbonate rocks in central Pennsylvania: Water Resources Research, v. 7, no. 5, p. 1295–1312.

Slaughter, T.H., and Darling, J.M., 1962, The water resources of Allegany and Washington Counties: Maryland Department of Geology, Mines and Water Resources Bulletin 24, 408 p.

Sun, R.J., 1986, Regional aquifer-system analysis program of the U.S. Geological Survey—Summary of projects, 1978–1984: U.S. Geological Survey Circular 1002, 264 p.

Swain, L.A., Hollyday, E.F., Daniel, C.C., III, and Zapecza, O.S., 1991, Plan of study for the regional aquifer-system analysis of the Appalachian Valley and Ridge, Piedmont, and Blue Ridge physiographic provinces of the Eastern and Southeastern United States, with a description of study-area geology and hydrogeology: U.S. Geological Survey Water-Resources Investigations Report 91–4066, 44 p.

Taylor, L.E., Werkheiser, W.H., DuPont, N.S., and Kriz, M.L., 1982, Groundwater resources of the Juniata River basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 54, 131 p.

Taylor, L.E., Werkheiser, W.H., and Kriz, M.L., 1983, Groundwater resources of the West Branch Susquehanna River basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 56, 143 p.

Williams, J.H., and Eckhardt, D.A., 1987, Groundwater resources of the Berwick–Bloomsburg–Danville area, east-central Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 61, 76 p.

Wood, C.R., 1980, Summary groundwater resources of Centre County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 48, 60 p.

Wood, C.R., Flippo, H.N., Jr., Lescinsky, J.B., and Barker, J.L., 1972, Water resources of Lehigh County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 31, 263 p.

Wood, C.R., and MacLachlan, D.B., 1978, Geology and groundwater resources of northern Berks County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 44, 91 p.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot (gal/min/ft)	0.2070	liter per second per meter

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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HYDROGEOLOGIC TERRANES AND POTENTIAL YIELD OF WATER TO WELLS IN THE VALLEY AND RIDGE PHYSIOGRAPHIC PROVINCE IN MARYLAND, NEW JERSEY, AND PENNSYLVANIA

By
E.F. Hollyday, G.E. Hileman, Mark A. Smith, and D.J. Pavlicek

1996