# GUIDELINES FOR NAMING AQUIFERS

THE FOLLOWING GUIDELINES for naming aquifers are based on many discussions among Survey hydrologists (Laney and Davidson, 1986). An essential requirement for evaluating the hydrologic properties of in-place earth materials is to define and map hydrogeologic units—aquifers and confining units—on the basis of relative permeability. Hydrogeologic units are determined indirectly through studies of the geologic materials (geologic mapping, surface geophysical surveys, borehole geophysical logs, drill cuttings and core descriptions, and so forth) and through hydrologic testing (aquifer tests, laboratory permeability tests on core samples, and so forth). The physical properties of all rock units change laterally and vertically. Unconformities and faults may affect the flow of ground water. The process of designating and naming aquifers and confining units, therefore, is somewhat subjective and can lead to confusion if not thoroughly documented. Guidelines for naming aquifers can help you avoid confusion and problems associated with hydrogeologic studies if the guidelines are straightforward and flexible and apply to varied scales from site specific to regional. The guidelines that follow include (1) discussions of the aquifer nomenclature, (2) the definition of the hydrogeologic framework, (3) the recommended procedures for naming aquifers, and (4) examples of naming aquifers. In this section the terms "rock-stratigraphic" and "time-stratigraphic" are used (see p. 45).

## AQUIFER NOMENCLATURE

Because aquifers do not lend themselves to neat and simple definitions, a flexible hierarchy of terms is used for largest (regional) to smallest (local) water-yielding units, as follows:

- Aquifer system (Poland and others, 1972),
- Aquifer (Lohman and others, 1972), and
- Zone (R.H. Johnston, written commun, 1985; Miller, 1986).

Parallelism should be avoided in the hierarchy of terms for water-yielding rocks and rock-stratigraphic terms—aquifer system (group), aquifer (formation), and zone (member)—because water-yielding rocks can cross geologic boundaries or can constitute only part of a geologic unit. The scale of the study also may determine the best usage; for example, at the local scale, an aquifer system could be defined totally within a single formation, but at the regional scale an aquifer system could consist of several formations. The guidelines must be flexible to meet a variety of hydrogeologic scales and settings.

A brief discussion of the terms "aquifer," "aquifer system," "zone," and "confining unit" provides a common reference base. Agreement on definitions is not complete, but the terms are adequate to transfer knowledge to readers of reports. These guidelines are not intended to formally redefine the terms or to define new terms to take their place.

### AQUIFER

The term "aquifer" probably has more shades of meaning than any other term in hydrology (Freeze and Cherry, 1979, p. 47). It can mean different things to different people and different things to the same person at different times. Meinzer (1923, p. 52–53) defined an aquifer as follows:

> A rock formation or stratum that will yield water in sufficient quantity to be of consequence as a source of supply is called an "aquifer," or simply a "water-bearing formation," "water-bearing stratum," or "water-bearer." * * * It is water bearing not in the sense of holding water but in the sense of carrying or conveying water.

Lohman and others (1972) refined Meinzer's definition as:

> A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Both definitions imply that the aquifer is bounded by or is included within the formation(s) (or stratum), but the concept of the aquifer extending across formational boundaries is not indicated explicitly. In many local study areas covering a few tens to a few hundreds of square miles, the aquifer and the formation may be the same, and defining the aquifer in such areas may present few problems. Since the late 1970's, however, regional aquifers that cover hundreds of thousands of square miles have been studied under the Regional Aquifer System Analysis (RASA) Program, and results of the these studies have shown that (1) regional aquifers may include many formations and rock types and (2) the aquifers may cut across formational and lithologic boundaries so that no one formation is completely representative of the aquifer. In studies of regional scope, the shapes and the boundaries of the permeable rocks that form the aquifer have greater importance to understanding the flow system than do the individual formational boundaries. A definition that places less emphasis on the formal term "formation" (see North American Commission on Stratigraphic Nomenclature, 1983) and more on "permeable rocks" has merit. For example, aquifer is defined in the "Glossary of Geology" (Bates and Jackson, 1980) as follows:

A body of rock that is sufficiently permeable to conduct ground water and to yield economically significant quantities of water to wells and springs.

Regardless of the fine points in any definition, delineating permeable rocks should be a major goal of hydrologists mapping and describing an aquifer. By the same token, detailed knowledge of the stratigraphic units and postdepositional processes (such as solution, cementation, folding, and faulting) are essential in determining the boundaries of the aquifer and in understanding the flow system. In addition, hydraulic properties (hydraulic conductivity and storage coefficient) are usually estimated indirectly by aquifer tests, analyses of drill cuttings and cores, borehole geophysical logging, and surface geophysical surveys. In many situations, hydrologic estimates and extrapolations can be based on rock type alone without any determination of hydrologic properties. For example, a widespread, thick clay separating two sand units could be designated tentatively as a confining unit on the basis of geologists' logs and borehole geophysical logs alone without any hydrologic data.

## Aquifer System

Poland and others (1972) defined "aquifer system' as follows:

A heterogeneous body of intercalated permeable and poorly permeable material that functions regionally as a water-yielding hydraulic unit; it comprises two or more permeable beds [aquifers] separated at least locally by aquitards [confining units] that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system.

The definition of Poland and others would be more general if the term "aquifers" were used in place of "permeable beds." "Bed" implies a single stratigraphic unit, whereas the individual aquifer could include or cross many "beds." "Confining unit" should be used instead of "aquitard" because the definition of confining unit is broad enough to include varying degrees of "leakiness."

The hierarchy of aquifer and aquifer-system names may not always be consistent in practice. Because of differences in scales of investigations, different authors may combine individual aquifers into a single aquifer system, which may be only a part of yet another even larger aquifer system of a larger area. Authors are responsible for explaining these relationships clearly by means of comparison charts and text descriptions.

## Zone

The term "zone" may be used to subdivide an aquifer to delineate a hydrologic characteristic that is not typical of the entire aquifer. For example, the "Fernandina permeable zone" is a highly permeable subunit of the Lower Floridan aquifer (Miller, 1986, p. B70). The zone consists of vuggy, locally cavernous limestone that is traceable for as far as 100 miles in coastal Georgia and Florida. The permeability of the zone greatly exceeds that of most of the Lower Floridan aquifer.

## Confining Unit

Lohman and others (1972) defined the term "confining bed" as a body of "impermeable" material stratigraphically adjacent to one or more aquifers. In nature, however, its hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer. Its conductivity relative to that of the aquifer it confines should be specified or indicated by a suitable modifier, such as "slightly permeable" or "moderately permeable."

Although the term "confining bed" (Lohman and others, 1972) is descriptive and could be used, the term "confining unit" is more appropriate, especially if more than a single bed makes up the confining unit. The term "bed" is incorrect usage for a thick sequence of stratigraphic units that could be of member or formation rank. Bed is particularly inappropriate when used for intrusive igneous rocks beneath an aquifer. The term "bed" has a formal definition (North American Commission on Stratigraphic Nomenclature, 1983, art. 26) and should not be used in definitions of aquifer nomenclature.

Many confining units are leaky under natural conditions and may contribute significant amounts of water to the aquifers they confine, or they may contribute even larger quantities of water if heads are lowered in the aquifer by pumping. Where withdrawals from aquifers have caused large declines in head, considerable water may be derived from storage in the confining unit. Poland and others (1972, p. 2) retained the terms "aquiclude" and "aquitard" in their definitions related to the mechanics of aquifer systems and land subsidence caused by fluid withdrawal. An aquiclude is defined as a body of saturated but relatively impermeable material that has very low values of "leakance" (the ratio of vertical hydraulic conductivity to thickness) and that allows negligible interaquifer flow. An aquitard is a saturated, poorly permeable bed whose values of leakance range from relatively low to relatively high. Where an aquitard is sufficiently thick, it may form an important ground-water storage unit.

For Survey reports, the general term "confining unit" is preferable to "aquitard," "aquiclude," and "aquifuge". The "leakiness" of the confining unit should be discussed if it can be estimated.

### Terms to Avoid

Terms intended to be synonymous with "aquifer" or "aquifer system" should be avoided. Terms such as "hydrofer" or "aquiformation" should not be used. "Aquigroup" should not be used in place of "aquifer system." The term "aquifer" may lack precision, but it has wide use and acceptance in the hydrologic literature. Coining new terms that are synonyms of aquifer and aquifer system or that propose slightly different meanings only creates confusion, especially among nonhydrologists. Use of the term "aquiformation," moreover, infers an equivalence between aquifer and formation that is not always correct.

## Definition of the Hydrogeologic Framework

In hydrogeologic studies, as in purely geologic investigations, the orderly, consistent designations of pertinent parts of the framework are essential to a clear reporting and understanding of the study results. In ground-water studies these designations involve defining and correlating water-yielding units and relating those units to established rock-stratigraphic units. Survey authors of reports on ground-water resources must follow the North American Stratigraphic Code for designating rock-stratigraphic units, just as authors of purely geologic reports do. The authors of ground-water reports also must identify significant water-yielding parts of the geologic framework. Commonly, the water-yielding parts do not correspond exactly to named geologic units and, therefore, do present additional nomenclatural problems. Exhaustive systematic guidelines for naming geologic units have been developed over several decades by the North American Commission on Stratigraphic Nomenclature, but comparable guidelines have not been developed for naming water-yielding units. The proper designation of hydrogeologic units involves the consistent use of ground-water terms as well as the actual naming of the units.

One of the first considerations in describing an aquifer in a report is mappability. The aquifer should be mappable at the map scale used in the report of the study area, but thin, highly transmissive aquifers that cannot be easily mapped at the principal map scale may still be important hydrologically. The report also should contain comparison charts; maps of the tops, thicknesses, and geographic extents of the aquifers; and hydrogeologic sections. Hydraulic characteristics should be discussed to show how the aquifers differ from the underlying and overlying confining units.

If additional information is needed to clarify the characteristics of an aquifer in the third dimension, a "type area" or "type locality" and (or) a "type well" can be described. Several surface exposures and wells may be required to characterize the aquifer if its characteristics change greatly vertically and laterally. If so, selected surface exposures and wells can be used to illustrate important aspects. For example, grain size, bedding thickness, faulting, folding, and effects of fracturing or solution may affect movement and storage of ground water. Borehole geophysical logs, drill cuttings and core descriptions, and drillers' and geologists' logs for wells can illustrate hydrologic properties in the subsurface.

A comparison chart is an essential part of a report that describes a ground-water flow system and aquifer names, and it should consist of three major components:

1. A correlation chart that shows rock- and time-stratigraphic (geologic) units for the water-bearing materials described in the report.
2. A comparison of hydrogeologic units to layers used in a digital flow model (if one is used).
3. A comparison of hydrogeologic units of the report with those in previous reports.

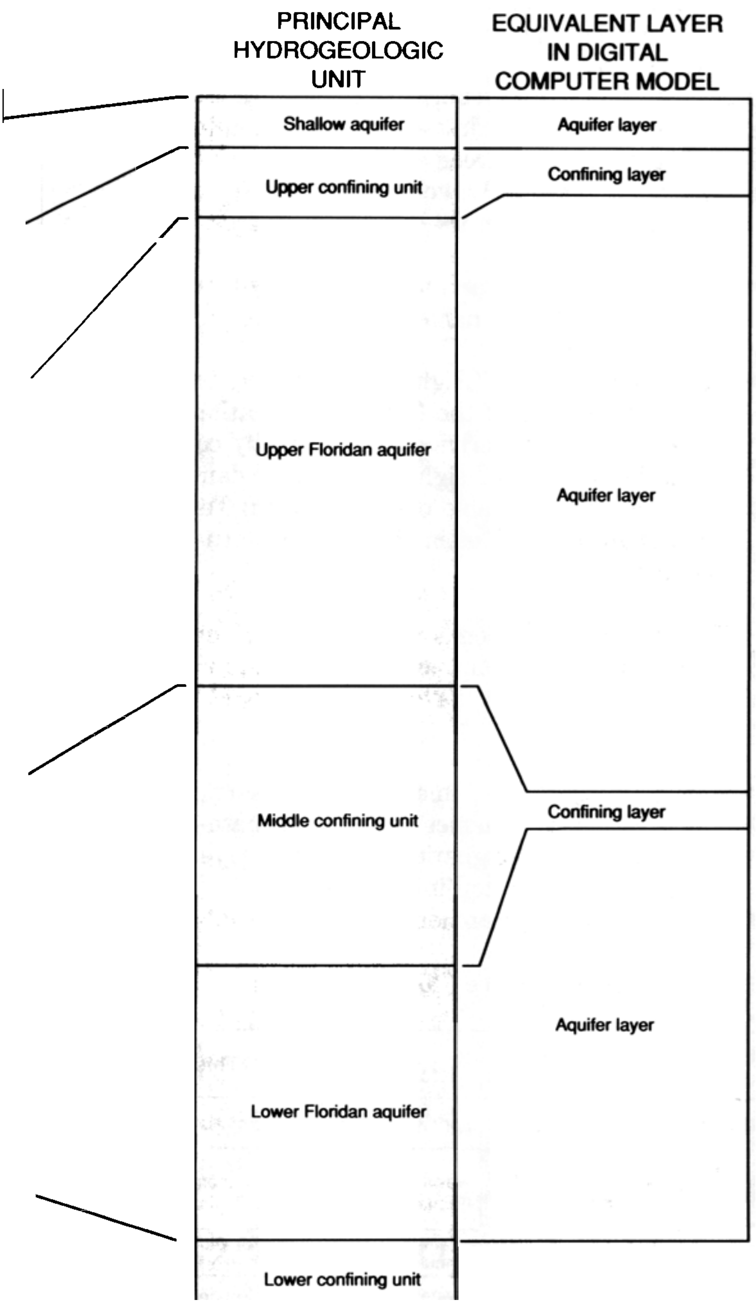
The amount of detail in the comparison chart depends on the scale and complexity of the investigation. If the report contains only a few geologic and hydrogeologic units, the comparisons may be shown in one illustration. The comparison chart should make clear to the reader the relationships of the hydrogeologic units to the geologic units (and to equivalent layers in the computer flow models if flow models are included in the report). For complicated investigations that involve many geologic and hydrogeologic units, two or three illustrations may be needed to show the comparisons.

## GEOLOGIC UNIT

| Erathem | System | Series | Stratigraphic unit | Thickness (meters) | Lithology | Aquifer |
|---|---|---|---|---|---|---|
| Cenozoic | Quaternary | Holocene | Unnamed alluvial lake and windblown deposits | 0–23 | Alluvium, freshwater marl, peats, and muds in stream and lake bottoms. Also, some dunes and other windblown sand | Shallow aquifer |
| | | | | | unconformity | |
| Cenozoic | Quaternary | Pleistocene | Pamlico Formation and marine and estuarine terrace deposits | 0–23 | Mostly marine quartz sand, unconsolidated and generally well-graded. Also, some fluviatile and lacustrine sand, clay, marl, and peat deposits | Shallow aquifer |
| | | | | | unconformity | |
| Cenozoic | Tertiary, Upper | Pliocene | Jackson Bluff Formation | 0–23 | Marine sands, argillaceous, carbonaceous; and sandy shell marl. Some phosphatic limestone | |
| Cenozoic | Tertiary, Upper | Pliocene | Alachua Formation | 0–30 | Nonmarine interbedded clay, sand, and sandy clay; much of unit is phosphatic, base characterized by rubble of phosphate rock and silicified limestone residuum in a gray and green phosphatic clay matrix | |
| Cenozoic | Tertiary, Upper | Miocene | Fort Preston Formation[1] | 0–30 | Nonmarine fluviatile sand, white to gray, variegated orange, purple, and red in upper part, fine- to coarse-grained to pebbly, clayey, crossbedded | |
| Cenozoic | Tertiary, Upper | Miocene | Hawthorn Formation | 0–91 | Marine interbedded sand, cream, white, and gray, phosphatic, commonly clayey; clay, green to gray and white, phosphatic, often sandy; dolomite, cream to white and gray, phosphatic, sandy, clayey; and some limestone, hard, dense, in part sandy and phosphatic. Tends to be sandy in upper part and dolomitic and limey in lower part | |
| | | | | | unconformity | |
| Cenozoic | Tertiary | Oligocene | Suwannee Limestone | 0–46 | Marine limestone, very pale orange, finely crystalline, small amounts of silt and clay | Floridan aquifer system |
| | | | | | unconformity | |
| Cenozoic | Tertiary, Lower | Eocene, Upper | Ocala Ls[2]: Upper member[3] | 0–99 | Marine limestone, cream to white, soft granular, highly porous, coquinal; often consists almost entirely of tests of foraminifers; cherty in places | Floridan aquifer system |
| Cenozoic | Tertiary, Lower | Eocene, Upper | Ocala Ls[2]: Lower member[4] | | Marine limestone, cream to tan and brown, granular, soft to firm, porous, highly fossiliferous; lower part at places is dolomite, gray and brown, crystalline, saccharoidal, porous | Floridan aquifer system |
| | | | | | unconformity | |
| Cenozoic | Tertiary, Lower | Eocene, Middle | Avon Park Formation | 183–488 | Marine limestone, light brown to brown, finely fragmental, poor to good porosity, highly fossiliferous (mostly foraminifers); and dolomite, brown to dark brown, slightly porous to good porosity, crystalline, saccharoidal, both limestone and dolomite are carbonaceous or peaty; gypsum is present in small amounts | Floridan aquifer system |
| Cenozoic | Tertiary, Lower | Eocene, Lower | Oldsmar Formation | 91–411 | Marine limestone, light brown to chalky, white, porous, fossiliferous, with interbedded brown, porous, crystalline dolomite; minor amounts of anhydrite and gypsum | Floridan aquifer system |
| Cenozoic | Tertiary, Lower | Paleocene | Cedar Keys Formation | 152–671 | Marine dolomite, light gray, hard, slightly porous to porous, crystalline, in part fossiliferous, with considerable anhydrite and gypsum, some limestone | |
| | | | | | unconformity | |
| Mesozoic | Cretaceous | | Upper and Lower Cretaceous rocks | 457–? | Mostly marine Upper Cretaceous carbonate and evaporate rocks, sands and shales; thin Lower Cretaceous clastic section in some of area | |
| | | | | | Coastal Plain bedrock | |
| Paleozoic and Precambrian | | | Devonian to Precambrian(?) rocks | Basement rocks | Marine Devonian, Silurian, and Ordovician quartzose sandstone and dark shale, lower Paleozoic(?) or Precambrian(?) rhyolite, tuff, and agglomerate | |

[1] Usage of Bureau of Geology, Florida Department of Natural Resources.
[2] Ocala Group of Bureau of Geology, Florida Department of Natural Resources.
[3] Crystal River Formation of Ocala Group.
[4] Inglis Formation and Williston Formation (older to younger) of Ocala Group.

**Figure 17.** A chart comparing geologic units, hydrogeologic units, and equivalent units in a digital ground-water flow model (from Tibbals, in press).




A comparison chart that interrelates geologic units, hydrogeologic units, and model layers is shown in figure 17. Figure 18 compares geologic and hydrogeologic units with those in previous reports. A chart such as figure 18 is especially important in reports that redefine and rename aquifers. Figure 19 summarizes hydrogeologic units made up of many rock-stratigraphic units. Unlike figure 17, figure 19 places the hydrogeologic units on the left side of the chart and combines the rock-stratigraphic units on the right side. This chart emphasizes hydrogeologic units primarily and rock-stratigraphic units secondarily, although considerable analysis of rock-stratigraphic data from throughout the study area was required to develop the chart. Such an analysis of time- and rock-stratigraphic units in a correlation chart should be shown as a separate illustration because of the great number of rock-stratigraphic units to be considered.

To prepare a comprehensive comparison chart, you must search the literature for all previous studies that contain rock-stratigraphic names and aquifer names in the project area. Your comparison chart should contain the following items:

- Headings entitled erathem, system, series, rock-stratigraphic unit, thickness, lithology, hydrogeologic unit, and hydrologic characteristics.
- The geologic units that are pertinent to the hydrology.
- The hydrogeologic units that you are using and how they relate to geologic units and previously named hydrogeologic units.
- A column that shows relations of hydrogeologic units to layers in the flow model, if one is included in the study.

Only the geology that pertains to the hydrology under study should be discussed and shown in detail. Your discussion should be limited mainly to what affects the movement and storage of ground water. An exception could be made if details of the stratigraphy were not well known before your hydrologic study, and hence by describing the hydrogeologic units you have clarified an understanding of the stratigraphy.

Differences of opinions as to what should constitute aquifer(s) and confining units(s) may still exist among hydrologists after your report is published. However, no uncertainty should exist as to what you include in your definition of the aquifer(s) and confining unit(s) and their relation to geologic and hydrogeologic units in previous investigations.

## Deriving Aquifer Names

Aquifer names used currently within the Survey, rightly or wrongly, are derived from the following sources:

- Rock-stratigraphic terms (Sparta aquifer).
- Geographic features (High Plains aquifer, Floridan aquifer).
- Time-stratigraphic terms (Cambrian-Ordovician aquifer).
- Lithology (limestone aquifer).

- ► Depth of occurrence ("500-ft" sand in the Memphis area).
- ► Depositional environment (shallow marine aquifer, glacial aquifer).
- ► Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer).
- ► Relative position (upper carbonate aquifer).
- ► Unusual locations (Clinton Street-Ballpark aquifer).
- ► Unusual geologic features of rock exposures (bird's-nest aquifer).

The many ways in which aquifers have been named and the varied scales of hydrologic investigations are among the causes of confusion regarding aquifer nomenclature. Until the advent of the RASA Program, few ground-water studies were areally large enough to face the problems of extending local aquifer and stratigraphic nomenclature to a regional scale. The gradational changes that are commonplace in geologic materials complicate the work of hydrologists who are trying to define aquifers and related confining units. At a study scale of a few tens to a few hundred square miles, gradations in the physical properties of the rocks are often not obvious, and because of the relative uniformity of the rocks within such an area, where a stratigraphic unit may make up an entire aquifer, rock-stratigraphic names can be applied to aquifers. At the scale of many of the RASA studies, however, differentiating regionally extensive units of relatively high or relatively low permeability becomes a problem within a sequence of rock units whose relations and variability are frequently complex, and whose names may change at political boundaries.

If your report involves hydrogeology, the Survey recommends that you first consider not naming aquifers. If aquifers are already named, or if the extent of an aquifer is reasonably well known, aquifer names should be derived from the following sources:

- ► Lithologic terms (sand and gravel aquifer).
- ► Rock-stratigraphic names (Sparta aquifer, after the Sparta Sand).
- ► Geographic names (High Plains aquifer, for the permeable parts of the Ogallala Formation and overlying and underlying hydrologically continuous deposits in parts of eight States; Floridan aquifer system, for permeable parts of several Tertiary carbonate formations in the Southeastern United States).

The Survey recommends that aquifer or aquifer-system names not be derived from the following sources (although some have been so-derived in the past):

- ► Time-stratigraphic names (Cretaceous aquifer).
- ► Relative position names (upper carbonate aquifer).
- ► Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer).
- ► Depositional environment (shallow marine aquifer, glacial aquifer).
- ► Depth of occurrence ("500-ft" sand).

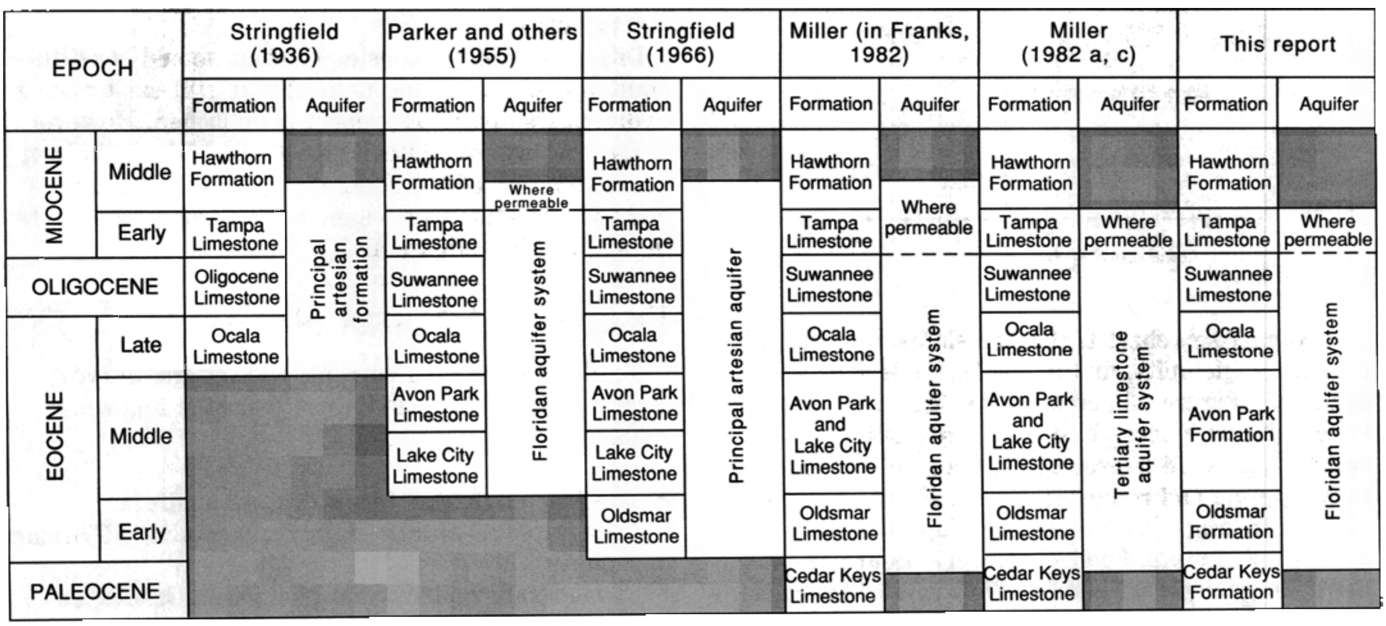



Figure 18. A chart comparing geologic and hydrogeologic units with those in previous reports (from Miller, 1986).

Acronyms (the first letter of each formation in a multiaquifer system).
Hydrologic condition ("principal artesian aquifer").

Each of these preceding sources of aquifer names is discussed in the following sections.

## Recommended Sources for Aquifer Names

Authors of reports on hydrogeology can handle aquifer nomenclature in the following ways: (1) Do not name the aquifers or (2) name the aquifers after lithologic terms, rock-stratigraphic names, or geographic names.

Water-bearing properties of rocks can be described without naming aquifers. Each rock unit and its water-bearing properties can be described in comparison charts and tables. Phraseology would be the principal difference between a report of this kind and one describing named aquifers. This approach could be used in studies involving both formal and informal rock-stratigraphic names, but it would apply particularly to areas where no formal rock-stratigraphic units had been designated or where the stratigraphy and the hydrology of the particular rocks are poorly known. Not cluttering the literature with aquifer names is advantageous if the hydrogeology of an area has not been studied in great detail, if a study describes an area in a cursory or reconnaissance fashion, or if a study area is so small that only a small part of an aquifer is investigated.

If aquifers must be named, use lithologic or rock-stratigraphic names to the extent permitted by permeability distribution and hydrologic continuity. Use geographic names for larger areas where lithologic or rock-stratigraphic names are inappropriate. For example, where an aquifer consists of a single rock-stratigraphic unit, the rock-stratigraphic name may be used for the aquifer. If a later study encompasses a larger area, judgment would be needed to determine if the rock-stratigraphic name remains appropriate. If the aquifer in the larger area consists of the same rock-stratigraphic unit as in the smaller area, the earlier name could be retained. However, a geographic name should be used if the aquifer consists of several units, none of which has an appropriate name, or if the aquifer extends across rock-unit boundaries. Such relations should be shown clearly in the comparison charts of the report.

If an aquifer is named for a rock-stratigraphic unit or a geographic feature, rules of priority should be followed, and a thorough literature search should be made to avoid name duplication. The name should be cleared through the Reston Geologic Names Unit and should not be preempted by a rock-stratigraphic name.

### Lithologic Names for Aquifers

Lithology-derived names of aquifers are useful in defining water-bearing materials where formal rock-stratigraphic names do not exist. The adjectives for lithologic names of aquifers may be based on lithologic terms—"sand and gravel aquifer," "granite aquifer," "limestone aquifer"—but if lithologic consistency throughout the extent of the aquifer is uncertain, a geographic name should be used. Lithologic names are especially useful for naming aquifers in glacial deposits. If several aquifers discussed in a report are in glacial deposits, however, lithologic terms for each might be similar, and local geographic names may be more appropriate.

### Rock-Stratigraphic Names for Aquifers

Rock-stratigraphic names may be used for aquifer names in studies that cover one State or parts of a State and an adjacent State. At the scale of such studies, the rock-stratigraphic unit and the aquifer commonly are equivalent. In addition to criteria for defining the hydrologic framework of a report, the following guidelines should be used, as appropriate, to assign names or to modify existing aquifer names based on rock-stratigraphic names:

1. Through the use of comparison charts, maps, and cross sections, show clearly how much of the rock-stratigraphic unit is included in the aquifer. In some areas, aquifers have been named for rock-stratigraphic units but consist of parts of the units only. In the Atlantic and Gulf Coastal Plains, sediments generally thicken oceanward and become progressively less permeable because of increasingly fine grain. Thus, an aquifer may thin as a formation thickens—the Tuscaloosa Formation or Group and the Tuscaloosa aquifer of Alabama, for example. A similar lack of agreement between an aquifer and a corresponding rock-stratigraphic unit of the same name can exist at any scale if the formation name is automatically used for an aquifer name without due consideration as to how much of the formation actually constitutes the aquifer.
2. Shorten the binomial name of the rock-stratigraphic unit for use as the aquifer name:

   A. Madison aquifer, after the Madison Group.
   B. Edwards aquifer, after the Edwards Limestone.
   C. Sparta aquifer, after the Sparta Sand.

| Hydrogeologic unit | | Thickness (feet) | Lithology and hydrologic characteristics |
|---|---|---|---|
| Western Interior Plains confining unit | | 0–6,000 | Shale layer of very low permeability separated by permeable limestones and sandstones. Leakage through shale is slow. |
| Ozark Plateaus aquifer system | Springfield Plateau aquifer | 0–1,500 | Permeable limestone, fractured and solutioned locally. Well yields range from 1 to 300 gallons per minute, but typical yields are 5–10 gallons per minute. |
| | Ozark confining unit | 0–1,500 | Shale of very low permeability; however, at most locations, thickness of shale is less than 20 feet. Thus, unit is moderately leaky. |
| | Ozark aquifer | 0–4,000 | Mostly dolostone with limestone and sandstone layers. Dolostone highly fractured with very permeable zones of fractured and solutioned dolostone. Well yields range from 2 to 2,000 gallons per minute, but typical yields are 200–400 gallons per minute. |
| | St. Francois confining unit | 0–730 | Shale, siltstone, dolostone, and limestone, all of low permeability. Unit is leaky to slightly leaky. |
| | St. Francois aquifer | 0–500 | Fractured and permeable dolostone and sandstone. Well yields range from 1 to 500 gallons per minute, but typical yields are 50–200 gallons per minute. |
| Basement confining unit | | | Mostly igneous and metamorphic rocks. Rocks are fractured and locally will yield small quantities of water to wells. No known aquifers beneath these rocks; thus, unit is the basal confining unit. |

**Figure 19.** A chart showing comparison of hydrogeologic units, rock-stratigraphic units, and time-stratigraphic units (modified from Jorgensen, written commun., 1986, and Jorgensen and others, in press).

The argument has been made that including the full rock-stratigraphic name would provide additional information (Edwards Limestone aquifer), but if an aquifer is adequately described in the comparison table, the text, and the maps, a full name is redundant (and is incorrect if additional rock types are included in the aquifer). Including all the modifiers, moreover, makes for awkward names. For existing, entrenched names of aquifers, lithologic modifiers should not be capitalized (Burnam limestone aquifer, not Burnam Limestone aquifer).

3. Do not use the name of a rock-stratigraphic unit for an aquifer name if the unit is not part of the aquifer.
4. Aquifer names based on multiple stratigraphic units:
   A. If an aquifer includes all or part of two rock-stratigraphic units, one on the other, both unit names are used, separated by a hyphen, and the name of the younger unit name comes first. For example, the lower Hell Creek-Fox Hills aquifer consists of the lower part of the Upper Cretaceous Hell Creek

| Rock-stratigraphic unit | Time-stratigraphic unit |
|---|---|
| Marmaton Group, Cherokee Group, Atokan rocks, Bloyd Shale, Hale Formation, Morrowan rocks, Pitkin Limestone, Fayetteville Shale, and Batesville Sandstone | Middle Pennsylvanian through Upper Mississippian (Chesterian) |
| Moorefield Formation, St. Louis Limestone, Salem Limestone, Warsaw Limestone, Boone Formation, including St. Joe Limestone Member, Keokuk Limestone, Burlington Limestone, and Fern Glen Limestone | Upper Mississippian and Lower Mississippian |
| Chouteau Group (Limestone) and Chattanooga Shale | Lower Mississippian and Upper Devonian |
| Clifty Limestone, Penters Chert, Lafferty Limestone, St. Clair Limestone, Brassfield Limestone, Cason Shale, Fernvale Limestone, Kimmswick Limestone, Plattin Limestone, Joachim Dolomite, St. Peter Sandstone, Everton Formation, Powell Dolomite, Smithville Formation, Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconade Dolomite, including the Gunter Sandstone Member, Eminence Dolomite, and Potosi Dolomite. | Middle Devonian through uppermost Cambrian |
| Elvins Group: Doe Run Dolomite, Derby Dolomite, Davis Formation | Upper Cambrian |
| Bonneterre Dolomite and Lamotte Sandstone | |
| Mostly igneous and metamorphic rocks | Precambrian |

Note.—Although measurements in this example are given in inch/pound units, metric (SI) units are now preferred. (See "Metric System," p. 122, for USGS policy.)

Formation and the underlying Fox Hills Sandstone. This usage conforms to that of map explanations, tables, cross sections, and the computerized Water Data and Storage Retrieval System (WATSTORE).

However, an aquifer name designated from units in order of decreasing age is acceptable if it is entrenched in local usage or has been used in legal terminology. For example, the oldest- to youngest-named Potomac-Raritan-Magothy aquifer in the Cretaceous Potomac Group and the overlying Raritan and Magothy Formations has longtime usage in New Jersey.

B. If an aquifer includes three or more superimposed rock-stratrigraphic units, the aquifer name may include all units youngest to oldest (hyphenated) or only the youngest and oldest units. For example, the Galena-Platteville aquifer of local Wisconsin usage is in the Galena Dolomite (youngest), Decorah Formation, and Platteville Formation. An appropriate geographic name would be a desirable alternative of a cumbersome hyphenated rock-stratigraphic name.

C. If the middle rock-stratigraphic unit is the primary aquifer, its name may be used, provided the overlying and underlying stratigraphic units are clearly identified. For example, the Edwards aquifer in Texas is in the Georgetown Limestone (youngest), Edwards Limestone, and Comanche Peak Limestone.

D. An aquifer that includes many water-bearing rock-stratigraphic units that are hydraulically connected vertically and laterally should not be named for any of the individual rock-stratigraphic units. A geographic name would be appropriate. For example, the Floridan aquifer system includes the Tampa Limestone, Suwannee Limestone, Ocala Limestone, Avon Park Formation, Oldsmar Formation, and part of the Cedar Keys Formation.

5. An abandoned rock-stratigraphic name should not be used for an aquifer name; the newly assigned stratigraphic name should be used instead. If, however, the abandoned name is entrenched in local usage or is a legal term in State regulations, the name may be used, but the stratigraphic change should be described in the introduction of the report and should appear on a correlation chart.

**Using rock-stratigraphic names for aquifers.** The use of rock-stratigraphic names for aquifers carries some risk of confusion because you must distinguish the rock-stratigraphic unit from the aquifer throughout the text and in the illustrations of your report. After having first used a name in full, you can shorten both rock-stratigraphic and aquifer names in text by dropping the rank or descriptive part of the name if doing so improves readability and causes no doubt in the mind of the reader. For example, if the Baker aquifer makes up a large part of the Baker Formation, but not all of it, confusion might result if you say, "The Baker is 450 feet thick south of the Possum River." (The Baker Formation or the Baker aquifer?) If such doubt might arise, be sure to use the term "aquifer" when discussing the aquifer.

To avoid unnecessarily long names and to clarify the distinction between the aquifer and the rock-stratigraphic unit, do not use lithologic modifiers of rock-stratigraphic names for aquifers. Thus, an aquifer made up largely of the Jacob Sand Member of the Blackjack Formation should be called the Jacob aquifer, not the Jacob Sand Member aquifer. Lithologic modifiers have been used in aquifer names by authors who believed the modifiers added useful information to the aquifer names, but if the aquifer is clearly defined in the comparison charts, a reader should have no difficulty learning its composition. In addition, a single lithologic modifier of a name may be incorrect if more than one rock type makes up the aquifer.

Descriptions of aquifers and rock-stratigraphic units should be clearly separated or distinguished in the text and illustrations. For example:

1. Information on the potentiometric surface, storage coefficient, and specific yield describes the aquifer, not the rock-stratigraphic unit.
2. Information on dip, strike, plunge, and deposition of sediments describes the rock-stratigraphic unit, not the aquifer.

Terms such as porosity and permeability could refer to either the aquifer or the rock-stratigraphic unit.

### Geographic Names for Aquifers

Geographic names can be the basis for aquifer names where (1) no rock-stratigraphic names are available, (2) no single rock-stratigraphic name or combination of rock-stratigraphic names (or lithologic names) would be appropriate, or (3) the use of previously named aquifers in small-area studies would not be appropriate. Geographic names are appropriate for aquifers of subregional extent where the location of the aquifer might provide more meaningful information than its physical characteristics. Geographic names include the names of cities, towns, districts, hills, mountains, lakes, rivers, creeks, and physiographic regions or subregions. In addition to geographic names, a regional aquifer name could be derived from a geologic structural feature (a basin, for example) that has relevance in the area underlain by the aquifer. Physiographic names should be from well-known sources, such as Fenneman's map (1946), "Physical Divisions of the United States." Geographic names should be from standard topographic quadrangles of the Geological Survey. The "High Plains aquifer" and the "Floridan aquifer system" are examples of regional aquifer names derived from physiographic and geographic names.

## NONRECOMMENDED SOURCES FOR AQUIFER NAMES

### Time-Stratigraphic Names

Time-stratigraphic boundaries do not necessarily coincide with rock-stratigraphic boundaries or other physical changes in the hydrologic characteristics of rocks and should not be used as a basis for placing aquifer boundaries or for naming individual aquifers. Aquifers have been named for time-stratigraphic terms, but later studies and more detailed mapping have shown that some parts of an aquifer may be older or younger than the time-stratigraphic unit in the aquifer name. For example, several years after the "Tertiary limestone aquifer" in the Southeastern United States was named, it was found to contain Upper Cretaceous rocks. Another possible complication is that longstanding time-stratigraphic boundaries have been changed in this country to agree with boundaries established under international geologic agreements (for example, the change in the Miocene-Pliocene boundary from 10 million years ago to 5 million). Also, terms such as "Cretaceous aquifers" are not strictly correct. The aquifer is not of Cretaceous age; it consists of rocks of Cretaceous age whose hydrologic properties are not the same as they were when the rocks were formed. "Aquifers in rocks of Cretaceous age" is correct and should be used instead.

Some aquifer names based on time-stratigraphic names are in the literature and are commonly used—the "Cambrian-Ordovician aquifer" of the North Central United States, for example. Other aquifers in the country have similar time-stratigraphic names that are entrenched in local usage. These names should be phased out if possible. Time-stratigraphic nomenclature should not be used for newly named aquifers, and existing time-stratigraphically based aquifer names should not be extended from local use to aquifers of regional scale.

### Relative Position

If a layer of saturated permeable rock overlies another layer of saturated permeable rock—regardless of differences in lithology—the two layers form one aquifer and should not be designated "upper and lower" aquifers. If they are mostly separated by mappable, distinctly less permeable confining units, they are two separate aquifers.

The terms "upper" and "lower" may be used where parts of an aquifer are separated by confining units if the full extent of the aquifer or aquifer system is reasonably well known. For example, the Floridan aquifer system was described as the "Upper Floridan aquifer" and "Lower Floridan aquifer" in the part of the area where the two units are separated by a regional confining unit. Where the confining unit is nonexistent, the term "Floridan aquifer system" is used, but in fact, the term "Floridan aquifer system" is correct throughout the area, including places where the two parts are separated by the confining unit. If you are referring to parts of the same aquifer that have some distinctive difference, the term "zone" is preferred. For example, use "upper zone of the Chicot aquifer" (not "upper Chicot aquifer").

### Alphanumeric Designations

Alphanumeric designations, such as "A1 aquifer layer" and "C1 confining layer," are useful in discussing layers of a numerical ground-water flow model, but they should not be used as aquifer names. A clear distinction must always be made in a report between the real flow system and the simulated flow system. Illustrations such as figure 17 help differentiate these distinctions and relations.

### Depositional Environment

Names based on depositional environment can be misleading and should not be used for aquifer names. For example, "shallow marine aquifer" may be totally unclear as to what is meant and included. Even if the aquifer were described as consisting of "sand deposited in a shallow sea," problems and additional confusion may arise if the rocks of the aquifer grade into hydrologically continuous deposits from a different depositional environment or grade into different rocks in a similar depositional environment. Likewise, a "glacial aquifer" may contain or be hydrologically continuous with other deposits or rocks that are not of glacial origin. Lithologic or geographic terms would be more appropriate.

### Depth of Occurrence

Aquifers should not be named after depth of occurrence. The aquifer named after the "2,000-ft" sand may well be present at a depth of about 2,000 ft at a given location where it was named in a local study, but on a regional scale the sand may be present elsewhere at a greater or lesser depth and may have no relation to the name derived from the local study. Established local usage may require the continued use of a name, but the name should not be extended to regional use.

### Acronyms

Aquifers or aquifer systems should not have acronyms for names, such as an aquifer name derived from the first letter of each rock-stratigraphic unit that makes up the aquifer. If many rock-stratigraphic units make up an aquifer, a geographic name unrelated to any of the rock-stratigraphic names should be used.

### Hydrologic Condition

Terms such as "water-table aquifer" and "artesian aquifer" are not recommended, because they are based on hydrologic conditions that can change as outside stresses change (pumping, climate). Hydrologic conditions also can vary from place to place. For example, an artesian aquifer can be dewatered by pumping, and an aquifer that is under artesian conditions within one place may be under water-table conditions in another.

# Recommendations for Naming Confining Units

Confining units should not be named unless a clear-cut need exists for understanding a complex aquifer system. If several aquifers and confining units are discussed, the confining units could be given individual names, but a hierarchy of terms for confining units comparable to aquifer system, aquifer, and zone is not necessary. If names are applied to confining units, they, like aquifer names, should be derived from lithologic terms, rock-stratigraphic names, or geographic names. If a confining unit consists of one rock-stratigraphic unit, the confining unit may be named after the rock-stratigraphic unit. If a confining unit consists of several rock-stratigraphic units, it could have the hyphenated name of the youngest and oldest units, or preferably, a geographic name.

A confining unit could be named after the aquifer it confines, but two possible situations may cause confusion. First, what name would be given if the confining unit separates two aquifers? It confines both. It could be named, however, for aquifers it overlies. If crystalline basement or other rock having low hydraulic conductivity forms the lowest confining unit, a name unrelated to an aquifer name should be chosen, such as "basal confining unit."

Second, if an aquifer is named for a rock-stratigraphic unit that forms all or most of the aquifer, the same name should not be used for a confining unit. In other words, the confining unit should not be named for a rock-stratigraphic unit that is not part of the confining unit. For example, in western South Dakota, the upper part of the Minnelusa Formation is an aquifer named the Minnelusa aquifer. This aquifer is overlain by a confining unit that consists of six formal rock-stratigraphic units. The confining unit should not be called the "Minnelusa confining unit," because the Minnelusa Formation is not a part of the confining unit. The options are (1) do not name the confining unit, (2) name it after an appropriate combination of rock-stratigraphic units that are in the confining unit, or (3) name the confining unit after a geographic feature. However, if the lower part of the Minnelusa Formation is a confining unit, the name "Minnelusa confining unit" could be used.

# General Procedures, Style, and Expression

## Redefining and Renaming Previously Named Aquifers

A previously named aquifer can be redefined and renamed, and the approach is the same as that for naming an aquifer for the first time. Redefining and renaming an aquifer should not be done casually or just to change the name. The guidelines in the previous pages apply. Comparison charts are important, especially charts that show the relation of renamed aquifers to previously named ones. No hard, fast rules can be given for redefining and renaming an aquifer, but justification should result from a thorough analysis of the hydrogeology and should represent an improvement in the understanding of the hydrology. Technical review should be used to judge the merit of the nomenclature changes. The work of Miller (1986) is an example of a detailed hydrogeological analysis that resulted in redefining and renaming the water-bearing units of the Floridan aquifer system. In reality, *all* aquifer names are informal names (North American Stratigraphic Code, 1983, art. 26) that might be changed with additional study. To represent clearly the hydrology of a particular area is more important than to retain old names or introduce new ones.

## Format Conventions for Aquifer Names

The following format conventions are recommended for reports that name aquifers or contain discussions of aquifer names:

- The terms "aquifer," "aquifer system," "zone," and "confining unit" are not capitalized.
- Terms such as sand and gravel aquifer and limestone aquifer are not capitalized or hyphenated.
- Adjective modifiers, except parts of formal geographic names, are not capitalized: Mississippi River alluvial aquifer.
- Relative-position terms—upper, middle, and lower—are not capitalized. However, the terms may be capitalized if they represent parts of a regional aquifer system that are separated by a major confining unit. For example, Miller (1986) formally divided the Floridan aquifer system into an Upper Floridan aquifer and a Lower Floridan aquifer in all Florida and parts of adjacent States.
- Quotation marks are not used for aquifer names unless the term is a misnomer. The term "500-ft" sand is set in quotes only because the sand is not

at 500 ft below land surface everywhere. (As mentioned before, depth of occurrence should not be used to name aquifers.)

- Hydrologic and geologic terms should be clearly distinguished.

  A. Water from the Madison aquifer—not Madison water.

  B. Wells completed in Madison Limestone (or aquifer)—not Madison wells.

## Examples of Designating and Naming Aquifers

Examples of designating and naming aquifers are shown in figure 20. The examples are hypothetical and generalized for convenience, but they illustrate characteristic hydrologic settings throughout the country. Even though most of the examples use rock-stratigraphic names, the options for naming aquifers in order of consideration are (1) do not name the aquifer, (2) use a lithologic name, and (3) use a rock-stratigraphic or geographic name, whichever is appropriate.

**Example 1: Aquifer and rock-stratigraphic unit coincide.** Example 1 shows an aquifer that coincides with a rock-stratigraphic unit and is confined above and below by much less permeable material. The aquifer probably would be named the Johnsville aquifer even though the full lateral extent of the aquifer may not be known.

**Example 2: Aquifer consists of one rock-stratigraphic unit and part of an adjacent rock-stratigraphic unit.** The aquifer shown in example 2 is made up of the lower two-thirds of the Whiskey Creek Formation (sandy silt and clayey sand) and the moderately cemented Devils Lake Sandstone. Hydrologically, the two units are continuous and form a single aquifer. The aquifer is confined above and below. The name of the aquifer could be taken from the rock-stratigraphic name "Whiskey Creek-Devils Lake aquifer." Likewise, a prominent geographic feature near the place where the aquifer was described (by wells or outcrops) could be the basis of the aquifer name. The description of the aquifer in the text, comparison chart, and illustrations should carefully state how the upper and lower boundaries of the aquifer were selected. In addition, the description should make clear that the upper formation and aquifer are not totally coincident.

**Example 3: Aquifer consists of a small part of two major rock-stratigraphic units.** The aquifer in example 3 consists mostly of the Murphy Member of the Ringer Formation and probably would be called the Murphy aquifer. If the Murphy Member had not been named, the aquifer might be called the Bell-Ringer aquifer. However, the aquifer makes up only a small part of each formation, especially the Bell Formation, so a local geographic name might be more appropriate.

**Example 4: Aquifer and aquifer system.** Example 4 represents an aquifer system consisting of three permeable carbonate formations and the sand facies of a clastic formation. The clay facies forms a confining unit over part of the area. If the study had included only the area east of the State line, two separate aquifers could have been defined—the Beckville-Jonesville aquifer and the Riley aquifer (or two aquifers named for geographic locations). If the study had included only the area west of the State line, the following options could be considered: (1) The aquifer might be called the Lewis aquifer if the sand were significantly more permeable than the limestone units, or (2) the aquifer might be called the Beckville-Riley aquifer if the permeability of the four units were not greatly different, or (3) the aquifer could be named after an appropriate geographic feature.

If the study area included all the units shown on the cross section, no individual rock-stratigraphic unit would be representative everywhere, and a geographic name should be used to name the aquifer system. If the sketch represented the full extent of the aquifer and the aquifer were given a name, say the Williamsburg aquifer, the parts above and below the confining unit could be named the Upper Williamsburg aquifer and the Lower Williamsburg aquifer in a manner similar to the naming of the Floridan aquifer system of Miller (1986). For local studies on either side of the State line, the local aquifer name could still be used if the names were entrenched in usage, but the authors of local reports should clearly show and explain the broader relation.

**Example 5: Aquifer system in a coastal area.** Example 5 illustrates an aquifer system (*A–B*) in a coastal area where the tendency has been to give separate aquifer names of hydrologically contiguous rock-stratigraphic units. For example, in a study area represented by section *A–B*, the aquifers from youngest to oldest are: surficial (the sand unit), Ford, Bass, Wilks, and Dade. In reality, all these named units form a single aquifer system that should be named after a physiographic or geographic feature. In a local-scale study represented by section *C–D*, the surficial deposits and the Bass Sand form one aquifer that should have a single name. It could be called the Bass aquifer as long as the designation clearly included the surficial deposits. The second aquifer under *C–D* would be the Wilks-Dade aquifer.

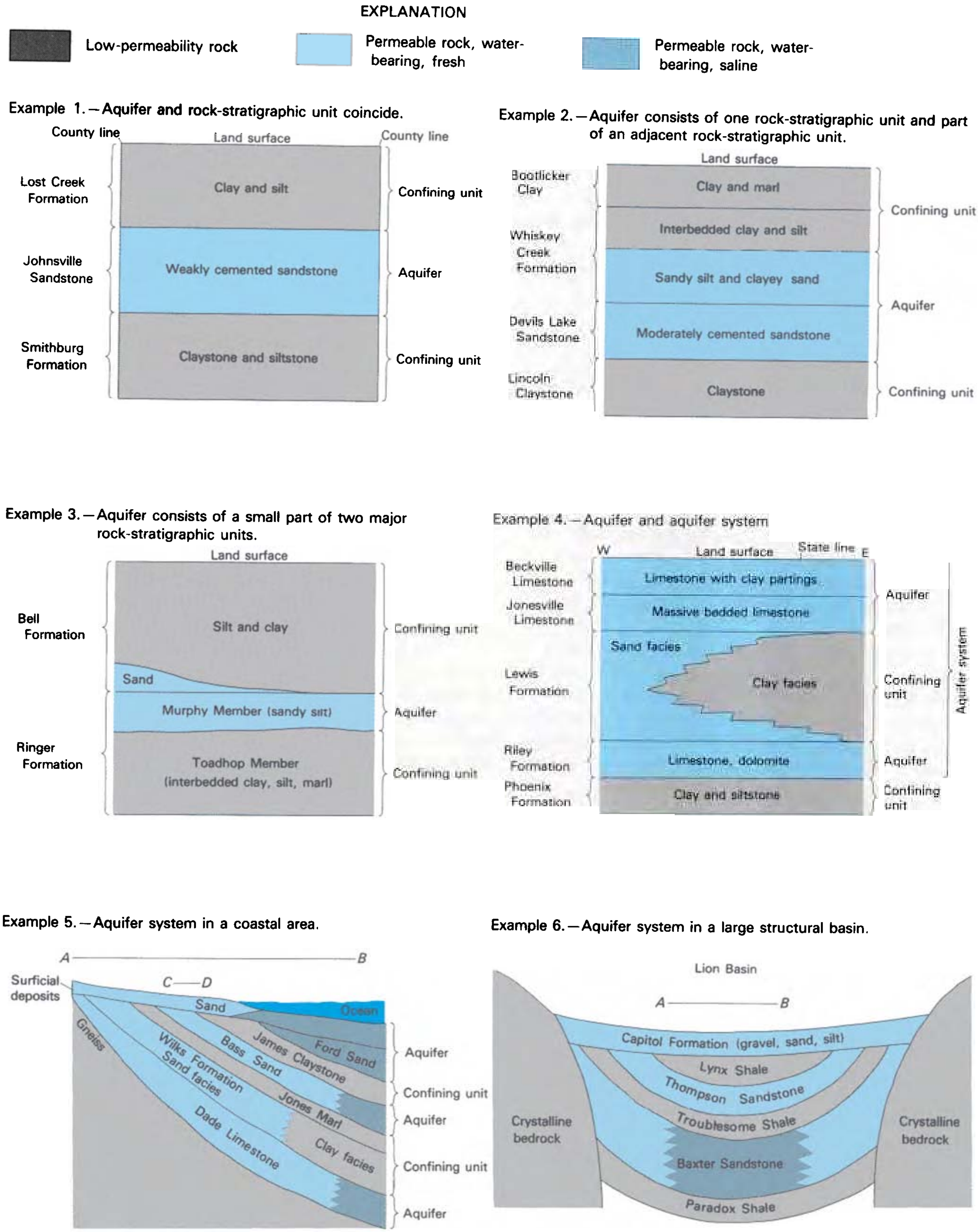
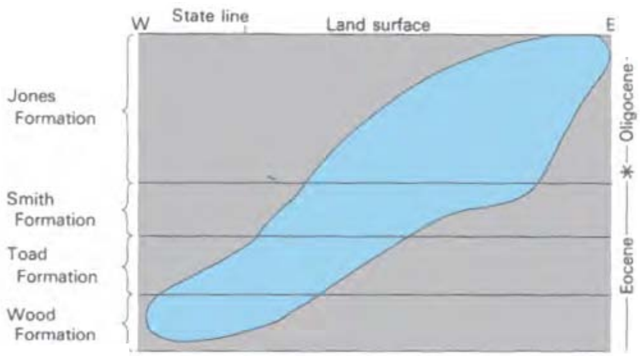
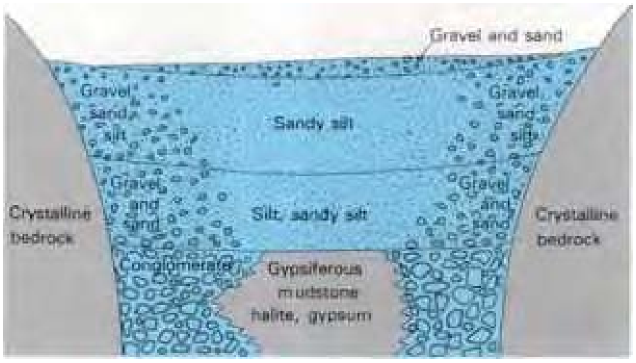



**Figure 20.** Examples of designating and naming aquifers.

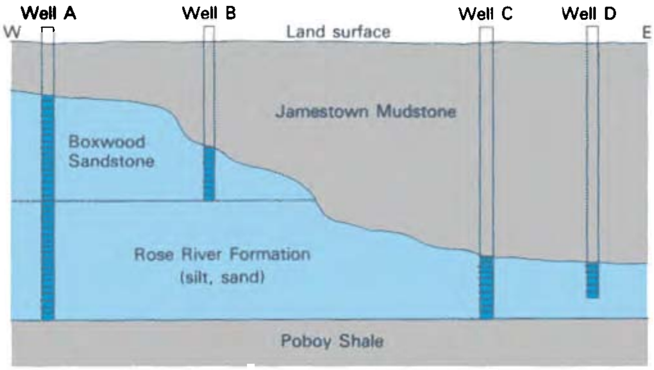
Example 7.—Aquifer crosses boundaries of rock-stratigraphic units and time-stratigraphic units.



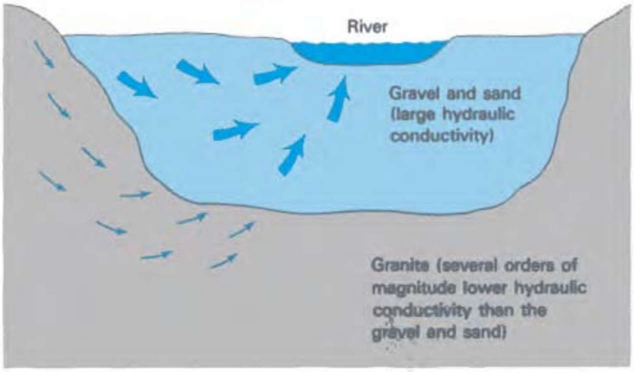

Example 8.—Aquifers in an alluvial basin in the West or Southwest



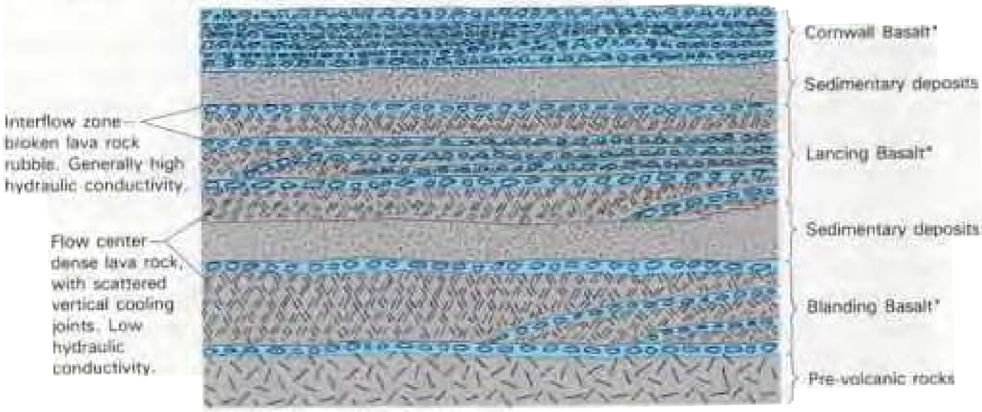

Example 9.—Use of aquifer terminology where rock-stratigraphic units are discontinuous.




Example 10.—Designation of aquifers and confining units for different purposes and scales of investigations.




Example 11.—Designation of aquifers in thick lava-flow sequences.




*Represents only a few of the flows in each basalt unit.

Aquifer materials that contain saline water are part of the same aquifer that contains fresh water. Interfaces between saltwater and freshwater are subject to movement, depending on the hydrologic conditions of the area, and should not be used as aquifer boundaries. However, the boundary between the salt water and fresh water and its apparent stability (or instability) should be defined as clearly as possible in the report.

**Example 6: Aquifer system in a large structural basin.** Example 6 depicts an aquifer system in a large structural basin. The aquifer system should be named after a physiographic or geographic feature, or as here, after a structural basin—the Lion aquifer system. If the tops and bottoms of the Capitol Formation, Thompson Sandstone, and Baxter Sandstone are all well defined, and if the boundaries of these units correspond largely to the boundaries of the aquifers in the system, rock-stratigraphic names could be used for individual aquifers. If the subsurface extent and boundaries of the rock-stratigraphic units are not well known, however, or if the individual aquifers consist of several rock-stratigraphic units, names unrelated to rock-stratigraphic terms should be assigned to the individual aquifers. If considerable uncertainty exists in defining the boundaries of the aquifers, the uncertainty should be indicated in the comparison charts and text. If the aquifer is well defined, it could be subdivided into the Upper, Middle, and Lower Lion aquifers, as was done for the Floridan aquifer system of Miller (1986). For local studies preceding the regional evaluation, as in the area represented by section *A–B*, individual aquifers might have been designated the Capitol aquifer, the Thompson aquifer, and the Baxter aquifer.

For subsequent local studies, the Lion aquifer system names could be used for individual aquifers unless the rock-stratigraphic names were entrenched or otherwise advantageous. If the rock-stratigraphic names are used as the basis for aquifer names, their corresponding equivalents in the regional aquifer system should be discussed and shown in the comparison table of the report.

**Example 7: Aquifer crosses boundaries of rock-stratigraphic units and time-stratigraphic units.** Example 7 shows an aquifer that crosses the boundaries of four rock-stratigraphic units and consists of parts of them. East of the State line the aquifer could be named the Jones-Smith aquifer; west of the State line it could be called the Toad-Wood aquifer. The aquifer boundaries bear no relation to the time-stratigraphic boundaries. In studies of the entire aquifer, a single rock-stratigraphic name is not appropriate; a geographic name should be used. Of course, a geographic name rather than a rock-stratigraphic name could be selected for the aquifer name at the local scale also.

**Example 8: Aquifers in an alluvial basin of the West or Southwest.** The sedimentary units shown in example 8 are representative of closed-basin deposits. In such a setting, the grain size generally decreases basinward from the source areas, and cementation increases at depth. Hydraulic conductivity likewise decreases downward and basinward. Even though the hydraulic conductivity generally is lower in the deeper units, many deposits in the upper part of the basin are hydraulically connected and consist of one aquifer. Most of the deposits do not have formal rock-stratigraphic names but may have informal names, such as basin fill, valley fill, cemented gravel, playa deposits, or lake deposits. Other rock units, such as volcanic flows interbedded with the basin deposits, may complicate the relationships. Well-defined confining clays in some basins subdivide the materials into two or more aquifers. In other basins, however, well-defined clay layers may be absent, or clay deposits may form "plugs" at depth in the centers of the basins. Your first option is to name no aquifers but to describe the water-bearing characteristics of the deposits. Informal rock names could be used (for example, valley-fill aquifer), or the aquifer could be named for a geographic feature, such as a basin or valley. Zones could be designated for hydraulic features that require emphasis or separation.

**Example 9: Use of aquifer terminology where rock-stratigraphic units are discontinuous.** The aquifer depicted in example 9 could be called the Boxwood-Rose River aquifer. Its upper boundary coincides with an erosional discontinuity, and although the Boxwood Sandstone is not present in the eastern part of the area, the name "Boxwood-Rose River aquifer" would be appropriate. Use of the aquifer name is illustrated by the wells in the sketch: Well A completely penetrates the Boxwood-Rose River aquifer, well B partly penetrates it, well C completely penetrates it, and well D partly penetrates it.

If a report were prepared on the area between wells C and D, the aquifer could be called the Rose River aquifer because the Boxwood Sandstone is not present in that area. However, if the entire sketch area were studied and if the Boxwood-Rose River aquifer were already named, the study report must contain text statements and comparison charts to show that the Rose River aquifer thickens west to include the overlying Boxwood Sandstone and there becomes the Boxwood-Rose River aquifer.

Aquifer materials that contain saline water are part of the same aquifer that contains fresh water. Interfaces between saltwater and freshwater are subject to movement, depending on the hydrologic conditions of the area, and should not be used as aquifer boundaries. However, the boundary between the salt water and fresh water and its apparent stability (or instability) should be defined as clearly as possible in the report.

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For subsequent local studies, the Lion aquifer system names could be used for individual aquifers unless the rock-stratigraphic names were entrenched or otherwise advantageous. If the rock-stratigraphic names are used as the basis for aquifer names, their corresponding equivalents in the regional aquifer system should be discussed and shown in the comparison table of the report.

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**Example 10: Designating aquifers and confining units for different purposes and different scales of investigations.** Example 10 depicts a highly permeable deposit of gravel and sand in a valley occupied by a major perennial stream. The bedrock is granite and is several orders of magnitude less permeable than the gravel and sand.

Because of the large permeability contrast, the deposit of gravel and sand is the aquifer, and the granite is the confining unit. If you were evaluating the potential for developing ground-water supplies from the gravel and sand, or were evaluating the interaction between ground water and surface water, you might consider the granite to be effectively "impermeable," and you could ignore the flow in the granite. If, however, you were evaluating the potential for storing high-level radioactive wastes in the granite, the designations of the aquifer and confining unit would not necessarily change, but you would have to consider the flow system through both units. The rate of flow through the granite into the gravel and sand would be slow, but you could not ignore it in evaluating minimum travel times of radionuclides that the ground water might transport through the granite. The depicted situation is similar to that of an aquifer overlain by a confining unit (such as clay over sand) that contributes water to the aquifer by leakage. A small to large part of the water withdrawn from the aquifer could come from the confining unit, but the designations of the aquifer and confining unit would not change. Therefore, the purpose of an investigation in a given area should not alter the designations of aquifers and confining units.

Aquifers and confining units may be designated differently in two or more investigations because of differences in scale or extent of the study areas. In an investigation of just the granitic terrane in the sketch (such as an evaluation of ground-water availability for domestic use), the granite would be the aquifer because it is the only water-bearing unit in the study area. A report on a larger area that included the gravel should mention the previous report and should describe how the various hydrogeologic units were selected. Similarly, a unit of low hydraulic conductivity might be utilized locally as an aquifer, whereas a regional evaluation might show it as a regional confining unit. You as author should explain the apparent anomaly by means of the comparison charts and text.

**Example 11: Aquifers and confining units in thick lava-flow sequences.** Thick lava-flow sequences, as on the Columbia Plateau (Heath, 1984), require special consideration in the designation of aquifers and confining units. These sequences may be hundreds to thousands of feet thick and may contain individual flows a few feet thick to a few hundred feet thick. The most permeable parts are interflow zones of lava-rock rubble a few feet thick at the tops of flows and thinner rubbly zones at the bases of overlying flows. The interflow zones are interrupted laterally, or they terminate; continuous aquifers, therefore, are identifiable for only a few miles (Newcomb, 1969). The part of a flow between interflow zones—the flow center—consists of dense, vertically jointed lava rock that cooled slowly. The interflow zones may account for only 1–30 percent of the volume of the rock, but their lateral hydraulic conductivity may be several orders of magnitude greater than the vertical hydraulic conductivity of the dense, vertically jointed rock, unless the top of the flow had been subjected to long subaerial weathering before burial. If the top of a flow were extensively weathered before being covered by another lava flow, clay minerals in the altered lava rock might reduce the permeability of the interflow zone. The interflow zones may contain discontinuous deposits of fine-grained sediment that have little hydrologic effect on the flow sequence or that may grade into wider spread sedimentary deposits. The hydraulic conductivity of widespread sedimentary deposits varies but usually is much less than that of a rubbly interflow zone.

Designating aquifers may be governed by the scale of the study and the thickness of the individual lava flows. Where individual flows are several hundred feet thick (the middle and lower part of the sketch), the interflow zones are easily recognized as individual aquifers, and the dense lavas between interflow zones are obvious confining units. The part of the flow sequence consisting of several permeable interflow zones separated by dense, much thicker lava would be an aquifer system. At the other extreme, the designation of aquifer versus aquifer system may not be as clear cut in a sequence where the individual flows are only a few feet thick (the upper part of the sketch). At some point the ratio of interflow zone to dense zone may become large enough that the multiple thin-flow sequence could be considered a single aquifer. A comparison can be made with a sequence of interbedded sandstone and shale: Taken as a whole, the sequence might behave hydrologically as a single aquifer and not an aquifer system, even though thin continuous "confining units" are part of the aquifer. Other information, such as head measurements versus depth in areas where the aquifer is under stress, might be used to determine whether the sequence under study behaves as a single aquifer or as several aquifers separated by confining units.

If you assume that the thin-bedded flows in the upper part of example 11 behave as a single aquifer, the hypothetical lava-flow sequence consists of an aquifer and two aquifer systems, all of which constitute an even larger aquifer system. A higher category than aquifer system might appear to be needed in the hierarchy of nomenclature to classify the water-bearing rocks in this example, but the term "aquifer system" adequately encompasses the example shown. An appropriate geographic name should be used for the entire hydrologic system represented by the sketch, such as the "Rome River aquifer system," after a major river in the area. The individual parts of the system could be called "the Upper," "Middle," and "Lower Rome River aquifer," as in the Floridan aquifer system (Miller, 1986). An alternate method of naming would give the upper, middle, and lower parts individual names based on rock-stratigraphic units (or appropriate geographic names) that make up the aquifers, as follows:

| | |
|---|---|
| Rome River aquifer system | Cornwall aquifer (after Cornwall Basalt)<br>Lancing aquifer (after Lancing Basalt)<br>Blanding aquifer (after Blanding Basalt) |

As in any other aquifer description, the characteristics of the dense, less permeable parts of the aquifer versus the very permeable interflow zones must be carefully described in the comparison tables and text.