POTENTIAL FOR CONTAMINATION OF SHALLOW AQUIFERS IN ILLINOIS

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POTENTIAL FOR CONTAMINATION OF SHALLOW AQUIFERS IN ILLINOIS

The potential for contaminating groundwater resources is a critical concern in Illinois. Contamination may result from land burial of municipal wastes and surface or near-surface disposal of wastes (septic systems; surface-spread sludge; agricultural pesticides, herbicides, and fertilizers; and accidental spills of chemicals or other contaminants). When chemical or biological agents from wastes enter surface water or groundwater, they present potential health hazards.

Earth materials that yield groundwater to wells are aquifers: porous, coarse-grained sand and gravel deposits in glacial drift, and porous or fractured bedrock. Aquifers are susceptible to contamination because their hydrogeologic properties allow waste effluents to travel rapidly. Yet whether a shallow aquifer actually becomes contaminated also depends on the properties of the earth/geologic materials that surround it.

The purpose of this project, initiated and supported by the Illinois Environmental Protection Agency, was to describe and map geologic materials to a depth of 50 feet throughout the state. Materials have been differentiated by thickness, texture, permeability, and stratigraphic position (where they lie in the vertical sequence between the surface and 50-ft depth). Because waste effluents travel through different materials at different rates, the susceptibility of aquifers within variable vertical sequences depends on the protection provided by overlying and underlying materials that are less permeable; restricting the movement of contaminants reduces the potential for contamination.

Thus, the combination of hydrogeologic properties and stratigraphic position of geologic materials provides the basis for mapping the potential for contaminating aquifers. By comparing sequences of geologic materials, we can rate the relative contamination potential for aquifers in any area of the state.

Two maps constructed for this study show the distribution of sequences of geologic materials and their comparative ratings. Each sequence was rated for the susceptibility of its water-yielding materials (aquifers) to contamination from waste-disposal practices. Ratings were made by comparing the capacities of earth materials to accept, transmit, restrict, or remove contaminants from waste effluents. The vertical sequences, not specific materials, were compared and rated.

Plate 1, Potential for Contamination of Shallow Aquifers by Land Burial of Municipal Wastes, identifies 18 sets of sequences. Sand-and-gravel or permeable-bedrock aquifers lying within 50 feet of the surface are most susceptible to contamination. These sequences, which receive the highest contamination-potential ratings, occur principally in the driftless and thin-drift areas of northern, northwestern, western, and extreme southern Illinois. Sequences with the lowest contamination potential contain either uniform till or other fine-grained materials at least 50 feet thick, or uniform till less than 50 feet thick but overlying impermeable bedrock; these cover large areas of northeastern and central Illinois.

Plate 2, Potential for Contamination of Shallow Aquifers by Surface and Near-Surface Waste Disposal, identifies 13 sets of sequences. Sand-and-gravel or permeable-bedrock aquifers lying near the surface are most susceptible to contamination; these sequences, which receive the highest contamination-potential ratings, occur principally in north-central, northwestern, and extreme southern Illinois. Sequences with the lowest contamination potential have a minimum 20 feet of uniform till or other fine-grained materials at the surface; these occur primarily in northeastern and central Illinois.

*For hazardous (toxic and radioactive) waste disposal, geologic materials must be evaluated to greater depths. The maps presented with this report cannot be used to determine hazardous waste-disposal sites.
Figure 1  Geologic map of Illinois (from Willman and Frye, 1970).
These maps are unique in their detail of geologic information, presented at a scale of 1:500,000 for the entire state. Their principal uses are

- for suggesting areas, not specific sites, where disposal of wastes will have minimum potential for contaminating groundwater resources;
- for screening areas with low contamination potential, as part of the process of locating new disposal sites.

The maps cannot be used to evaluate specific sites. A program of test drilling, sample collection, laboratory analyses, detailed site description, and geologic interpretations—in short, on-site investigation is the only acceptable procedure for determining the suitability of a site for waste disposal.

Previous Studies
Since the early 1960s, people have recognized that groundwater contamination is a regional problem (Hackett, 1965). In Illinois, early geologic maps showing areas sensitive to landfilling of wastes were produced by Sheaffer, Von Bohm, and Hackett (1963) for northeastern Illinois and by Cartwright and Sherman (1969) for the entire state. Also in 1969, Walker mapped and discussed the contamination potential of “unconsolidated” and bedrock aquifers of Illinois.

Geologic materials have been classified for waste disposal in geology-for-planning studies completed for Putnam and portions of Bureau, Marshall, and La Salle Counties (McComas, 1968); St. Clair County (Jacobs, 1971); McHenry County (Hackett and McComas, 1969); De Kalb County (Gross, 1970); Lake County (Larsen, 1973); Sangamon, McLean, and part of Christian Counties (Bergstrom, Piskin, and Follmer, 1976); McHenry, Lake, Cook, Du Page, Kane, and Will Counties (Kempton, Bogner, and Cartwright, 1977); De Witt County (Hunt and Kempton, 1977); Rock Island County (Anderson, 1980); and Boone and Winnebago Counties (Berg, Kempton, and Stecyk, 1984).

DISTRIBUTION OF GEOLOGIC MATERIALS
The general distribution of subsurface materials in Illinois is shown on figures 1 and 2. Subsurface deposits form two distinct groups: hard, consolidated deposits or bedrock, and relatively soft, unconsolidated deposits.

Bedrock materials differ greatly depending on age, depth of burial, and origin:
- Precambrian rocks, principally composed of granite, form the basement rocks (fig. 1).
- Cambrian through Pennsylvanian sedimentary rocks are warped and tilted, generally dipping toward southeastern Illinois and thickening to 15,000 feet in the center of the Illinois Basin. The youngest strata, primarily shale and siltstone with some sandstone and relatively thin beds of limestone and dolomite, cover a large area of north-central, central, and southern Illinois. The oldest strata, mostly limestone, dolomite, and sandstone, are found at bedrock surface around the margins of the basin in northern, western, and southern Illinois.
- Cretaceous and Tertiary rocks, relatively soft deposits such as bedded clays, silts, and sands, are found in small areas of western and southern Illinois (fig. 1).

Geologic materials dating from the Quaternary were deposited by continental glaciers (fig. 2). They are referred to as unconsolidated materials, overburden, or glacial drift. In Illinois, the distribution of these earth materials is due to (1) the thickness of debris left by the glaciers (fig. 3), (2) the configuration of bedrock surface (fig. 4), and (3) erosion. Generally, unconsolidated deposits are thickest where they fill valleys carved into the bedrock surface.

Glacial deposits are primarily composed of
- till, materials deposited directly by a melting glacier, mostly pebbles and cobbles in a matrix of clay, silt, and sand;
- outwash, largely sand and gravel carried from the glacier by rapidly flowing meltwater rivers, then redeposited along meltwater rivers or in lakes;
- lacustrine deposits, silt and clay that settled out in quiet-water lakes and ponds;
- loess, windblown silt.

Other unconsolidated materials include relatively recent river deposits (alluvium), slope wash (colluvium), and peat and muck.

Of these deposits, glacial till and outwash predominate. Where bedrock is near the surface, only one till may be present. Thicker drift areas may contain several tills, as well as outwash and lacustrine deposits.


SOURCE, MOVEMENT, AND AVAILABILITY OF GROUNDWATER
The source of groundwater is precipitation—both rain and snow infiltrating loose particles of the soil and eventually percolating downward. Below a certain depth, called the “top of the zone of saturation” or “water table,” almost all openings (pores) in the earth materials are filled with water. (Above the water table, pore spaces are filled with both water and air.) This definition of water table is not related to the availability of groundwater to wells. A tightly packed, fine-grained material may be completely saturated with water, yet the yield and rate of recharge (movement of water into the well) would not be sufficient for use.

Groundwater is stored in the zone of saturation in openings ranging from tiny spaces between particles of clay and silt, to gaps in sand and gravel, to large crevices in dolomite and limestone. The pore space in any earth material is its porosity, expressed as a percentage of the total
Figure 2  Surficial materials of Illinois (modified from Quaternary Deposits of Illinois, Lineback 1979).
Figure 3  Thickness of Pleistocene deposits in Illinois (from Willman and Frye, 1970; summarized from Piskin and Bergstrom, 1967).
Figure 4  Topography of the bedrock surface of Illinois (from Willman and Frye, 1970; summarized from Horberg, 1950; and others).
volume of the material. The size and interconnection of pores determine how easily water moves through materials from areas of high potential energy to areas of low potential energy (i.e. hydraulic gradient) (fig. 5). The property of a material that describes the ease of water movement is called the hydraulic conductivity or permeability. The rate of groundwater and contaminant movement depends upon

- the hydraulic conductivity,
- the hydraulic gradient,
- the effective porosity of the geologic material.

Table 1 shows the estimated hydraulic conductivity of typical geologic materials in Illinois.

Water table. Under natural conditions, the water table roughly parallels the surface topography, rising under the uplands and intersecting the surface along streams, lakes, swamps, and springs (fig. 5). At intersections, groundwater enters surface-water bodies because of gravity flow from nearby areas where the water table is higher. From season to season and year to year, the position of the water table and the discharge of groundwater to streams fluctuate.

The water table can be located in any material. Even after a well has been drilled below the water table, groundwater is only rapidly available from material with sufficient hydraulic conductivity. Thus, the presence of water does not necessarily mean the presence of an aquifer. Any large excavation below the water table—even in materials with low hydraulic conductivity—will fill with water, though very slowly.

![Figure 5](Image)

Idealized scheme showing groundwater flow from areas of high potential energy to areas of low potential energy (modified from Freeze and Cherry, 1979).

Aquifer. An aquifer is a body of earth materials yielding enough water to a well to satisfy the need for drilling it. So an aquifer supplying adequate water for a single residence might not be an aquifer for a municipality. In this report, the term aquifer refers to earth materials capable of yielding water to several residences.

Aquifers may be unconfined or confined (fig. 6). In an unconfined aquifer, the water table is the top of the aquifer; no impermeable materials overlie the aquifer, confining it. In a confined aquifer, also known as an artesian

<table>
<thead>
<tr>
<th>Geologic material</th>
<th>cm/sec</th>
<th>gpd/ft²</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean sand and gravel</td>
<td>$1 \times 10^{-3}$</td>
<td>$&gt;20$</td>
<td>May be highly permeable</td>
</tr>
<tr>
<td>Fine sand and silty sand</td>
<td>$1 \times 10^{-5}$ to $1 \times 10^{-3}$</td>
<td>0.2 to 20</td>
<td></td>
</tr>
<tr>
<td>Silt (loess, colluvium, etc.)</td>
<td>$1 \times 10^{-6}$ to $1 \times 10^{-4}$</td>
<td>$1 \times 10^{-1}$ to 2</td>
<td></td>
</tr>
<tr>
<td>Gravelly till, less than 10% clay</td>
<td>$1 \times 10^{-7}$ to $1 \times 10^{-5}$</td>
<td>$2 \times 10^{-3}$ to $2 \times 10^{-2}$</td>
<td>Often contains gravel/sand lenses or zones</td>
</tr>
<tr>
<td>Till, less than 25% clay</td>
<td>$1 \times 10^{-8}$ to $1 \times 10^{-6}$</td>
<td>$2 \times 10^{-4}$ to $2 \times 10^{-2}$</td>
<td>Often contains gravel/sand lenses or zones</td>
</tr>
<tr>
<td>Clayey tills, greater than 25% clay</td>
<td>$1 \times 10^{-9}$ to $1 \times 10^{-7}$</td>
<td>$2 \times 10^{-5}$ to $2 \times 10^{-3}$</td>
<td>Often contains gravel/sand lenses or zones</td>
</tr>
<tr>
<td>Sandstone</td>
<td>$&gt;1 \times 10^{-4}$</td>
<td>$&gt;2$</td>
<td></td>
</tr>
<tr>
<td>Cemented fine sandstone</td>
<td>$1 \times 10^{-7}$ to $1 \times 10^{-4}$</td>
<td>$2 \times 10^{-3}$ to 2</td>
<td>Frequently fractured</td>
</tr>
<tr>
<td>Fractured rock</td>
<td>$&gt;1 \times 10^{-4}$</td>
<td>$&gt;2$</td>
<td>May have extremely high hydraulic conductivity</td>
</tr>
<tr>
<td>Shale</td>
<td>$1 \times 10^{-11}$ to $1 \times 10^{-7}$</td>
<td>$2 \times 10^{-7}$ to $2 \times 10^{-3}$</td>
<td>Often fractured</td>
</tr>
<tr>
<td>Dense limestone/dolomite (unfractured)</td>
<td>$1 \times 10^{-11}$ to $1 \times 10^{-8}$</td>
<td>$2 \times 10^{-7}$ to $2 \times 10^{-4}$</td>
<td></td>
</tr>
</tbody>
</table>
aquifer, the groundwater is confined under pressure greater than atmospheric pressure by overlying, relatively impermeable materials. This pressure causes the water in a well to rise above the top of the aquifer. If the water in a well rises to the surface, it is a flowing artesian well.

In some places, materials above the main water table become saturated, resulting in perched water tables: for example, several feet of windblown silt (loess) may overlie a clay-rich zone (paleosol) developed in glacial till. Because silt is more porous than clay, water will generally move more easily through the loess than through the clay and collect just above the clay, producing a saturated zone or perched water table. Also, small, relatively thin sand and gravel layers between loess and clay-rich till might form perched groundwater zones, although they rarely yield enough water to supply even a small household. High water tables and perched groundwater frequently cause problems such as wet basements, soft foundations, and septic tank failures.

Recharge. Water that refills the groundwater reservoir is called recharge. A groundwater flow system (fig. 7) shows water moving through the earth from recharge to discharge areas. The earth's gravity is the source of energy that causes groundwater to flow; however, water moves in the direction of the hydraulic (energy) gradient (fig. 5). Water flows in horizontal as well as vertical paths through the earth.

Regional flow systems are composed of small, local systems. A local flow system might include only a small pond serving as a discharge area for the uplands next to it. The uplands would be the local recharge area. In turn, this system could be a part of a larger system that discharges into a major river such as the Mississippi River or the Illinois River (fig. 7).

Recharge is spread over large areas and does not come from one source or even from small local sources. In relatively humid regions, such as Illinois, streams that flow for most of the year serve as groundwater discharge areas. The entire interstream system forms the recharge area.

Geologic Materials That Yield Groundwater: Aquifers
Two principal types of material yield groundwater in Illinois: (1) sand and gravel deposits within glacial drift and along river valleys, and (2) sandstone, limestone, and dolomite formations within bedrock. Freshwater occurs from only a few feet deep to as much as 2,000 feet deep in parts of the state.

Wells in glacial sands and gravels yield from 1 to 2 gallons per minute (gpm) for households to several thousand gpm for industrial or municipal supplies. In areas of thick drift, sand and gravel deposits may be extensive and deeply buried. Some sand and gravel deposits occur near the base of the drift and in ancient buried valleys cut into the bedrock surface, although they can occur anywhere, at any depth within the drift. Shallow sand and gravel is most common in river valleys. Where drift is thin, generally isolated sand and gravel deposits occur.

Drift materials that yield little or no water to wells include pebbly clay glacial till, silty lake deposits, windblown silt (loess), and residual soils. Because of their often fine texture, all these materials slow the movement of water into and between aquifers. Tills are the most common as well as the thickest of non-aquifer drift deposits. The texture of till is fairly uniform; however, particle sizes may vary greatly from one till to another. Lake deposits that accumulated behind ridges of glacial deposits (moraines) and in ice-clogged river valleys consist primarily of silts and clays, but may include sand. Loess consists mostly of silt, but may locally contain very fine sand- or clay-size particles. Residual soils are generally clayey, but are not thick and extensive enough to be important.

Although groundwater conditions in the bedrock vary considerably, bedrock units are more consistent in
character than drift deposits. Also their distribution is better documented. Depth and water-yielding properties of bedrock can often be predicted. Bedrock formations dip into the Illinois Basin, a spoon-shaped structural depression that is deepest in Hamilton, Wayne, Edwards, and White Counties. Rock units that produce drinkable water at 2,000 feet in northern Illinois lie much deeper in the Illinois Basin; they also contain brine because water becomes more saline as it moves toward the deep part of the Basin. In the southern and western parts of the state, the maximum depth of potable water is usually much less than 2,000 feet. In some areas of south and central Illinois, saline water may be encountered near the top of the bedrock.

Permeable limestones, dolomites, and sandstones underlie the glacial drift in the northern quarter and along the western edge of the state (fig. 1). In those areas, shallow bedrock forms a principal aquifer, supplying water for domestic, municipal, and industrial uses; these fractured and creviced limestones and dolomites sometimes yield more than 1,000 gpm. In the rest of the state, the Pennsylvanian rocks underlying the drift contain only minor aquifers—a few thin sandstones of low permeability and an occasional fractured limestone or shale. Yields are low, rarely more than enough for a small domestic supply, although yields of over 50 gpm have been reported. In all areas of the state, crevicing and fracturing are most likely to be present in the uppermost 50 or 75 feet of the bedrock, just below the drift.

Physical Properties
That Reduce Concentrations of Contaminants
Dilution, dispersion, and filtering. In turbulent surface waters, dilution, and dispersion effectively reduce the concentration of contaminants. By contrast, the smooth, even flow of groundwater slows dilution and dispersion of refuse leachate or septic effluent.

Filtering effectiveness is directly related to the size of openings between particles: a clean gravel (containing little sand, clay, or silt) with large pores will be a poor filter; a fine-grained material with small pores will be more effective. Although filtering may remove bacterial contaminants, it does not affect dissolved chemical contaminants.

Attenuation. Through ion exchange, clays (and to some extent, silts) reduce the concentrations of some objectionable substances in landfill leachate or septic effluent. Much like a household water softener, these fine-grained materials exchange ions in the leachate with harmless ions (calcium and magnesium) naturally held on the surface of the clay particles. Because this is an exchange process, the amount of total dissolved solids does not change. Also, the natural organic content of soils plays an important role in attenuation. Organic matter adds to the cation exchange capacity of the soil. But more importantly, the attenuation of organics in leachate relates directly to the natural organic matter in soil.

Little or no attenuation of either chemicals or bacteria occurs where groundwater, landfill leachate, or septic-tank effluent move through joints and fissures in rocks. Where creviced limestones are a source of water, extreme caution is necessary when evaluating a potential site for a landfill, for large concentrations of septic systems, or for concentrated spreading of sewage sludge.

For natural protection of groundwater, Illinois has used this guideline for years: at least 30 feet of relatively impermeable (fine-grained, tightly packed) material capable of attenuation should separate the base of a landfill from an aquifer. The origin of this practice is unknown. Recent research into the movement of contaminants through geologic materials (Hughes, Landon, and Farvolden, 1968) in addition to what is generally known about the movement of groundwater suggest this guideline is conservative.
PREPARING THE MAPS

A geologic stack-unit map was constructed to show how earth materials are distributed both horizontally and vertically throughout the state. Units of earth materials are not only distributed across land surface, but also in layered or “stacked” sequences below the surface. Standardized symbols indicate that a given geologic unit
- covers a specified area,
- ranges from a few to several feet thick,
- lies at a certain depth or within a certain depth limit,
- has specific physical (including hydrogeologic) properties.

This combined horizontal/vertical format (fig. 8) identifies relationships between units, particularly in vertical sequences: for example, sand and gravel underlies 20 feet of impermeable clay in one sequence, and overlies it in another. By introducing a dynamic factor such as groundwater or waste effluent, it becomes important to show where sand and gravel, silt, clay, or limestone lie in the sequence. Because materials have distinct hydrogeologic properties, they also have varying capacities to prevent groundwater contamination: some materials accept and transmit contaminants easily, thus increasing the potential for contamination; others restrict the movement of or remove contaminants, thus lessening the potential.

By identifying, describing, and most important, mapping both the vertical and horizontal distribution of earth materials, it becomes possible to rate sequences and evaluate areas for potential aquifer contamination (plates 1 and 2).

Constructing a Stack-Unit Map

The procedures, which are described by Kempton (1981) and diagrammed in figures 8a to 8f, begin with U.S. Department of Agriculture Soil Conservation maps and U.S. Geological Survey topographic maps (figs. 8a, 8b). Because soils are grouped according to the earth materials from which they formed, a soil-geologic map is actually a surficial geologic map. Topographic maps (1:24,000 and 1:62,500 scale) show both physical and cultural features.

On the topographic/soil base map, drift thickness (fig. 8c) and stratigraphic units (units at different depths) were plotted using information from geologic reports and maps, field observations, water-well logs and samples, engineering logs and core samples, and test drilling at selected sites. Physical and mineralogical properties from the various geologic materials were added. If possible, data on surficial units were checked against soil maps. In many cases, cross-sectional diagrams (fig. 8d) were constructed to help identify the continuity of subsurface units, particularly buried deposits of sand and gravel and other materials with high hydraulic conductivities. A stack-unit map to a depth of 20 feet was constructed (fig. 8e), and then the distribution of subsurface permeable materials between 20 and 50 feet deep was added to the existing stack-unit map (fig. 8f).

Sources of Information

Fortunately, detailed stack-unit maps to a depth of 20 feet were available for several counties: De Kalb County (Gross, 1970); Sangamon, Macon, and a part of Christian Counties (Bergstrom, Piskin, and Follmer, 1976); McHenry, Lake, Cook, Du Page, Kane, and Will Counties (Kempton, Bogner, and Cartwright, 1977); Boone and Winnebago Counties (Berg, Kempton, and Stecyk, 1984); Kankakee County (Berg and Kempton, unpublished); Vermilion County (W. H. Johnson, unpublished); Champaign County (Killey, unpublished); Madison County (McKay, Fox, Hines, and Killey, unpublished); and Marion, Fayette, and Effingham Counties (Ball and Follmer, unpublished). Partially completed stack-unit maps of Lee and Bureau Counties (Kempton, unpublished) and Henry County (Anderson and Johnson, unpublished) were also used.

For the remaining counties, stack units of materials were obtained by combining information from the map, *Quaternary Deposits of Illinois* (Lineback, 1979), with subsurface stratigraphic data from many geologic studies, maps, field notes, test drilling, and water-well logs.

Data for subsurface sand and gravel deposits and permeable bedrock units within 50 feet of the surface appear in publications for selected counties: Boone and Winnebago (Berg, Kempton, and Stecyk, 1984); McHenry, Lake, Kane, Cook, Du Page, and Will (Kempton, Bogner, and Cartwright, 1977); Shelby, Moultrie, Douglas, Coles, Edgar, and parts of De Witt, Macon, Christian, Piatt, Champaign, and Vermilion (Kempton, Morse, and Visocky, 1982); and northern Vermilion County (Kempton et al., 1981). Deposits in the remaining counties were identified by examining and evaluating more than 25,000 well logs and sample-set descriptions on file at the Illinois State Geological Survey.

The stack-unit map also shows bedrock, such as shale or dense Pennsylvanian limestone, that does not contribute to groundwater contamination. The *Geologic Map of Illinois* (Willman, 1967) and recent investigations by Willman and Kolata (1978) and Kolata and Graese (1983) defined boundaries between bedrock materials. New well logs also provided data to revise parts of the drift thickness map of Illinois (Piskin and Bergstrom, 1975), particularly in west-central Illinois along the Mississippi River from Rock Island County in the north to Calhoun and Jersey Counties in the south. The 50-foot thickness contours set by Piskin and Bergstrom were used almost exclusively in areas underlain by Pennsylvanian shale and limestone.

Depth Limit

Setting a depth limit for a stack-unit map depends on how it is to be used. In this case, a two-fold purpose directed a two-fold study to determine how susceptible shallow aquifers are to contamination (1) from land burial of municipal wastes—a practice usually occurring in trenches about 20 feet deep, and (2) from concentrated disposal
of wastes on or just below land surface. Detailed stratigraphic data are essential in the upper 20 feet in order to map materials that may become contaminated by surface and near-surface wastes, or to map materials for trench excavations. For land burial of municipal wastes, the depth limit for mapping is 50 feet because refuse is frequently buried in trenches about 20 feet deep. It is important that materials in the 20- to 50-foot interval be identified because of the recommendation that at least 30 feet of relatively impermeable drift and/or dense bedrock underlie the base of the refuse trench. This thickness should protect groundwater resources deeper than 50 feet from contamination (Cartwright and Sherman, 1969; Hughes, Landon, and Farvolden, 1971).

Availability and Accuracy of Geologic Data

In general, both availability and accuracy of data decrease with depth. Surface and near-surface data (0 to 20 ft) are at least 75 percent accurate because information is plentiful for this interval where most land-use activity occurs. Mapping the distribution of subsurface permeable bedrock and sand and gravel units (20 to 50 ft deep) relied primarily on water-well and test-well data. The density of data varied considerably depending upon location in the state. The least documented areas are in west-central Illinois outside areas of coal and oil exploration and residential expansion. The best documented areas are in highly urbanized northeastern Illinois and in the southern counties where thousands of coal and oil wells show the thickness of drift and the type of surficial bedrock.

Data for most of the state were plotted on maps with a scale of 1:62,500 and then transferred to maps with a scale of 1:250,000. Areas that are near map boundaries or contain a complex sequence of materials are difficult to map accurately because units or deposits grade into each other or wedge out. Additional field data will confirm or revise boundaries. Probably the most accurate parts of the map are the large areas mapped as one geologic material; for example, the geologic sequences rated E and D on plate 1.

Because units are often complex at the 1:250,000 scale, some were combined. Also, discontinuous units less than 3 feet thick were too small to be included. Although the combining of geologic units reduced map accuracy in some areas, it was necessary for the final reduction to a scale of 1:500,000—to accommodate mapping the entire state.

Contamination-Potential Maps

Two contamination-potential maps (plates 1 and 2) were developed from the basic, geologic stack-unit map of Illinois (figs. 8g, 8h). The map for land burial of municipal wastes, with a depth limit of 50 feet, was constructed first; boundaries enclosing units with similar hydrogeologic characteristics were traced from the stack-unit maps onto polyester film (fig. 8g). Next, the map for surface and near-surface disposal of wastes (fig. 8h), with a depth limit of only 20 feet, was made by transferring some unit boundaries from the land-burial map. This ensured consistency with the original stack-unit map. Detailed information from the upper 20 feet of the stack-unit map was added later.

Within map boundaries, related stack units or vertical sequences of materials were combined into sets of geologic sequences: unique sets were identified, then described by relating type, texture, and permeability of materials to depth, thickness, and position in the geologic sequence. (Note: there are fewer sets of sequences on plate 2 because materials below 20 feet were excluded.)

Sets of vertical geologic sequences were then rated by comparing the capacities of earth materials to accept, transmit, restrict, or remove contaminants from waste effluents. Finally, the assigned ratings were added to each specified map unit.

Plate 1, Potential for Contamination of Shallow Aquifers from Land Burial of Municipal Wastes. Sequences of geologic materials (from 0 to 50 ft deep) were rated for their water-retaining/water-yielding (hydrogeologic) properties, attenuation capacities (removal of contaminants from water passing through them), and release rates of non-attenuated contaminants. For example, sand-and-gravel and permeable-bedrock aquifers are most susceptible to contamination from waste effluents; so geologic sequences containing these materials receive a high rating: A to C (fig. 9). Shale, dense limestone, or thick deposits of till are least susceptible to contamination because they do not form aquifers; so sequences containing only these materials receive a low rating: D to G (fig. 9).

Plate 2, Potential for Contamination of Shallow Aquifers from Surface and Near-Surface Waste Disposal. Sequences of geologic materials (from 0 to 20 ft deep) were rated for their water-retaining/water-yielding properties and attenuation capacities. Because sand-and-gravel and permeable-bedrock aquifers transmit water rapidly, they are most susceptible to contamination from waste effluents. Geologic sequences containing these materials receive a high rating: A to C (fig. 10). Uniform till or other fine-grained materials are least likely to transmit contaminants from waste effluents; so sequences containing these materials receive a low rating: D (fig. 10).

Detailed descriptions and ratings of geologic sequences are presented in the final section of this report.

*Municipal wastes include solid, semi-solid, and liquid wastes (both domestic and industrial chemical refuse) but not toxic, hazardous wastes.
Figure 8 Constructing the contamination-potential maps.
**e**
Completed stack-unit map to a depth of 20 ft
- c-alluvium
- hhm-outwash sand and gravel
- Og-jointed and permeable bedrock
- pl-eolian sand
- py-colluvium
- wia-sandy till
- wia-o-burial outwash below till
- zu-paleosol

**f**
Stack-unit map outline with buried sand and gravel and bedrock between 20 to 50 ft of the surface
- Dark gray: Sand and gravel 20 to 50 ft below surface
- Light gray: Bedrock 20 to 50 ft below surface

**g**
Land burial of wastes map: sequences of geologic materials rated A1 to D for capacity to provide protection from contamination

**h**
Surface and near-surface waste disposal map: sequences of geologic materials rated A1 to D1 for capacity to provide protection from contamination

Figure 8 (continued)
USING THE MAPS

Plates 1 and 2 provide a sound basis for preliminary appraisals of earth materials and geological sequences on a regional scale: first, for selecting new waste-disposal sites, and second, for checking the suitability of existing waste-disposal sites and operations (such as large subdivisions with concentrated septic systems).

Since these two maps show the basic geology of Illinois, they can be used strictly as generalized geologic maps to a depth of 20 or 50 feet. Also, they can be used—either as bases or models—for other evaluation projects to describe and rate sequences of geologic units for sand and gravel resources, shallow aquifers, and general construction conditions.

The maps cannot be used to evaluate sites for wastes that require long periods of "containment." Identifying geologic materials largely in terms of how long it would take a contaminant to move through them (hydraulic gradient and hydraulic conductivity) is important but not sufficient information. Deciding where to bury radioactive wastes requires data from depths much greater than the 50-foot limit of these maps. Areas rated E, F, and G on plate 1, for instance, can only indicate thick, uniform till that may be suitable for such use.

Finally, these maps cannot be used as substitutes for site-specific evaluations because of local complexities in geologic materials. Other site-specific and seasonal factors that could not be included were slope variations, density of disposal sites, distance to nearby water wells, construction details of the wells, frost depth (for septic systems), and local land utilizations. All are beyond the scope of the project and/or the scale of the maps. Such factors must be determined on a site-by-site basis.

SELECTING AND INVESTIGATING SITES

Land Burial of Municipal Wastes

In general, selecting specific sites for land burial of wastes should follow procedures outlined by Cartwright and Sherman (1969) (table 2). The preparation of plate 1 included several of these steps, such as identifying the type and thickness of glacial material and type of bedrock within 50 feet of land surface.

Sites suitable for land burial of wastes, including sanitary landfills, are most likely to be found in areas rated D, E, F, and G on plate 1 (fig. 9). Topography and other physical characteristics of the proposed sites should be considered, particularly how they will effect site operations and development: for example, land burial of wastes often occurs below the top of the zone of saturation—in contact with groundwater. Even in materials with low permeability, the water table often rises into the refuse. Since low-permeability materials are not normally a source of drinking water, they would be rated as having a low contamination potential. In parts of southern and western Illinois, however, where shallow groundwater resources are

<table>
<thead>
<tr>
<th>Table 2. Criteria for evaluating sanitary landfill sites (from Cartwright and Sherman, 1969).</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Type of unconsolidated material</td>
</tr>
<tr>
<td>Favorable Glacial till; lake silts and clay; windblown silt (loess)</td>
</tr>
<tr>
<td>Unfavorable Sand and gravel</td>
</tr>
<tr>
<td>2) Thickness of unconsolidated material</td>
</tr>
<tr>
<td>Favorable 50 ft or more (30 ft, if no trenching is proposed)</td>
</tr>
<tr>
<td>Unfavorable &lt;50 ft (&lt;30 ft, if no trenching is proposed)</td>
</tr>
<tr>
<td>3) Type of bedrock</td>
</tr>
<tr>
<td>Favorable Shale</td>
</tr>
<tr>
<td>Unfavorable Sandstone; fissured limestone or dolomite</td>
</tr>
<tr>
<td>Questionable Limestone or dolomite not known to be fissured</td>
</tr>
<tr>
<td>4) Local sources and potential sources of water</td>
</tr>
<tr>
<td>Favorable Deep bedrock wells; sand and gravel wells with logs showing thick impermeable cover over aquifer; dug wells if 500 ft or more from the site</td>
</tr>
<tr>
<td>Unfavorable Shallow bedrock wells (particularly in fissured limestone); sand and gravel wells with logs showing thin cover over aquifer</td>
</tr>
<tr>
<td>5) Site topography</td>
</tr>
<tr>
<td>Favorable Flat upland areas; heads of gullies and ravines; dry strip mines</td>
</tr>
<tr>
<td>Unfavorable (Require operational engineering) Depression. Where water accumulates; lower reaches of gullies; stream floodplains; other sites near surface-water areas where leachate might discharge into the water</td>
</tr>
</tbody>
</table>

If the combinations of 1, 2, 4, and 5 or 1, 3, 4, and 5 are favorable, there is little probability that groundwater contamination will occur.
Figure 9
Ratings, vertical sequences, and descriptions of geologic materials for Plate 1: Land Burial of Municipal Wastes. The ratings are based on the capacities of materials to accept, transmit, restrict, or remove contaminants from waste effluents.
Figure 10
Ratings, vertical sequences, and descriptions of geologic materials for Plate 2: Surface and Near-Surface Waste Disposal. The ratings are based on the capacities of materials to accept, transmit, restrict, or remove contaminants from waste effluents.
scarce, relatively fine-textured materials may be the only shallow source of drinking water. Local geologic conditions, density of wells, and general groundwater availability in these areas must be considered before deciding where to place landfills.

Once a potential site has been identified, the general conditions indicated on plate 1 should be verified from water-well logs, any other surface and subsurface data for the immediate area, and at least one preliminary test hole at the site. Samples should be collected, described, and evaluated. If the site appears favorable, a detailed study should follow, including (1) test drilling and sample collection; (2) laboratory analyses for grain size, hydraulic conductivity, cation exchange, Atterburg Limits, and other pertinent data for each geologic unit encountered; (3) the geology of the site described in some detail; (4) the potentiometric surface of any aquifer present, and (5) the rates and direction of groundwater flow (both vertically and horizontally). All holes should be drilled to at least 30 feet below the planned trench bottom (about 50 feet), and at least one should be 100 feet or more deep. The number of holes drilled depends on the size of the site and the nature and distribution of the materials encountered. Obviously, when thicknesses of materials are relatively uniform and geology of the site is predictable, fewer test holes would be required.

Once the initial test drilling is completed, all samples should be described and maps constructed for specific sites. An example of the types of geologic methods used in many engineering projects, including studies of waste disposal sites, is provided in Landon and Kempton (1971).

Surface and Near-Surface Waste Disposal
Plate 2 identifies areas where septic systems or surface-spread wastes may contaminate shallow aquifers. For selecting (or avoiding) specific sites at the local level, this map can only be used as a guide—beginning the screening process. On-site studies are necessary to determine detailed information on soil characteristics, topography, and drainage.

To ensure functioning of waste-disposal facilities without exceeding the capacities of earth materials to naturally remove contaminants requires planning. Data needed for the short term include (1) the capacities of soils to remove contaminants from wastes (attenuation), and (2) the capacities of materials to accept wastes (infiltration rates). Data needed for long-term planning involve population growth, regional development, and impact on usable groundwater. Even in the most sensitive geologic environments, widely separated septic systems or the occasional usage of sludge on farm land are not likely to contaminate regional water supplies. Yet concentrated septic systems from suburban expansion, increased loads of sewage sludge from urban and industrial growth, or buildup of fertilizers and other chemicals from soil and crop maintenance can cause problems. Clearly, selecting and investigating sites should involve the long-range development of an area.

Attenuation capacities of soils are most important at the surface where sources of contamination include sludge, agricultural fertilizers and chemicals, and accidental chemical spills. Under these conditions, the entire surface soil functions to attenuate or remove contaminants. Other methods of waste disposal or land treatment place the source of potential contaminants just below the surface, often in the lower part of the solum. For example, with septic-tank systems, the top of a tank is buried about 3 feet deep with a shallow overflow filter or seepage field. At this depth attenuation by the surface soil is limited because only the base of the soil functions to eliminate contaminants.

Below the surface soil, the character of geologic materials governs the attenuation of contaminants. Materials with high hydraulic conductivity, such as sand and gravel or permeable bedrock, readily accept wastes but can contribute to groundwater contamination by providing little attenuation. By contrast, materials with low hydraulic conductivity, such as silt or clayey till, shale, or dense unfractured limestone, restrict the movement of contaminants and provide greater attenuation; however, they may not accept wastes or allow infiltration of excess water, which may lead to operation problems or possibly surface-water contamination from septic systems or surface-spread wastes.

Plate 2 identifies areas, not specific sites, where concentrated septic systems or long-term multiple applications or overapplication of sewage sludge might lead to contamination of shallow aquifers. The most sensitive areas are rated A1, A2, and A3; in these geologic sequences, septic effluents or water draining from sludge may move rapidly downward to sand and gravel or fractured bedrock (fig. 10).

Suitable sites with minimum contamination potential are likely to be found in areas rated D1, D2, and D3, containing uniform till or impermeable bedrock within the upper 20 feet.

Once an area has been identified as having a low potential for contamination, then individual sites can be investigated. Infiltration rates, soil characteristics, surface and subsurface drainage, and topography must all be suitable for surface or shallow waste disposal. Procedures for checking sites are the same as those for checking land-burial sites (listed in the preceding section). Also, detailed U.S. Department of Agriculture (Soil Conservation Service) soil survey maps, which are now available for many counties, provide much of this information. The County Soil and Water Conservation District or University of Illinois Extension Service can aid in evaluating specific sites.

**SUMMARY OF GEOLOGIC SEQUENCES**

**Land Burial of Municipal Wastes**
Plate 1 identifies 18 sets of geologic sequences—each rated for the susceptibility of its water-yielding materials (aquifers) to contamination from land burial of municipal wastes. Ratings were made by comparing the capacities of earth materials to accept, transmit, restrict, or remove
contaminants from waste effluents passing through vertical geologic sequences. The vertical sequences, not specific materials, were compared and rated. Figure 11, which also appears on plate 1, summarizes the limitations of geologic materials.

Not only were actual sand-and-gravel and bedrock aquifers mapped, but also sand-and-gravel and bedrock units that are potential aquifers. This broad-based mapping was necessary because different areas of the state use different types of materials for their drinking supplies. For example, shallow sand and gravel would not generally be a source of drinking water in northern Illinois, but it may be used as an aquifer in south-central Illinois. Also in southern Illinois, uniform tills as well as shale sometimes supply local water. No distinction was made as to whether or not a region actually uses a particular geologic unit for potable water.

A — the most susceptible sequences, mainly sand and gravel or permeable bedrock directly below land surface; primarily located in north-central, northwestern, and extreme southern Illinois; also adjacent to the Mississippi River in western Illinois.

B — sequences including sand and gravel within 20 feet of the surface. Naturally protective materials with low hydraulic conductivity often overlie and always underlie the sand and gravel. This situation occurs extensively in south-central Illinois, centering around Montgomery County, and to a lesser extent in northeastern Illinois.

C — sequences with permeable bedrock or sand and gravel between 20 and 50 feet of land surface. Because land-burial trenches are usually 20 feet deep, aquifers within 30 feet of the base of the trench may be contaminated by landfill leachate. Overlying materials with low hydraulic conductivity provide some natural protection to the potential water supply. Although these sequences occur throughout the state, they are concentrated mainly in the western, south-central, and southern parts of the state.

D to G — geologic sequences with the lowest potential for contaminating aquifers; these contain either uniform till or other fine-grained materials at least 50 feet thick, or uniform till less than 50 feet thick but underlain by shale or limestone of low permeability. No identifiable sand and gravel zones were recognized in the till. Areas rated E and D are slightly more susceptible because aquifers may be present in the drift or bedrock below a depth of 50 feet. Areas rated F and G are considered less susceptible because till, shale, or dense limestone underlie potential sites for burial of wastes. Every county in Illinois contains geologic sequences like these, with low contamination potential, but the greatest areal coverage is in northeastern and central Illinois.

Surface and Near-Surface Waste Disposal
Plate 2 identifies 13 sets of geological sequences—each rated for the susceptibility of aquifers to contamination from surface and near-surface wastes. Ratings were made by comparing the capacities of earth materials to accept, transmit, restrict, or remove contaminants from waste effluents passing through vertical geologic sequences within 20 feet of land surface. The vertical geologic sequences, not specific materials, were compared and rated.

Plate 2 also assesses geologic sequences for potential problems with the operation of shallow waste-disposal systems: for example, materials that accept wastes also allow contaminants to move rapidly through geologic sequences. While septic systems appear to be functioning well, waste effluents may be entering shallow water supplies. Thus the contamination potential of these sequences is high. In materials that do not readily accept wastes, septic systems may fail or leachate springs break out; yet the overall potential for contaminating aquifers is low.

Concentrations of septic units or frequent applications of agricultural chemicals or sludge may overload the capacities of materials to remove contaminants. Topography and soil characteristics may add to the problems. Figure 12, which also appears on plate 2, summarizes the limitations of geologic sequences.

The geologic conditions shown on plate 2 are generally not as severe as those identified on plate 1, largely because soil attenuates contaminants from surface wastes.

A — the most susceptible sequences; sand and gravel or permeable bedrock within 5 feet of the surface; also all alluvial materials. Principal areas are north-central, northwestern, and extreme southern Illinois; also adjacent to the Mississippi River in western Illinois.

B — permeable bedrock generally between 5 and 20 feet of land surface; principally found in north-central, northwestern, western, and southern Illinois.

C — shallow sands and gravels within 20 feet of land surface. Although overlying and underlying materials generally restrict contaminants, a high potential for surface breakouts (springs) of leachate exists. These sequences are primarily located in south-central and northeastern Illinois.

D — least susceptible sequences, with a minimum of 20 feet of uniform till or other fine-grained materials at the surface. They primarily occur in northeastern and central Illinois.
### Figure 11
Summary: geologic limitations for land burial of municipal wastes. (*Map units in parentheses indicate secondary or local limitations.)*

<table>
<thead>
<tr>
<th>Primarily bedrock</th>
<th>Primarily glacial drift</th>
<th>Materials generally having few limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limitation</strong></td>
<td><strong>Limitation</strong></td>
<td><strong>Groundwater contamination potential</strong></td>
</tr>
<tr>
<td>Groundwater</td>
<td>Trench construction</td>
<td>Trench design problems and/or</td>
</tr>
<tr>
<td>contamination</td>
<td>problems and/or</td>
<td>surface contamination</td>
</tr>
<tr>
<td>potential</td>
<td>surface contamination</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>(A1)*</td>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td></td>
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<tr>
<td>A5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td></td>
<td>C2</td>
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<td>C3</td>
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<td>C4</td>
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<tr>
<td>C5</td>
<td></td>
<td></td>
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<tr>
<td>F</td>
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</tbody>
</table>

### Figure 12
Summary: geologic limitations for surface and near-surface waste disposal. (*Map units in parentheses indicate secondary or local limitations.)*

<table>
<thead>
<tr>
<th>Primarily bedrock</th>
<th>Primarily drift</th>
<th>Materials generally having few limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limitation</strong></td>
<td><strong>Limitation</strong></td>
<td><strong>Groundwater contamination potential</strong></td>
</tr>
<tr>
<td>Groundwater</td>
<td>Surface</td>
<td>Trench design problems and/or</td>
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<tr>
<td>contamination</td>
<td>contamination</td>
<td>surface contamination</td>
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<tr>
<td>potential</td>
<td>(acceptance) or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>construction</td>
<td></td>
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<tr>
<td>A1</td>
<td>(A1)*</td>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
<td></td>
<td>(A3)</td>
</tr>
<tr>
<td>A4</td>
<td></td>
<td>AX</td>
</tr>
<tr>
<td>B1</td>
<td></td>
<td>(B1)</td>
</tr>
<tr>
<td>B2</td>
<td></td>
<td>(B2)</td>
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<td>B3</td>
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<tr>
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<td></td>
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<tr>
<td>C3</td>
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<tr>
<td>C4</td>
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<td>C5</td>
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</table>

POTENTIAL FOR CONTAMINATION OF SHALLOW AQUIFERS IN ILLINOIS
DESCRIPTIONS AND RATINGS OF GEOLOGIC SEQUENCES
Plate 1: Potential for Contamination of Shallow Aquifers by Land Burial of Municipal Wastes

Sequences, Ratings, and Descriptions

A
— modern river deposits, thick glacial sand and gravel or permeable bedrock at or within 20 feet of the surface.

Geologic limitations. The potential for contaminating shallow aquifers is high. These materials are only suitable for land burial of noncontaminating wastes.

ft
20
50

A1
— permeable sandstone, dolomite, or limestone lying at or within 20 feet of land surface throughout these areas. Bedrock is primarily Ordovician, Silurian, and Mississippian; Pennsylvanian bedrock is described elsewhere.

Significant groundwater supplies may be obtained from these materials. Porous sandstone and fracture and joint systems in limestone and dolomite allow water and contaminants to move rapidly into shallow wells finished in these materials. Up to 20 feet of till, loess, or lacustrine materials may overlie the bedrock, but provide little protection from leachates of wastes buried in trenches, which are commonly 20 feet deep. Hydraulic conductivity in sandstone and fractured rock is usually more than $1 \times 10^{-4}$ cm/sec.

This map sequence occurs mostly in the driftless and thin-drift areas of northern and southern Illinois as well as on the slopes adjacent to the Mississippi and lower Illinois Rivers.

Geologic limitations. The potential for contaminating shallow aquifers is high. Land burial should be restricted to noncontaminating wastes.

Principal counties. Alexander, Carroll, Greene, Hardin, Jersey, Jo Daviess, Johnson, Kankakee, Monroe, Ogle, Pike, Pope, Scott, Stephenson, Union, Whiteside, and Winnebago.

A2
— permeable sand and gravel lying at or near land surface, usually more than 50 feet thick. Deposits are primarily of Wisconsinan age (Henry Formation). These deposits are found along most major rivers; those overlain by modern alluvium have been mapped as AX. Other deposits include thick Illinoian sand and gravel (Pearl Formation), the Mounds Gravel of Tertiary age, and sand and gravel of Cretaceous age (figs. 1 and 2).

Geologic limitations. The potential for contaminating wells finished in these materials is high. Also, contaminants may be discharged directly into nearby streams. Because hydraulic conductivity averages $1 \times 10^{-3}$ cm/sec, contaminants migrate rapidly.


A3
— permeable (fractured) Mississippian limestone or dolomite generally within 20 feet of the surface; sand and gravel occurs between 20 and 50 feet, wherever the bedrock is deeper than 20 feet.

Geologic limitations. The potential for contaminating shallow aquifers is high. In this geologic sequence, aquifers are slightly less susceptible to contamination than aquifers in sequences rated A1 and A2 because thick till or loess overlies bedrock in some parts of the A3 areas.

Principal counties. Adams and Rock Island.
Sequences, Ratings, and Descriptions

**A4**
- Pennsylvanian sandstone within 20 feet of the surface; often cemented and less permeable than limestone, dolomite, and sandstone in A1 sequences; may be overlain by relatively impermeable, fine grained materials.

*Geologic limitations.* The potential for contaminating shallow aquifers is high. In some areas the sandstone is the source of local water supplies; hydraulic conductivity ranges from $1 \times 10^{-7}$ to $1 \times 10^{-4}$ cm/sec.

*Principal counties.* Clark, Clay, Crawford, Edwards, Effingham, Franklin, Gallatin, Jasper, Jefferson, Johnson, Marion, Perry, Pope, Richland, Wabash, Wayne, and Williamson.

**A5**
- permeable bedrock of Ordovician, Silurian, or Mississippian age within 20 feet of the surface in about one-half of each sequence. In the other half, bedrock lies between 20 and 50 feet deep. Overlying materials are loess and/or till. No sand and gravel was identified within the glacial materials.

*Geologic limitations.* The potential for contaminating aquifers is high. This rating is the lowest of the A ratings because thick loess or till may provide some protection to groundwater supplies by restricting the movement of contaminants.

*Principal counties.* Hancock, Henderson, Kankakee, Monroe, Whiteside, and Winnebago.

**AX**
- modern river alluvium consisting of unconsolidated, variably textured materials ranging from clay to gravel (Cahokia Alluvium). These areas also include narrow terraces of sand and gravel (Henry Formation) as well as small deposits of peat (Grayslake Peat) and lacustrine silt and clay (Carmi Member, Equality Formation).

*Geologic limitations.* The potential for contaminating both surface water and groundwater is high. During seasonal flooding due to proximity to waterways, these materials are highly unsuitable for land burial of wastes.

*Principal areas.* Modern alluvium occurs along major rivers and streams throughout the state. The most extensive deposits occur along the Mississippi, Illinois, and lower Rock Rivers; significant deposits also occur along the Ohio, Wabash, Sangamon, and Kaskaskia Rivers. Counties with dense networks of small streams bordered by alluvium include Jo Daviess, Ogle, Stephenson, and Winnebago.

**B**
- steep slopes on sandstone or sand and gravel lying within 20 feet of the surface.

*Geologic limitations.* The potential for contaminating aquifers is high and severely limits land burial of waste products. In general, these areas are suitable only for non-contaminating wastes.

**B1**
- sand and gravel at the surface, less than 20 feet thick; underlain by till or impermeable bedrock. Although the sand and gravel is used for local well points, these deposits generally do not yield large quantities of water.

This geologic sequence occurs mostly on the Wisconsinan till plain or along its margin in northeastern Illinois (Batavia and Wasco Member, Henry Formation, or Dolton Member, Equality Formation). Sequences rated B1 can also be found on the Illinoisan till surface (Pearl Formation, Hagarstown Member) (fig. 2).

*Geologic limitations.* The potential for contamination of surface water and groundwater is high. High hydraulic conductivity of about $1 \times 10^{-3}$ cm/sec makes these materials an excellent medium for transport of contaminants. Because water may flow along contacts between materials with different textures (such as sand and gravel over
dense bedrock) and discharge on slopes, there is also a potential for surface-water contamination.

**Principal counties.** Champaign, Cook, Edgar, Iroquois, Kane, Kankakee, McHenry, and Vermilion.

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sand and gravel within 20 feet of the surface, overlain by relatively impermeable till or other fine grained material. Till or dense bedrock always underlie water-bearing materials.

Thin 2- to 5-foot, continuous, shallow deposits of this sand and gravel are used for residential wells through much of south-central Illinois. In northern Illinois, where deeper aquifers are plentiful, these deposits are generally not used; but the potential for use remains.

**Geologic limitations.** The potential for groundwater contamination is high because wastes in 20-foot trenches will be in contact with water-bearing sand and gravel. Also, the potential for surface-water contamination is high because water may flow along contacts between materials with different textures (such as sand and gravel over dense bedrock), then discharge on slopes.

**Principal counties.** Bond, Bureau, Christian, Clinton, De Kalb, Effingham, Fayette, Grundy, Kane, Kendall, Logan, Macon, Macoupin, Madison, Marion, McHenry, Montgomery, Sangamon, and Shelby.

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thick loess underlain by sandstone or fractured limestone on ridge tops and slopes, and underlain by shale on lower slopes and valley bottoms. This geologic condition is restricted to areas of steeply sloping topography where differentiation of complex materials was difficult to map.

**Geologic limitations.** The potential for contamination of surface water is high because groundwater may flow along the contact between the sandstone and the shale.

**Principal counties.** Calhoun and Jackson.

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permeable bedrock or sand and gravel between 20 and 50 feet of the surface; overlain by uniform till or other fine grained materials.

**Geologic limitations.** The potential for contamination remains high, although it is lower than in the sequences rated A and B because less than 30 feet of protective materials overlie the water-bearing materials. These areas should be restricted to non-contaminating wastes. Other wastes may be buried under controlled conditions, such as the collection or treatment of leachate in engineered sites.

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permeable bedrock of Ordovician, Silurian, and Mississippian age between 20 and 50 feet deep. This sequence of geologic materials is similar to A1; but more than 20 feet of till or other fine grained material overlies the bedrock.

**Geologic limitations.** The contamination potential is the highest of all C ratings, although till or fine grained materials may give considerable protection to underlying water supplies.

**Principal counties.** Cook, Henderson, Jersey, Kankakee, Pike, Warren, Whiteside, and Will.

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continuous sand and gravel unit (often thin) between 20 and 50 feet deep; always overlain by relatively impermeable till or other fine grained material and underlain by till or dense bedrock. The C2 sequence is similar to the B2, except that the overlying fine grained materials are more than 20 feet thick. This sand and gravel is used as a residential aquifer more frequently than shallower sands and gravels.
Geologic limitations. The potential for contamination is high, although thick overlying deposits protect aquifers. The C2 rating is lower than the C1 rating because sand and gravel, which is less permeable than fractured bedrock, filters some contaminants.


— permeable bedrock of Ordovician, Silurian, and Mississippian age between 20 and 50 feet deep in one-half the area and more than 50 feet deep in the other half. The bedrock is overlain by till or other fine-grained materials. No sand and gravel was detected within the glacial materials. This geologic sequence is similar to A5, except that the overlying materials are much thicker in C3 than in A5.

Geologic limitations. The contamination potential is high; however, the thick overburden often provides more protection than is found in areas rated C1 and C2.

Principal counties. Carroll, Cook, Greene, Jersey, Lee, Randolph, Stephenson, and Whiteside.

C4

— cemented Pennsylvanian sandstone between 20 and 50 feet deep; overlain by relatively impermeable till or other fine-grained materials. This sequence is similar to A4, which is overlain by less than 20 feet of materials.

Geologic limitations. The potential for contaminating shallow aquifers is considerably lower than it is in sequences containing fractured limestone, dolomite, and permeable sandstone (C1 and C3). A minimum of 20 feet of low-permeability overburden also reduces the contamination potential.

Principal counties. Crawford, Jefferson, Marion, Perry, Washington, Wayne, and Williamson.

C5

— locally occurring sand and gravel within 50 feet of the surface, overlain principally by loess and till. This rating also applies to lacustrine materials more than 20 feet thick because of the possibility that they contain sand and gravel. Specific data are lacking for C5 areas that contain lacustrine materials.

Geologic limitations. The potential for contamination is difficult to predict. Site investigations are essential before considering these areas for landfill burial of wastes.


D

— uniform, relatively impermeable sandy till or other fine-grained material greater than 50 feet thick; no identifiable sand and gravel.

Geologic limitations. In general, the potential for contamination is low—because of the thick till and the absence of water-bearing sand and gravel. Also, this material provides fairly good attenuation of contaminants and is suitable for most wastes. The principal limitation, which makes areas rated D less suitable than areas rated E (silty or clayey till), is relatively high hydraulic conductivity, which ranges from $1 \times 10^{-7}$ to $1 \times 10^{-5}$ cm/sec. The hydraulic conductivity of these sandy tills is often above the maximum allowable standard for certain toxic substances occasionally found in municipal landfills.

DESCRIPTIONS AND RATINGS OF GEOLOGIC SEQUENCES
Plate 1—continued

Sequences, Ratings, and Descriptions

<table>
<thead>
<tr>
<th>ft</th>
<th>E</th>
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</table>
| 20 | uniform, relatively impermeable silty or clayey till or other fine-grained materials more than 50 feet thick; no sand and gravel identified. This is the most widespread geologic condition mapped in Illinois.  

   Geologic limitations. The potential for contamination is low because of low hydraulic conductivity, 1 x 10^-9 to 1 x 10^-7 cm/sec, and good attenuation capacities. Areas rated E are generally suitable for most wastes. There is one limitation that makes areas rated E less suitable than areas rated F and G (shale or dense Pennsylvanian limestone): an aquifer may occur below a depth of 50 feet.  

   Note. Several counties in north and northeastern Illinois have continuous, fine-grained till at least 200 feet thick. Very low hydraulic conductivities, moderate-to-high exchange capacities (attenuation), and fair-to-good drainage allow burial of municipal wastes with little or no possibility for aquifer contamination.  

| 50 |

<table>
<thead>
<tr>
<th>ft</th>
<th>F</th>
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</table>
| 20 | shale or relatively impermeable limestone within 20 feet of the surface; possibly overlain by till or other fine-grained materials.  

   Geologic limitations. The potential for contamination is low because (1) there is only a slight chance that a major aquifer will occur near the surface, and (2) these bedrock materials provide the highest order of natural protection. With hydraulic conductivity ranging between 1 x 10^-11 to 1 x 10^-7 cm/sec for shale and 1 x 10^-11 to 1 x 10^-8 cm/sec for dense unfractured limestone, migration of contaminants is minimal.  

   Many areas rated F are located in sloping topography, which is unsuitable for land burial sites. Also, excavation of trenches may be difficult in some parts of F areas because bedrock is so close to the surface.  

| 50 |

<table>
<thead>
<tr>
<th>ft</th>
<th>G</th>
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</table>
| 20 | shale or relatively impermeable limestone between 20 and 50 feet deep; overlain by till or other fine-grained materials; no identifiable sand and gravel.  

   Geologic limitations. The potential for contamination is very low in areas rated G. Unconsolidated deposits at least 20 feet thick overlie the bedrock. Also, more clay is contained in the unconsolidated deposits than in the shale or limestone: increasing the clay content increases the attenuation capacity of these sequences. Finally, engineering and constructing land burial trenches is easier in areas with thick, unconsolidated deposits than in areas (rated F) with thin, unconsolidated deposits overlying bedrock.  

   Principal counties. Maquoketa Shale of Ordovician age (fig. 1) underlies areas rated G in Boone, Carroll, De Kalb, Kane, McHenry, Ogle, Stephenson, and Whiteside Counties. Pennsylvanian shale and dense limestone underlie areas rated G in Bond, Clinton, Effingham, Greene, Grundy, Henry, Jersey, Kankakee, Macoupin, Madison, Marion, McDonough, Menard, Sangamon, St. Clair, and Warren Counties. |
| 50 |
DESCRIPTIONS AND RATINGS OF GEOLOGIC SEQUENCES
Plate 2: Potential for Contamination of Shallow Aquifers by Surface and Near-Surface Waste Disposal

Sequences, Ratings, and Descriptions

A
- modern river deposits, thick glacial sand and gravel or permeable bedrock at or within 20 feet of the surface.
  
  Geologic limitations. The potential for contamination is high.

A1
- jointed limestone or dolomite, or porous sandstone, of Ordovician, Silurian, and Mississippian age (fig. 1), within 5 feet of the surface. Bedrock residuum or a thin loess often overlies the bedrock.
  
  Geologic limitations. The potential for contamination is high. Concentration of septic systems or frequent applications of agricultural chemicals or sewage sludge are likely to contaminate groundwater supplies.
  
  Because of high hydraulic conductivity, these materials readily accept wastes and allow contaminants to move rapidly into these aquifers. Also, bedrock lying within 5 feet of the surface often makes it difficult to install septic systems.
  
  Principal counties. Alexander, Calhoun, Cook, Du Page, Gallatin, Greene, Hardin, Jackson, Jersey, Johnson, Kane, Kankakee, Kendall, Madison, Massac, Ogle, Pike, Pope, Pulaski, Randolph, Saline, Stephenson, Union, Will, and Winnebago.

A2
- thick deposits of permeable sand and gravel at land surface; overlain by less than 5 feet of loess or silty lacustrine materials. Deposits are primarily the Wisconsinan Henry Formation, but they also include thick Illinoian sand and gravel of the Pearl Formation; the Mounds Gravel of Tertiary age; and Cretaceous sand (figs. 1 and 2).
  
  Geologic limitations. The potential for contaminating shallow aquifers is high. Septic systems and other surface wastes may be in direct contact with highly permeable materials. Because hydraulic conductivity averages $1 \times 10^{-3}$ cm/sec, contaminants migrate rapidly.
  

A3
- thick, permeable sand and gravel overlain by 5 to 20 feet of loess or silty lacustrine materials.
  
  Geologic limitations. The potential for contaminating shallow aquifers is high. This sequence is rated slightly lower than A1 and A2 because silty surficial materials provide some protection to underlying water-bearing materials: hydraulic conductivities of $1 \times 10^{-6}$ to $1 \times 10^{-4}$ cm/sec retard the movement of contaminants into sand and gravel. Also, silt provides some attenuation.
  

AX
- modern river alluvium consisting of unconsolidated, variably textured materials ranging from clay to gravel (Cahokia Alluvium). These areas also include narrow terraces of sand and gravel (Henry Formation) as well as small deposits of peat (Grayslake Peat) and lacustrine silt and clay (Carlin Member, Equality Formation).
  
  Geologic limitations. The potential for contaminating both surface- and groundwater is high. With seasonal flooding and erosion due to proximity to waterways, these materials are highly unsuitable for surface and near-surface waste-disposal facilities.
  
  Principal counties. Modern alluvium occurs along major rivers and streams throughout the state. The most extensive deposits occur along the Mississippi, Illinois, and lower Rock Rivers; significant deposits also occur along the Ohio, Wabash, Sangamon, and Kaskaskia Rivers. Counties with dense networks of small streams bordered by alluvium include Jo Daviess, Ogle, Stephenson, and Winnebago.
DESCRIPTIONS AND RATINGS OF GEOLOGIC SEQUENCES
Plate 2—continued

Sequences, Ratings, and Descriptions

B — permeable bedrock between 5 and 20 feet deep; overlain by till or other fine-grained materials.

Geologic limitations. The potential for contaminating shallow aquifers is high.

B1 — jointed dolomites 5 to 20 feet deep (usually within 10 feet of the surface); overlain by sandy till, which may contain a relatively impermeable weathered zone (paleosol). A residuum and thin loess deposits are commonly found on the bedrock surface.

Geologic limitations. The potential for contamination is high. Sandy till (hydraulic conductivity $1 \times 10^{-7}$ to $1 \times 10^{-5}$ cm/sec), a paleosol, and bedrock residuum provide more protection to underlying water-yielding materials than silt (A3 sequences) provides.

Counties. Ogle, Stephenson, and Winnebago.

B2 — jointed bedrock 5 to 20 feet deep; overlain by loess and/or clayey or silty till, which may contain a relatively impermeable weathered zone (paleosol).

Geologic limitations. The contamination potential is high; however, B2 sequences are rated lower than B1 for two reasons. First, underlying aquifers are protected better by silty or clayey till, with hydraulic conductivities ranging from $1 \times 10^{-9}$ to $1 \times 10^{-7}$ cm/sec, than by sandy till. Second, although silt has a lower attenuation capacity than sandy till, in the B2 sequences the loess (silt) is so thick—at least 15 feet thick—that attenuation may mitigate the effects of leachates.

Principal counties. Carroll, Greene, Jersey, Jo Daviess, Johnson, Monroe, Ogle, Pike, Pope, Scott, Stephenson, Union, and Whiteside.

B3 — cemented Pennsylvanian sandstone within 20 feet of the surface; overlain by relatively impermeable till or other fine-grained materials.

Geologic limitations. The potential for contaminating shallow aquifers is relatively high. Hydraulic conductivity ranges from $1 \times 10^{-7}$ to $1 \times 10^{-4}$ cm/sec. This sequence is rated slightly lower than B1 through B2 because of the cementation and low permeability of the sandstone.


B4 — permeable bedrock of Ordovician, Silurian, and Mississippian age, lying within 20 feet of the surface in about one-half of each sequence, and more than 20 feet deep in the other half. Uniform till or loess overlies the bedrock.

Geologic limitations. The potential for contamination is lower than in sequences rated A and B1 through B3. Thick loess or till restricts the movement of contaminants; no bedrock is exposed at the surface.

Principal counties. Adams, Hancock, Henderson, Kankakee, Monroe, Rock Island, Whiteside, and Winnebago.

C — thin sand and gravel within 20 feet of the surface.

Geologic limitations. The potential for contaminating both surface water and groundwater is moderate.

C1 — sand and gravel at the surface, less than 20 feet thick; underlain by till or impermeable bedrock. Although the sand and gravel is used for some local well points, these deposits generally do not contain large quantities of water.

This geologic sequence occurs mostly on the Wisconsinan till plain or along its
DESCRIPTIONS AND RATINGS OF GEOLOGIC SEQUENCES
Plate 2—continued

Sequences, Ratings, and Descriptions

margin in northeastern Illinois (Batavia and Wasco Members, Henry Formation, or Dolton Member, Equality Formation). Sequences rated C1 can also be found on the Illinoian till surface (Pearl Formation, Hagarstown Member) (fig. 2).

Geologic limitations. The potential for contamination of surface water and groundwater is high; however, high hydraulic conductivity of about $1 \times 10^{-3}$ cm/sec makes these materials an excellent medium for transport of contaminants. Because water may flow along contacts between materials with different textures (such as sand and gravel over dense bedrock) and discharge on slopes, the potential for contaminating surface water is particularly high.

Principal counties. Champaign, Cook, Edgar, Iroquois, Kane, Kankakee, Macon, McHenry, and Vermilion.

C2

--- sand and gravel within 20 feet of the surface; overlain by till or other fine-grained materials; underlain by till or dense bedrock.

Geologic limitations. The potential for contaminating shallow aquifers is moderate. Sand and gravel generally occurs between 10 and 20 feet deep, so at least 10 feet of overlying till or other fine-grained material provides some natural protection.

Principal counties. Bond, Bureau, Christian, Clinton, De Kalb, Effingham, Fayette, Grundy, Kane, Kendall, Logan, Macon, Macoupin, Madison, Marion, McHenry, Montgomery, Sangamon, and Shelby.

D

--- uniform till or other fine-grained materials more than 20 feet thick; no identified sand and gravel.

Geologic limitations. The potential for contaminating shallow aquifers is low, but there may be acceptance problems.

D1

--- uniform, relatively impermeable sandy till extending from the surface to more than 20 feet deep; no interbedded sand and gravel.

Geologic limitations. The potential for contamination is low. Fairly good attenuation of contaminants makes these areas generally suitable for surface and near-surface disposal of wastes.

Acceptance of wastes is mainly limited by high water tables, which interfere with proper functioning of disposal systems where effluents may actually move upward to land surface. Another limitation is the steeply sloping topography of many D1 areas. In these locations, water flowing along contacts between materials with different textures (such as sand and gravel over dense bedrock) may break out as leachate springs. Finally, perched water tables are common where relatively impermeable weathered zones (paleosols) slow percolation.


D2

--- uniform, relatively impermeable silty or clayey till or other fine-grained materials extending from the surface to more than 20 feet deep; no interbedded sand and gravel. These are the most common, widespread materials in the state.

Geologic limitations. The potential for contamination is low. Septic systems should not contaminate groundwater provided they are installed properly. At some sites, low hydraulic conductivity may cause acceptance problems: wastes may remain at or near the surface for a long time, especially during heavy precipitation. Conditions are worse in areas with soil drainage problems.

Perhaps the best sites for surface and near-surface waste disposal are located in D1 and D2 areas with ablation till overlying basal till. Ablation till, which is loosely
Sequences, Ratings, and Descriptions

Sequences, Ratings, and Descriptions

compacted, poorly sorted, and often sandy and porous, allows effluents to drain. By contrast, the underlying basal till is compact, dense, and commonly fine grained, thus it protects underlying aquifers.

Seventy percent of Illinois is rated D2 for surface and near-surface waste disposal.

— relatively impermeable shale or limestone within 20 feet of the surface; overlain by till or other fine-grained materials. D3 is identical to sequences rated F on plate 1.

Geologic limitations. The potential for contaminating shallow aquifers is very low because of the low hydraulic conductivity of till and other fine-grained materials combined with the even lower hydraulic conductivity of shale and dense limestone. However, acceptance problems may be more common than in D1 and D2 areas. Also, installing septic systems will be more difficult where bedrock is within a few feet of the surface.

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