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ENGINEERING GEOLOGY OF ST. LOUIS COUNTY, MISSOURI

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ABSTRACT

Geologic factors that influence land use in St. Louis County are defined and evaluated to assist in urban development. Physical properties of bedrock and unconsolidated materials as well as topographic features are defined as map units which represent specific engineering geology criteria. An accompanying engineering geologic map emphasizes distribution of rock formations and soils having similar engineering properties.

The extent that the geologic environment might influence or control land use is noted by a three-level rating system. A classification of slight, moderate, or severe denotes the severity of potential land-use or engineering problems caused by geologic features. Each map unit is evaluated with respect to waste disposal, water pollution, slope stability, excavation properties, bearing capacity, conservation of mineral resources, and special problems.

The most significant problems are associated with thick loess deposits covering a sequence of shales, sandstones, and limestones. Additional problems of more limited extent are noted where limestones with sinkholes and caves are covered with loess deposits.

This report, which is regional in concept, is designed to be useful in long-range planning; detailed information and precise boundary conditions are not given.

INTRODUCTION

This report and the accompanying engineering geologic map describe the engineering geology of St. Louis County, Missouri, for use in determining the most efficient, economical, and environmentally-sound program for land development and urban growth. The map and text are designed primarily for use by property owners, engineers, architects, real estate developers, and land-use planners. The geologic information and engineering interpretation must be considered as general guides and not as substitutes for a complete, on-site investigation prior to initiation of any land-use project. The map scale, 1:63,360 (1 inch to a mile), is too small to include the detailed information normally provided on 7½-minute quadrangle maps (1:24,000). This smaller scale is most useful at regional planning levels. It was, therefore, chosen as the method for presenting information on the more significant engineering geologic factors of St. Louis County as a basis for county-wide planning and development.

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Conventional geologic and pedologic (soil) maps, although essential for fundamental scientific investigation, do not provide the specific information required for most engineering purposes. A geologic map shows the distribution of bedrock formations, and a pedologic map presents information on the soil or natural medium of plant growth. An engineering geologic map, however, is derived from both of these basic maps, but emphasizes the engineering properties of the rock formations and soils. Some of the unit boundaries shown on the engineering geologic map closely follow geologic formation and/or pedologic boundaries; others transgress these boundaries. Bedrock and soil that have similar engineering characteristics are mapped as one unit without regard to their geologic or pedologic classifications. This assures that only the physical properties of the material affecting construction are adequately interpreted for use in engineering practice.

The term "soil" is used to denote all material above bedrock. The different soil types are subdivided (according to mode of origin) into five basic classifications with similar engineering characteristics:

1. **Alluvial soils:** Materials transported and deposited by streams; all sediments within floodplains and terraces are included in this category.

2. **Colluvial soils:** Materials deposited near the base of hillslopes or bluffs; accumulated by slow mass movement downslope.

3. **Residual soils:** Materials formed or left in place by the decomposition or disintegration of the parent rock.

4. **Eolian soils (loess):** Clay- and silt-sized materials transported by wind; these soils cover most of the bedrock and residual soils within the county.

5. **Glacial soils:** Heterogeneous mixture of clay- to boulder-size material deposited by glaciers. A few patches of soil have been tentatively classified as glacial material within St. Louis County (Goodfield, 1965).

ACKNOWLEDGMENTS

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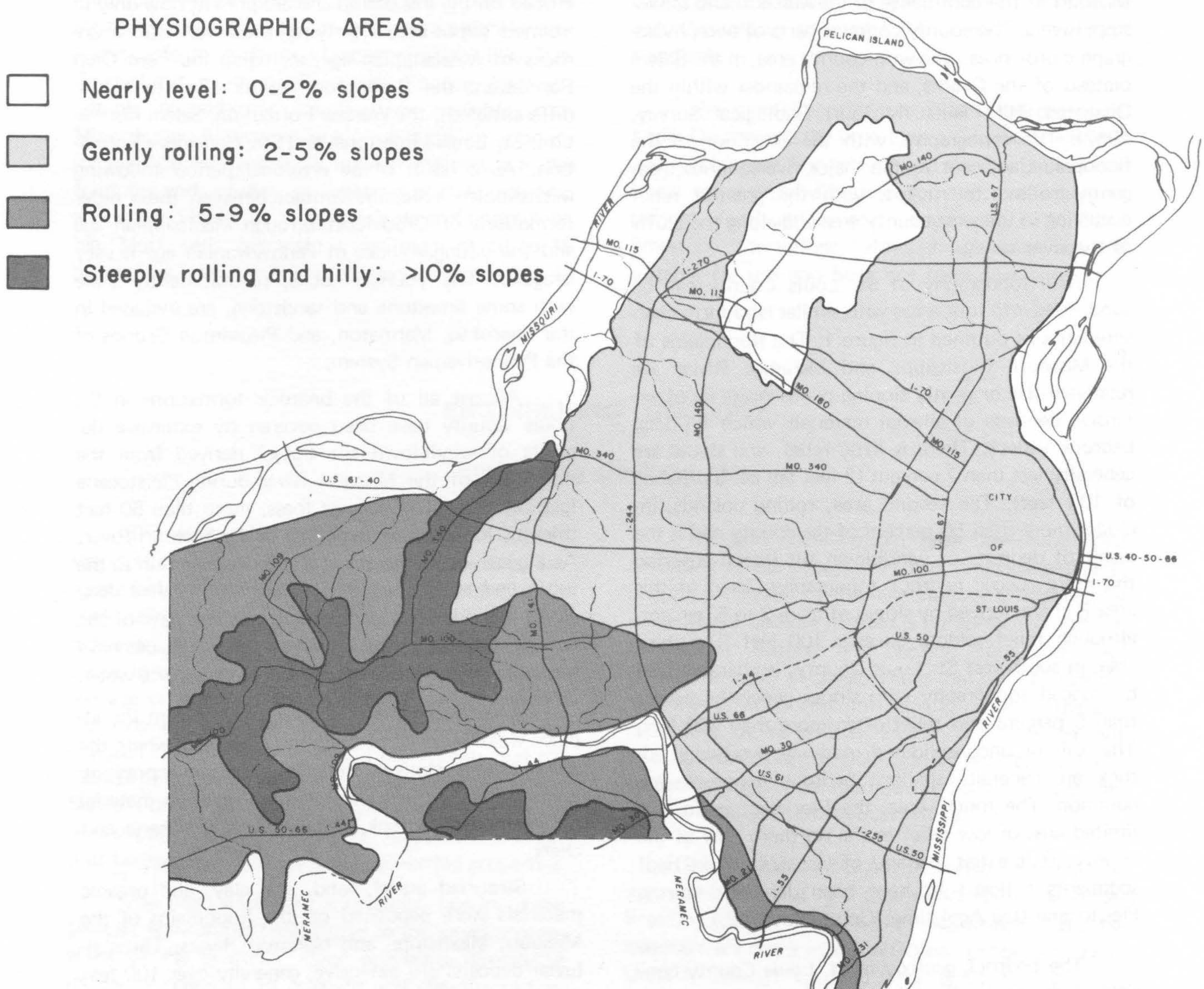


Figure 1. Physiographic map of St. Louis County, Missouri. Data from U. S. Geological Survey topographic maps.

GEOLOGIC SETTING

St. Louis County is on the eastern border of Missouri at the confluence of the Missouri and Mississippi Rivers. The county contains parts of two physiographic provinces: the west-county area, in the Salem plateau of the Ozarks, and the remainder within the Dissected Till Plains (Missouri Geological Survey, 1967). The topography, with the exception of the floodplains adjacent to the major rivers, varies from gently rolling to rugged, with the greatest relief occurring in the west-county area and along the bluffs of the river valleys.

The topography of St. Louis County can be subdivided into four areas with similar land form characteristics as outlined in figure 1. The floodplains of the Missouri, Mississippi, and Meramec Rivers are relatively flat or gently sloping plains made up of extensive deposits of alluvial materials which fill deep bedrock valleys. There is little relief, and slopes are generally less than 2 percent (2 feet fall per a distance of 100 feet). The second area, rolling uplands, includes more than 50 percent of the county and is the result of deposits of windblown silt (loess) covering the more rugged bedrock topography. Most of this area is characterized by slopes of from 2 to 5 percent, although relief seldom exceeds 100 feet. The third area, in southwest St. Louis County, is characterized by rugged topography with slopes generally greater than 5 percent and relief often more than 200 feet. The soils or unconsolidated materials overlying bedrock are generally shallow; bedrock exposures are common. The fourth area, the Florissant basin, is a limited area of low relief in the northern part of the county. It is a flat lowland of lacustrine (lake bed) sediments believed to have been deposited during Pleistocene (Ice Age) time (Goodfield, 1965).

The bedrock geology in St. Louis County consists of essentially flat-lying sedimentary formations, mostly limestone and dolomite. A slight regional northeast dip has been modified by several minor northwest-southeast trending folds or flexures and by a broad, irregularly shaped structural basin (Florissant basin) in northern St. Louis County. Geologic formations exposed in St. Louis County range in age from Ordovician to middle Pennsylvanian (tbl. 1). The Ordovician rocks include (from oldest to youngest) the St. Peter Sandstone; Joachim Dolomite; and the Plattin, Decorah, and Kimmswick Formations. Most of the overlying Maquoketa Shale has been removed by pre-Mississippian erosion. The Glen Park Limestone and Bushberg Sandstone (Devonian) were also eroded during this period and are present now only in isolated exposures. Overlying these formations are rocks of Mississippian age, including the Fern Glen Formation; the Burlington-Keokuk Limestone (undifferentiated); the Warsaw Formation; Salem Formation; St. Louis Limestone; and Ste. Genevieve Formation. As a result of an erosional period following Mississippian time, the contact between these older formations of Ordovician through Mississippian age and the younger rocks of Pennsylvanian age is very irregular. The younger rocks, predominantly shale with some limestone and sandstone, are included in the Cherokee, Marmaton, and Pleasanton Groups of the Pennsylvanian System.

Almost all of the bedrock formations in St. Louis County have been covered by extensive deposits of windblown silt (loess) derived from the floodplain of the Missouri River during Pleistocene (glacial) time. The deepest loess, more than 50 feet thick, is found along the bluffs of the Missouri River. As a general rule, however, these deposits thin to the south and are seldom more than 5 to 10 feet deep along the ridgetops in the southwestern part of the county. Loess deposits on the adjacent hillsides have generally been removed or reworked by surface water.

A residuum (residual soil) derived from the in-place weathering of bedrock has developed where the loess cover is relatively thin. The residuum is predominantly clay but includes the more resistant material of weathered bedrock, principally quartz sand and chert.

Stratified gravel, sand, silt, clay, and organic materials were deposited on the floodplains of the Missouri, Mississippi, and Meramec Rivers. These alluvial deposits are extensive, generally over 100 feet deep in the Mississippi and Missouri valleys and up to 60 feet deep in the Meramec valley. Less extensive deposits are located along Fee Fee, Bonhomme, and Creve Coeur Creeks. Fine sand and silt often remain as terraces on the valley slopes as remnants of older alluvial deposits at higher elevations. Goodfield (1965) presents a detailed discussion of the unconsolidated surficial materials in St. Louis County.

Ground water is obtained from two principal sources in St. Louis County and is quite variable in both quantity and quality. Large quantities of water are available from the alluvium of the Mississippi, Missouri, and Meramec Rivers. Yields of 50 gallons of water per minute to more than 1,000 gallons of water per minute can be expected, especially where the alluvium is thick and contains little silt- or clay-sized material. Bedrock aquifers are present in the extreme southwestern part of the county where potable water is available to a depth of approximately 800 feet. Throughout much of St. Louis County, however, potable groundwater supplies are available from Mississippian limestones only to a depth of approximately 100 feet above sea level. Water occurs in the fractures and solution passageways of the limestone, and water yields are highly variable and unpredictable. Most wells will yield a maximum of 10 to 15 gallons per minute. This groundwater source is subject to pollution, however, because sinkholes, open crevices, and enlarged bedding planes allow surface water to enter the aquifers. It is recommended that all private wells in St. Louis County be properly cased and grouted and that all water supplies from these wells be treated to meet Public Health Department standards.

The most important mineral resources of St. Louis County are the limestone products. The Plattin and Kimmswick Formations and the St. Louis Limestone are extensively used for concrete aggregate, cement, road stone, and agricultural lime. Other limestone formations, although present, are less suitable for use and have not been developed.

ENGINEERING GEOLOGY

Engineering Geologic Map

The engineering geologic factors most influential in land-use planning are shown as map units, designated by Roman numerals. These represent specific engineering geologic conditions which have been delineated and evaluated with respect to their significance in land-use planning. They are independent of the age or origin of the materials involved (tbl. 1). For example, the Fern Glen Formation, part of the Osagean Series of the Mississippian System, and the Warsaw Formation and the lower portion of the Salem Formation of the Meramecian Series of the Mississippian System, have been mapped as a single unit because they have similar engineering properties.

The most important engineering factors of the geologic environment are related to the physical properties of the bedrock. These properties directly or indirectly relate to all strength and stability parameters required for engineering studies. In addition, the composition and texture of the bedrock generally affect the physical properties of the soils formed from it. Thus, the primary or unit classifications have been made from an evaluation of bedrock characteristics. In some cases, however, the extensive deposits of unconsolidated materials such as alluvium or loess so completely mask the bedrock that these materials become the controlling factors for engineering design. In such situations they have been designated as map units to show their importance in land-use planning.

The unit classifications have been subdivided according to the topography, soil, drainage, and engineering properties of the overlying soils. Topography is significant because it often is the surface expression of geologic features and because slope and relief govern the types of development that can be planned. Drainage is important, influencing not only the susceptibility of material to erosion and flooding, but also the potential for pollution of surface and subsurface waters. These subunits have subscript designations with small alphabetical letters.

The primary units are described in numerical sequence according to a provisional statewide classification system. Under this classification, alluvial materials are designated Unit I; carbonate bedrock is Units II through V; shale is Units VI through VIII; sandstone is Unit IX; and cyclic deposits are Unit X. This nomenclature is being used by the Missouri Geological Survey for engineering geologic studies pending national review of engineering geologic maps and symbols and adoption of a uniform system.

Plate 1 is a generalized engineering geologic map of St. Louis County. Table 1 outlines the basic criteria used in classifying engineering geologic units, presents the symbols used on geologic maps, and correlates them with the engineering geologic symbols used on plate 1. The map units are described in table

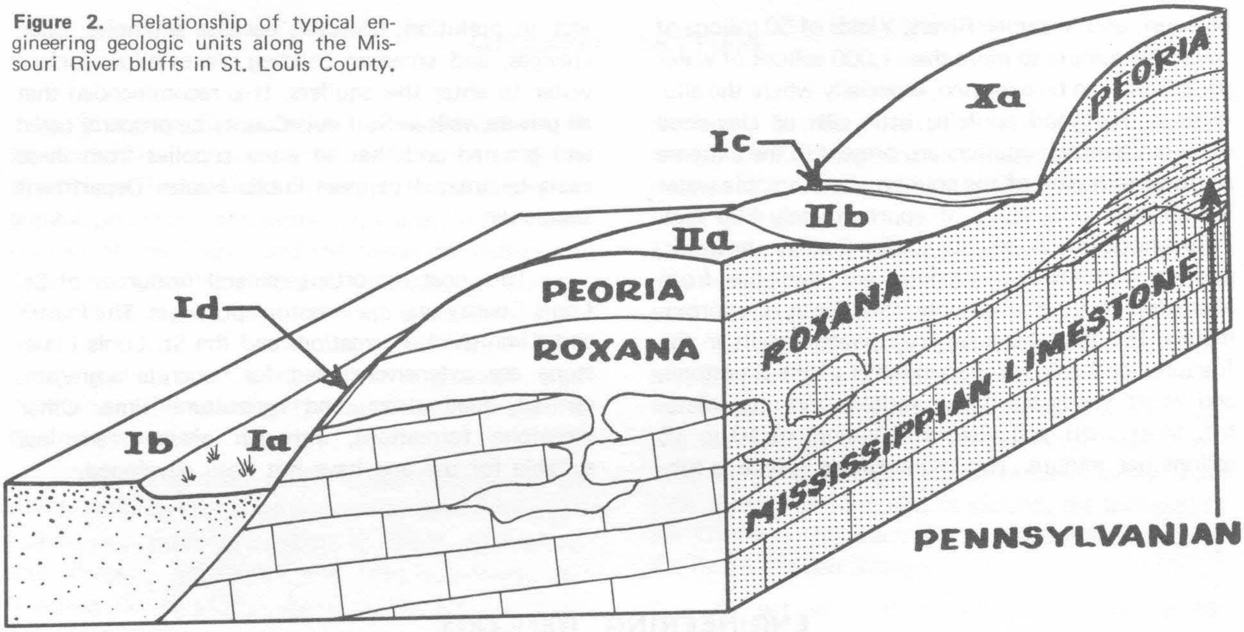


Figure 2. Relationship of typical engineering geologic units along the Missouri River bluffs in St. Louis County.

2 and are accompanied by a listing of the characteristics upon which the classifications are based.

Unit I - Alluvium

Unit I and its subdivisions consist of alluvial materials ranging in size from coarse gravel to clay. The deposits generally show stratification (layering) and segregation of materials according to grain size. Alluvium covers the valley floors of all the major streams and some of the larger creeks within the county. However, only the thickest alluvium—the deposits of the Missouri, Mississippi, and Meramec Rivers—can be shown at this scale.

Significant differences were found in the engineering characteristics of the alluvial deposits in St. Louis County; these materials are classified as three subunits (fig. 2). Subunit I-a represents the thicker materials of stratified gravel, sand, silt, and clay filling the valleys of the Meramec, Missouri, and Mississippi Rivers. Subunit I-b delineates stratified sand, silt, and clay in terraces above the present floodplains of the larger streams. These deposits are remnants of Pleistocene terraces common along many stream valleys although only those of broad areal extent have been mapped at this scale. Subunit I-c denotes stratified silt and clay with some fine sand and organic materials included in lake bottom (lacustrine) deposits of Pleistocene age.

Subunit I-a: The thickest alluvium in the major river valleys is mapped as I-a. The thickness ranges from 40 to 60 feet in the Meramec valley to well over 100 feet in the Missouri and Mississippi valleys. The composition is heterogeneous, generally consisting of stratified sand, silt, and clay with beds of gravel and lenses of organic material. Silt and clay mixed with organic deposits occur in isolated areas such as in remnants of old meander scars or oxbow lakes (former stream channels). These vary in thickness from less than 1 foot to more than 20 feet.

Engineering problems encountered in Subunit I-a are generally related to the variability of the soil, high water table, and flooding potential. The variability in materials is critical because strength and permeability values change significantly from layer to layer and detailed investigations are needed to evaluate subsurface conditions. In addition, when organic materials are encountered, they require special design criteria.

Because of the close association with major streams, periodic flooding must be anticipated, although the extent of flooding may be reduced by levees, flood walls, or other provisions. However, any flood protection facility may act as a dam during flood periods and actually compound the flooding problem. Even when protection is provided, the high groundwater levels and pressures in the permeable materials may cause additional engineering problems.

Areas classified as Subunit I-a are suited for most land-use development if the problems of flooding and material variability are taken into consideration. However, the high groundwater levels, very permeable soils, and flooding potential render the area unsuitable for sanitary landfill sites. Water retention ponds or sewage lagoons may be satisfactorily operated with proper remedial measures although soil permeability, groundwater levels, and flood hazards again will influence the suitability of a sewage lagoon site.

The most significant mineral resources found within Subunit I-a are the sand and gravel deposits in the major river valleys. Most production comes from gravel pits along the Meramec River since gravel deposits found along the Missouri River generally have too much silt, clay, and organic material mixed with them to be economically redeemable. No gravels of commercial quality are known along the Mississippi River in St. Louis County. The alluvial materials included in this category provide a major source of industrial and municipal groundwater supplies within the county.

Subunit I-b: The material mapped as Subunit I-b is found as terraces on valley walls parallel to the river bottoms. These terraces represent remnants of previous river deposits formed during the latter part of the Pleistocene when the rivers were flowing at a higher elevation (Goodfield, 1965). Only those terraces of major areal extent are noted in this report.

Soil in these terraces ranges from 15 to 25 feet in thickness and consists of stratified or layered deposits of sand, silt, and clay. The surfaces of the terraces are covered with thin loess and/or colluvial soils washed from the adjacent slopes. Most of the terraces are apparently underlain by bedrock rather than other alluvial material (Goodfield, 1965). With the exception of local areas where lateral seepage from bedrock or adjacent valley slopes occur, these areas are well above groundwater levels.

The terraces are well suited to development; they are above the level of frequent flooding and are composed of materials suitable for most types of construction activity. Waste disposal lagoons and sanitary landfills can be placed on some terraces, although artificial sealants, padding, or compaction may be needed to prevent downward percolation of the fluids.

Subunit I-c: This area (Subunit I-c) includes materials deposited under standing water or lake bottom conditions (lacustrine environment). These lake bed deposits include fine sand, silt, clay, and organic sediment up to 100 feet thick that have been covered by a 5- to 25-foot thick layer of loess.

The area is referred to as the Florissant basin (Krusekopf and Pratapas, 1919). The lacustrine sediments were deposited during glacial time when the drainage from the basin was temporarily blocked to form a lake. Today, the area is characterized by flat topography with poorly developed drainage. The lacustrine soil under the loess has a very high water content and is more compressible than many other alluvial soils. Due to the nature of the underlying bedrock and the type of soil within the lacustrine environment, the internal drainage is poor.

Unit II - Carbonate Bedrock with Extensive Surface Weathering

Limestones of the Salem, St. Louis, and Ste. Genevieve Formations (Mississippian) have similar engineering properties and are considered as one unit (Unit II) in this study (fig. 3). The limestones have uniform beds which are generally 1 to 4 feet thick. The Salem Formation is the most argillaceous (contains clay material) of the group and grades into a shaly limestone at its base. Because of the different engineering properties associated with the shale, this lower part of the Salem is included in Unit VI. The St. Louis and Ste. Genevieve Formations are primarily massive, fine-grained limestones containing occasional thin shale beds and chert.

Solution features developed by chemical weathering of the limestone have significantly affected the physical properties of these formations. Generally, these solution features are restricted to beds nearest the surface, although they may extend to a considerable depth. Water, moving downward from the surface along the joints and bedding planes, has enlarged vertical and horizontal fractures in the limestone, producing an irregular and unpredictable surface between the bedrock and overlying soils. Vertical solution channels may become so extensive as to leave pinnacles of rock buried under a cover of soil. Some solution may also take place along the horizontal bedding planes, developing to such an extent that large unweathered blocks of limestone are completely surrounded by residual clay. In addition, if bedrock becomes so thin above a cavern that it can no longer support the overburden, it may collapse and form a sinkhole. Intense sinkhole development is termed

Salem Formation St. Louis Formation

Figure 3. Views of the Salem and St. Louis Formations showing similarity in characteristics affecting engineering geology.

"karst" topography. Solution features are evident in only a few locations in St. Louis County because of the thick loess cover (fig. 4). Solution-enlarged openings in the bedrock are probably distributed over a much larger portion of the Unit II area than is indicated on the surface.

Limestone from Unit II is an important mineral resource. It is currently being quarried for use as concrete aggregate, Portland cement, dimension stone, and agricultural lime and is a significant factor in the mineral economy of the St. Louis area.

Unit II has been divided into four subunits according to the engineering characteristics of the overlying soils. Three of these subunits are based on the extent and type of materials overlying the bedrock. The fourth outlines the surface expression of karst topography. These subunits have gradational changes and the boundaries drawn to define them are therefore somewhat arbitrary.

Subunit II-a: Subunit II-a forms a narrow band of bluffs and ridgetops adjacent to the Missouri River floodplain. Here the limestone bedrock is covered by two layers of very thick loess deposits. The upper layer (Peoria) is composed of a uniform, nonstratified, windblown silt with little or no clay and limited soil profile development. This thick deposit (15 to 30 feet) of low-clay loess is the predominant surficial material and has the typical engineering properties associated with loess. It will stand in a vertical slope, has high vertical permeability, and will lose strength upon wetting. Underlying this deposit of low-clay loess is a second loess (Roxana) which has a significantly higher clay content. The Roxana loess may attain a thickness of 25 feet or more. It has lower vertical and horizontal permeabilities than the overlying loess and moisture, migrating downward through the upper loess, collects at the contact. Moisture content in the lower loess ranges from 5 to 10 percent higher than in the upper loess and approaches the plastic limit.

A thin zone of residual clay and partially decomposed bedrock is usually present between the lower loess and the underlying bedrock. This is a true residual soil that is formed from the limestone. This material has a very low permeability and acts as an additional barrier to the downward movement of water. These horizons, where there is change in the permeability of the materials, become saturated and can act as planes for slope failure when lateral support is removed by erosion or excavation.

The main engineering problem in Subunit II-a is soil creep that occurs on the steeper slopes (20 percent or greater) and is accentuated when houses, other types of loading, or moisture are added to the load. The movement is gradual but is intensified along the slide planes between the loesses or at the top of bedrock. Subunit II-a is well suited to most land use, although artificial sealants may be required for water impoundment facilities.

Subunit II-b: The II-b area is similar to Subunit II-a. In II-b, however, the upper horizon of low-clay is relatively thin (less than 5 feet thick) and acts only to mantle the high-clay loess below. This high-clay loess is the predominant surficial material and its engineering characteristics are most important. Because of the clay content, the physical characteristics of the loess are somewhat modified, having lower permeability values and slope stability parameters than the low clay loess.

The thickness of the combined loesses decreases away from the Missouri and Mississippi River floodplains. The total thickness of the loessial cover ranges from more than 50 feet near the bluffs to less than 10 feet over the southern areas. Most of the area mapped as Unit II is classified as Subunit II-b.

The most serious engineering problem is slope failure, generally through soil creep, which may increase in rate of movement until slides occur. This usually occurs along the stratification layers associated with the loess and is accentuated where water, such as effluent from waste disposal facilities or pavement runoff, saturates the materials.

Subunit II-c: Subunit II-c denotes areas where the solution features of the underlying bedrock are not masked by the overlying soils. These areas, mapped as II-c, are the karst (sinkhole) topography. Only two areas are shown on the map—one in the northern part of the county near Florissant, and the other in the southern part of the county near the confluence of the Meramec and Mississippi Rivers. There are smaller sinkhole areas, particularly along the western boundary of Subunit II-b, that are not shown because of the scale of this map.

The most serious engineering problem encountered in Unit II is in this area. There is a tendency for soil creep to occur along the slopes of a sinkhole. If the sinkhole becomes plugged with debris, it will retain surface drainage and may cause local flooding. Because of the direct infiltration into the groundwater regime, sinkholes are entirely unsuitable for any type of waste disposal. With remedial measures for drainage and slope stability, however, these areas are satisfactory for most land use (fig. 5).

Subunit II-d: The material in Subunit II-d is the residual soil developed on the carbonate (limestone) bedrock. The thickness of the soil ranges up to 30 feet or greater. There may or may not be a thin modified loess cover on the residual soil. The residual soil generally is a well structured clay that breaks into a

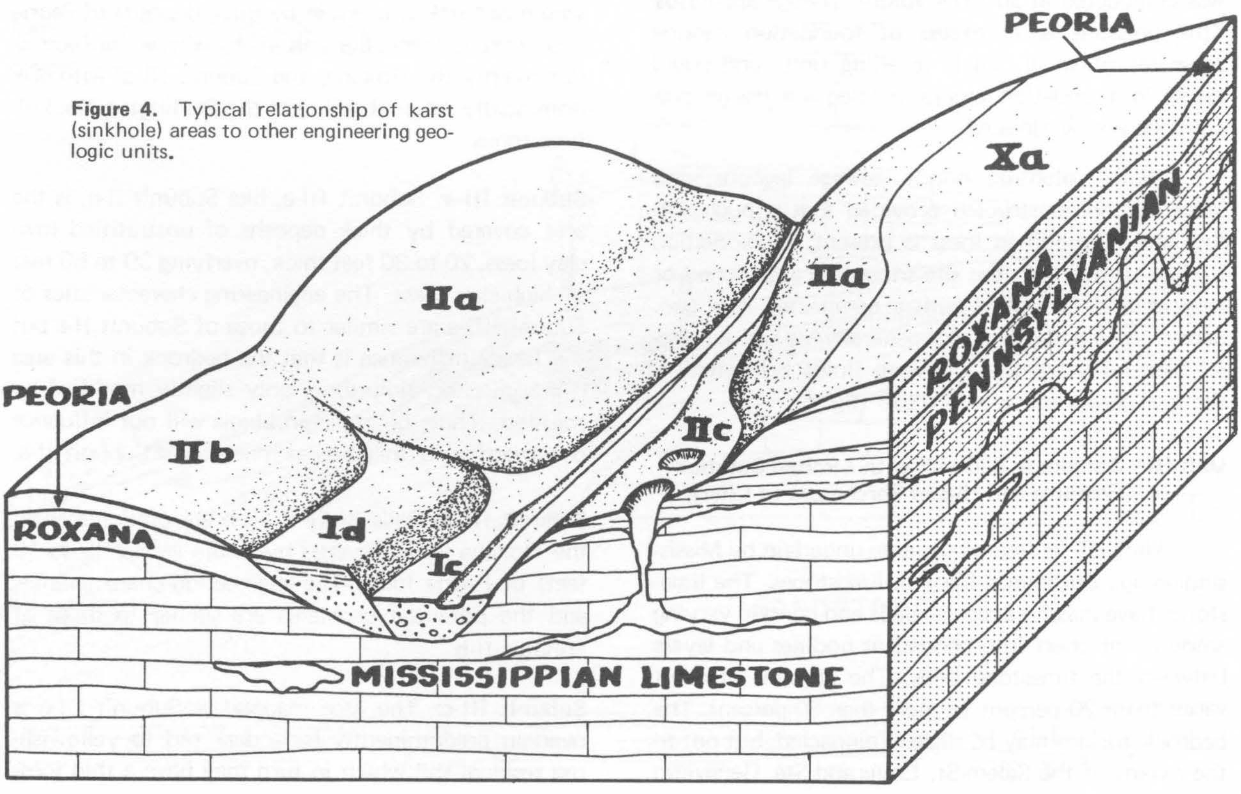


Figure 4. Typical relationship of karst (sinkhole) areas to other engineering geologic units.

Figure 5. Residential development in a karst (sinkhole) area, north St. Louis County.

loose, granular mass when dried. When wet, however, it is a plastic, sticky clay with very low to moderate internal drainage. This soil has a tendency to swell upon wetting, and swelling pressures in excess of 3,300 pounds per square foot were recorded when it was compacted in an FHA volume change apparatus. This pressure is in excess of foundation bearing pressures of small, single dwelling units and could result in foundation cracks if adequate design precautions are overlooked.

Water retention ponds, sewage lagoons, and lakes can be constructed provided that enough surface soil of modified loess is present. If excavation is close to bedrock, the site should be abandoned or overcut and backfilled with a compacted clay pad. Septic tanks and drainfields generally are not successful because movement of waste fluids is limited by the low permeability of the soil (fig. 6).

Unit III - Carbonate Bedrock with Limited Solution Features and Higher Percentage of Chert

Unit III represents the area underlain by Mississippian age Burlington-Keokuk limestones. The limestones have massive irregular beds and contain varying amounts of chert interbedded as nodules and layers between the limestone beds. The amount of chert varies from 20 percent to more than 50 percent. The bedrock surface may be slightly pinnacled, but not to the extent of the Salem-St. Louis and Ste. Genevieve Formations. Enlarged solution joints and bedding planes are common and are often filled with a loose, blocky clay.

Three major mappable subunits in St. Louis County have been noted. These are: Subunit III-a, where bedrock is overlain by thick deposits of Peoria and Roxana loess; Subunit III-b, where the loess is dominantly the Roxana; and Subunit III-c, with predominantly residual soil over the Burlington-Keokuk limestones.

Subunit III-a: Subunit III-a, like Subunit II-a, is the area covered by thick deposits of unstratified low-clay loess, 20 to 30 feet thick, overlying 30 to 50 feet of high-clay loess. The engineering characteristics of Subunit III-a are similar to those of Subunit II-a but the major difference is that the bedrock in this area is a high chert limestone, only slightly modified by solution. Thus, bedrock problems will not influence construction in this area as much as in Subunit II-a.

Subunit III-b: Soils in Unit III-b are predominantly the Roxana loess, covered by a thin veneer (5 to 10 feet) of Peoria loess. The engineering characteristics and the potential problems are similar to those of Subunit II-b.

Subunit III-c: The area mapped as Subunit III-c is overlain predominantly by a dark red to yellowish-red residual soil which in turn may have a thin loess cover. The residual soil has a high percentage of chert derived from the parent bedrock and is classified as gravelly clay or clayey gravel. The chert fragments within the soil frequently exhibit the same bedding characteristics as they did in the parent rock. The clay-size materials in the soil have a blocky structure and as a result the permeability is usually high, closer to values expected for a silty sand.

The most serious problem of Subunit III-c results from the high permeability of the residual soil. Water retention facilities such as lakes or sewage lagoons may prove unsatisfactory if too much water is lost through seepage. Artificial sealants can be used to reduce downward seepage from lagoons and lakes, and there are local areas of colluvial soil which can be used as a compacted dirt pad to reduce permeability. Septic tanks and filter fields generally are unsatisfactory as the high permeability of the residual soil allows rapid drainage of waste liquids into the groundwater system and thus contributes to pollution. Slope stability and solution-related problems are less severe in Subunit III-c than in the other subunits and most land uses, other than waste disposal, may be considered.

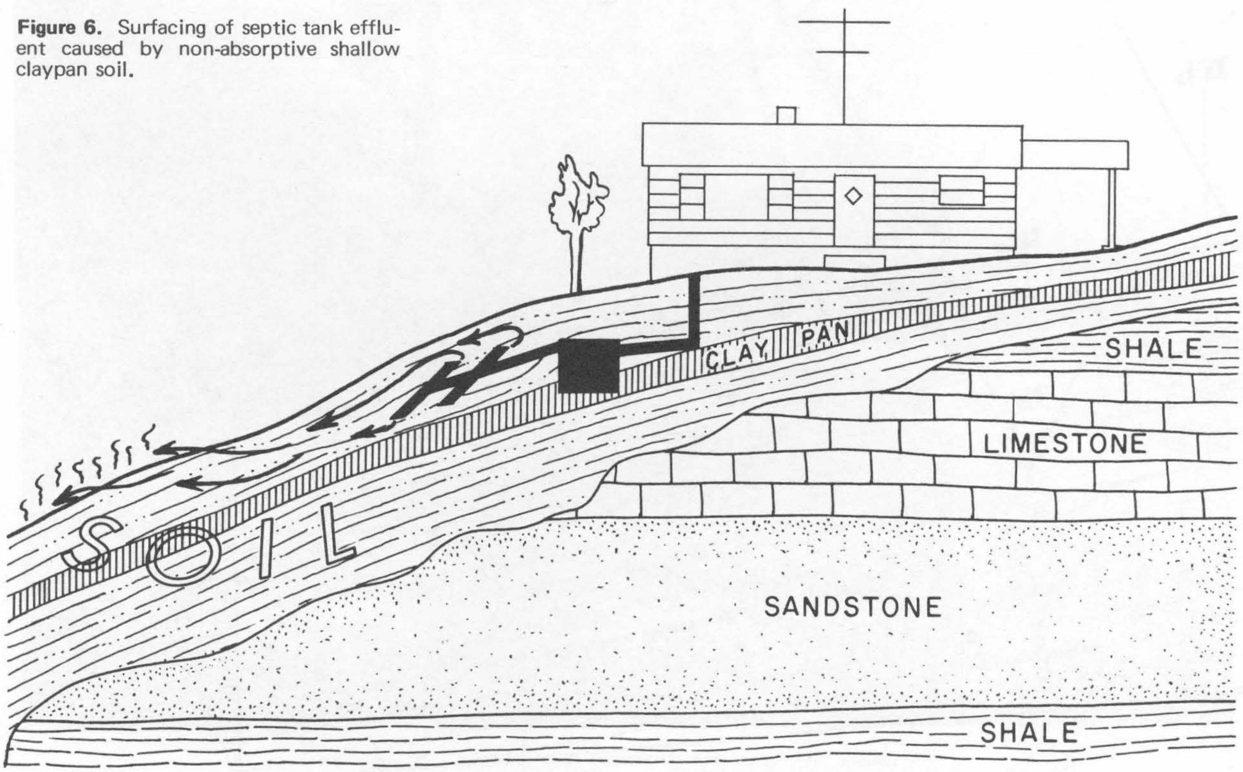
Unit IV - Carbonate Bedrock, Well-Developed Solution Features, and Caverns

The Unit IV area is underlain by the Kimmswick, Decorah, and Plattin Formations of Ordovician age.

The Kimmswick is a medium to massive, evenly bedded limestone with a distinctively pitted or "honeycombed" weathering surface. The Plattin Formation is thin to medium bedded with a pitted weathering surface similar to the Kimmswick Formation. Included in the Plattin are minor amounts of shale or clay partings. The Decorah is a thin, shaly limestone present between the Kimmswick and Plattin which is seldom more than 20 feet thick. Because of its limited thickness, it is not considered an important unit in regional engineering geological studies but is noted as a possible cause of slope failure.

Several areas of the Kimmswick and Plattin have been dissected by solution-enlarged fractures, and caves have developed along joints and bedding planes. The cavernous conditions, sinkholes, and general solution effects are not as prevalent as the limestones of Unit II but do constitute a serious engineering problem where soil cover is relatively

Figure 6. Surfacing of septic tank effluent caused by non-absorptive shallow claypan soil.



thin. Both the Kimmswick and Plattin limestones can be considered important mineral resources as they are excellent sources of concrete aggregate, Portland cement, and agricultural lime. In addition, these limestones provide a limited source of groundwater.

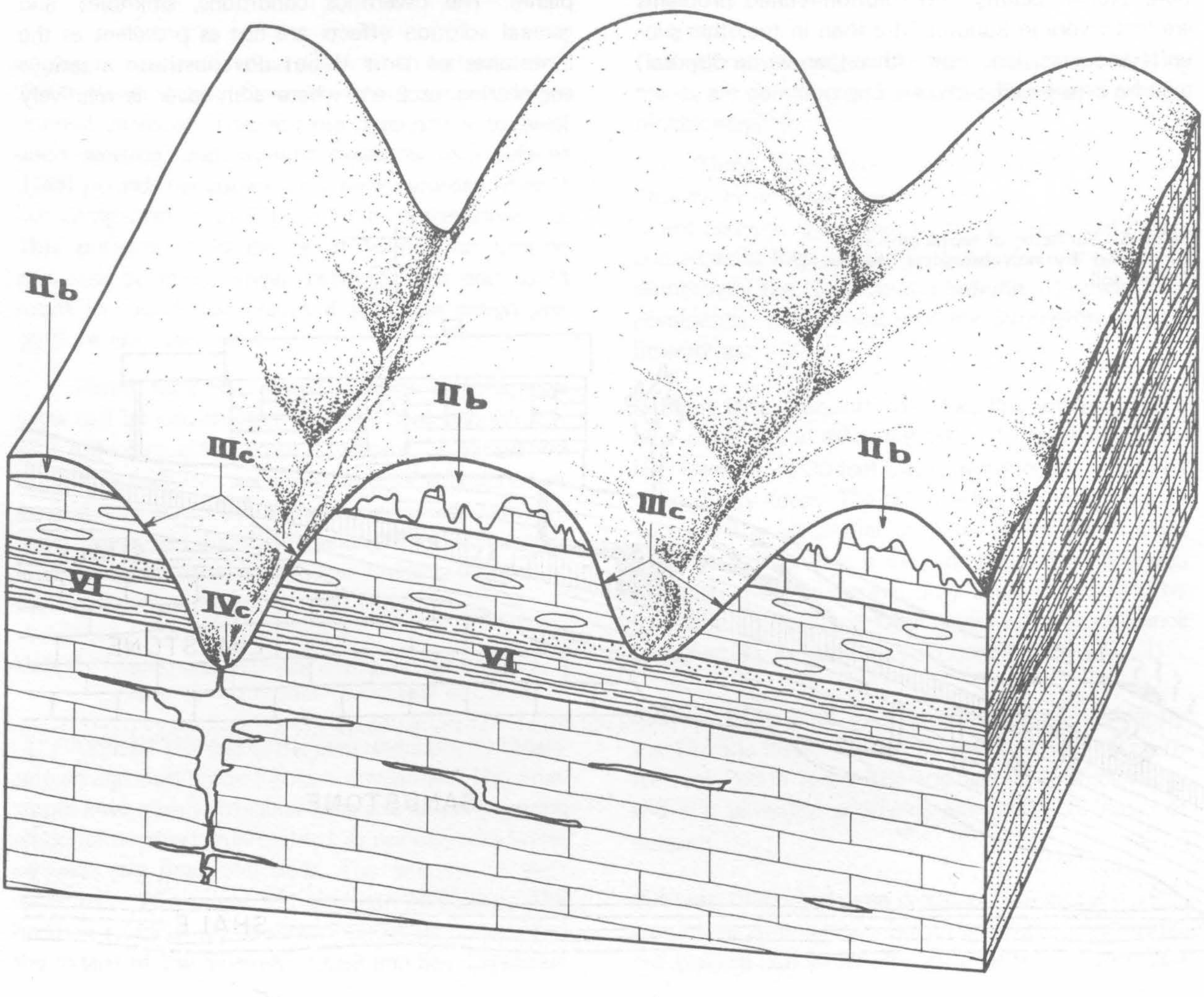
The soils that overlie the Kimmswick and Plattin Formations have been mapped as three subunits: Subunit IV-a, deep loess over limestone similar to Subunit II-a; Subunit IV-b, shallow loess over limestone similar to Subunit II-b; and Subunit IV-c, a residual soil formed predominantly on the Kimmswick-Plattin Formations.

Subunit IV-a: Subunit IV-a depicts areas where the Kimmswick-Plattin limestones are overlain by thick deposits of low-clay Peoria loess and high-clay Roxana loess. Only a small area in the extreme northwest corner of St. Louis County is included in this classification. Generally, engineering characteristics described under Subunit II-a are applicable to Subunit IV-a. The major problem is the slide potential developed at the contact of the two loesses.

Subunit IV-b: Subunit IV-b is a small area not far from the bluffs of the Missouri River in the extreme northeastern corner of the county where the loess cover overlying the Kimmswick and Plattin limestones is predominantly the high-clay Roxana. Engineering characteristics and potential land-use problems are similar to Subunit II-b, and the same considerations should be applied for land-use planning.

Subunit IV-c: Subunit IV-c denotes areas of residual soil developed on the Kimmswick and Plattin limestones, generally along the narrow valleys draining into the Missouri and Meramec Rivers in the western part of St. Louis County (fig. 7). This residual soil is a reddish brown, firm, well-structured clay that is

Figure 7. Relationship of engineering geologic units in western St. Louis County.



"fat" and sticky when wet and hard and granular when dry. The well-structured, residual clay is very permeable. Because this soil forms into hard, sand-size cubes that are not readily broken down, permeabilities are seldom decreased to any extent by common engineering practices.

Because of the permeability of the soil and its occurrence over limestones (which are also permeable), improperly built and/or located waste disposal sites are a pollution hazard to both the subsurface and surface water supplies. However, local accumulations of colluvial soil and modified loess, not mapped on this scale, are less permeable and may be used for small water retention ponds. The residual soil deposits are generally shallow. Because of the cavernous nature of the bedrock, site investigation should extend through the soil cover and well into bedrock to evaluate bedrock soundness. The clay within the soil will swell upon wetting, although swelling pressures are classified as marginal and generally will not be great enough to cause foundation problems.

Unit V - Carbonate Bedrock, Limited Solution, Flagstone Development of Weathered Surface

The bedrock in Unit V is the Joachim Dolomite. Because of its limited extent and uniform cover of predominantly residual soil, it has not been subdivided. The Joachim is evenly bedded, silty dolomite with interbedded limestone and shale in some portions. The beds range in thickness from less than 1 foot to no more than 3 feet. Upon weathering, these beds part and break into flat slabs or flagstones. Soil development from bedrock is shallow with rock outcrops common except near the base of hills.

The residual soil developed on the Joachim is a sticky clay similar to the residual soil developed on the Kimmswick and Plattin limestones of Unit IV. However, because the soil is thin, Unit V is poorly suited for waste disposal or water retention facilities. The colluvial soils at the base of some hillslopes generally are thicker, less permeable and can be used for ponds or sewage lagoons.

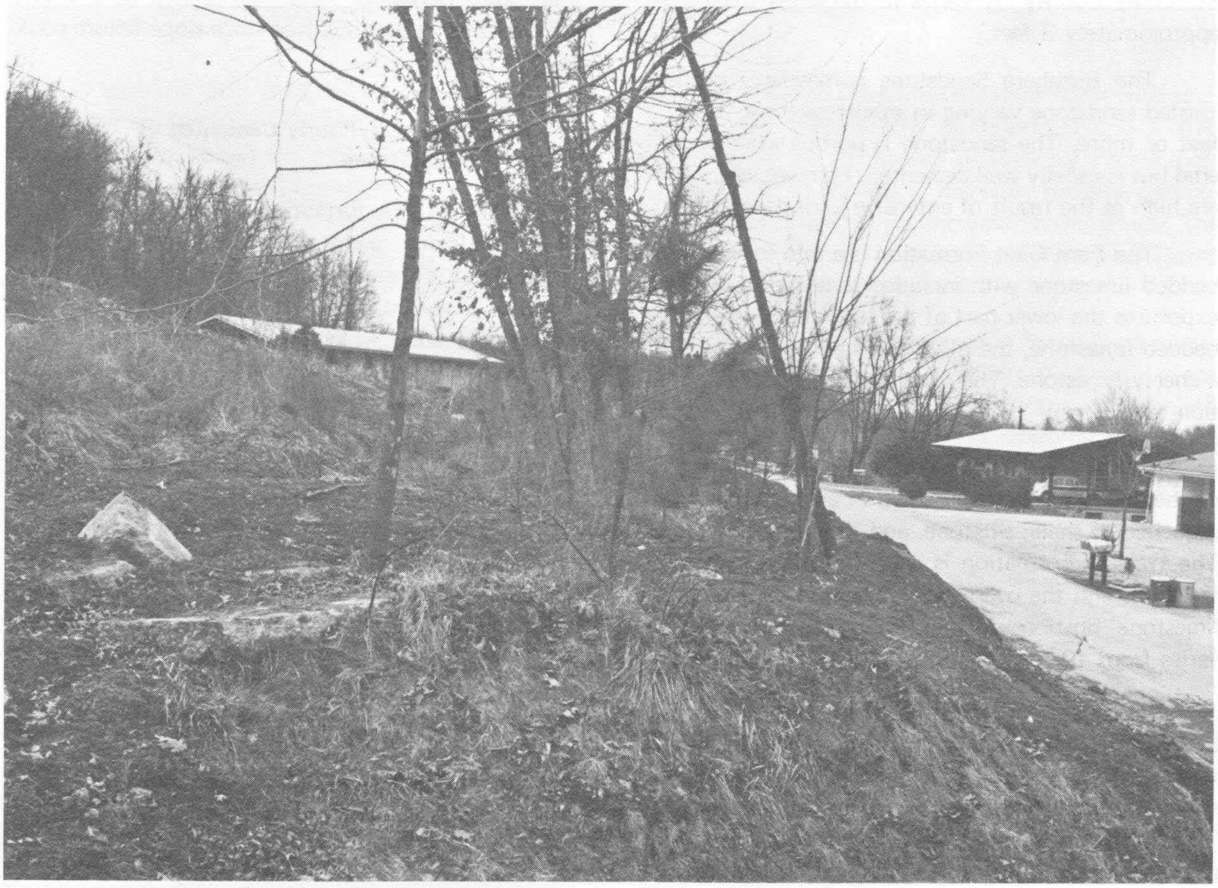


Figure 8. Leaning trees indicating soil creep over shales.

Unit VI - Predominantly Shale and Clay Shale, Highly Plastic on Weathering, Unstable Slopes

Area VI includes bedrock from various geological formations which are included here as one unit. Regionally, land-use development characteristics and engineering properties of the various formations of Unit VI are similar, although variation in specific properties can be expected between formations. Included in Unit VI are the Ordovician Maquoketa Shale, the Devonian Glen Park Limestone and Bushberg Sandstone, and the Mississippian Fern Glen, Warsaw, and part of the Salem Formations.

The Maquoketa Formation is a thinly laminated, silty, dolomitic shale, which locally contains nodules or lenses of shaly limestone. The formation is not continuous in the St. Louis area. The thickness varies widely up to a maximum of 15 feet.

The Glen Park, a thin- to medium-bedded limestone, is present only in isolated exposures in western St. Louis County. It varies in thickness from 2 to approximately 3 feet.

The Bushberg Sandstone is massively bedded, jointed sandstone varying in thickness from 10 to 30 feet or more. The sandstone is porous when weathered but is usually well cemented. Permeability values are high as the result of extensive joint development.

The Fern Glen Formation is a thin to massively bedded limestone with included shale beds. At most exposures the lower part of the formation is a thickly bedded limestone, the middle a shale, and the upper a cherty limestone. The total thickness of the formation ranges from 20 to 45 feet.

The Warsaw Formation and the lower portion of the overlying Salem Formation are composed of a sequence of shale, siltstone, and thin limestone beds. The Warsaw Formation is generally 60 feet in total thickness and the overlying shale, siltstone, and shaly limestone portion of the lower Salem Formation varies from 10 to 20 feet.

In general, the residual soil that overlies the bedrock of Unit VI is a dark gray, highly plastic material with low permeability. The soil is unstable on sloping ground and soil creep is common (fig. 8). The soil has a tendency to swell, although swelling pressures are seldom high enough to cause foundation failure except in local areas.

An additional slope stability problem is encountered in the thick shales of the Maquoketa and Warsaw Formations. The exposed or weathered bedrock is very weak, and any change in natural conditions that increases moisture content or steepens the slopes may lead to slope failure. The added moisture may come from septic tank effluent, stripping of vegetation, or interference with natural drainage. The slope stability problems are less serious where the shale is interbedded with siltstone or limestone.

Although these areas have been classified as hazardous for any type of construction because of slope instability, there are areas where slope stabilization is possible provided proper engineering techniques are used. Even the most hazardous shale zones can be stabilized by using more elaborate engineering techniques. Therefore, it is strongly urged that construction or planning the Unit VI area be initiated only after detailed engineering studies have been made. These studies should include a detailed geologic study and soil mechanics analyses. Indiscriminate building in Unit VI could cause hardships on the individual, developer, and the county as a whole. Public safety is also involved since slope failure could be catastrophic.

Unit VIII - Massive, Poorly Cemented Sandstone

The bedrock formation of Unit VIII is the St. Peter Sandstone, a massive sandstone in the southwest corner of the county (fig. 9). The sandstone does not have distinct joints or bedding planes. Thus, while permeable, water seepage is extremely slow. The surface of the St. Peter sandstone becomes case-hardened when weathered. The St. Peter is an important water-bearing formation. The typical St. Peter outcrop area is covered by a thin soil that may not be thick enough for waste disposal by sewage lagoon facilities; sewage disposal by septic tanks and drainfields should not be allowed. Leakage around water retention structures can become a nuisance if the case-hardened surface of the sandstone is broken and then covered by the impounded water. The greatest source of trouble is the erodibility of the overlying soil when it is stripped of vegetative cover.

Unit X - Cyclic, Predominantly Shales, Some Sandstones and Limestones

Unit X denotes areas of Pennsylvanian bedrock covered (as were the Mississippian limestones of

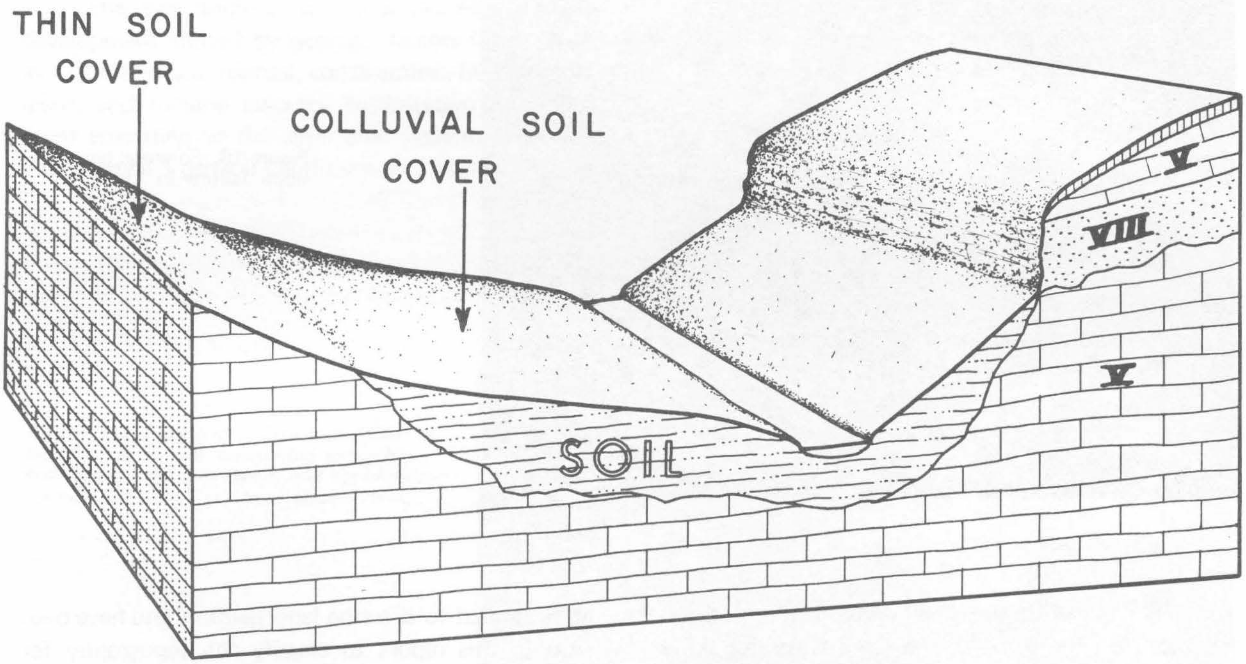


Figure 9. Relationship of engineering geologic units in southwestern St. Louis County.

Units II and III) with thick loess. The loess has obscured the contact between the bedrock formations. Boundary lines drawn to separate this unit from others are based on data obtained from limited drilling records and must be considered approximate. The bedrock is a cyclic sequence of shales, sandstones, siltstones, and limestones with occasional thin seams of coal and clay. The beds are relatively thin, ranging from a few inches to several feet thick. Although individual beds may vary greatly in their engineering characteristics, they have been considered collectively in the overall evaluation of Unit X.

Unit X has been divided into two subunits in this study. An additional subunit of expansive clay was noted on a more detailed study (Rockaway and Lutzen, 1970), but could not be mapped at the scale of the regional map. The two subunits are defined by the engineering characteristics of the overlying loess cover.

Subunit X-a: This is a narrow band of thick loess parallel to the bluffs of the Missouri River with engineering properties similar to Subunit II-a. It is characterized by 20 to 30 feet of low-clay Peoria loess overlying 30 to 50 feet of high-clay Roxana, particularly when there is an increase in moisture. The loesses are thick and engineering problems associated with the bedrock are minimal.

Subunit X-b: Where the overlying Peoria loess is relatively thin the engineering properties of the Roxana loess, particularly with respect to slope stability and water retention, become most important. Subunit X-b, similar to Subunit VI-b, denotes areas where this situation has developed over the Pennsylvanian formations.

The major problems experienced in both divisions of Unit X, but particularly Subunit X-b, are related to the slope stability of the overburden and bedrock (fig. 10). The shale and clay shales become weak when exposed to the atmosphere and slopes are unstable when too steep or saturated.

TOPOGRAPHY

Many of the important considerations in land-use planning such as waste disposal, utilities, highway and building design, and natural resource development are influenced by topography. The location of roads, utility lines, design of surface drainage, erosion control features and to a certain extent, the design

Figure 10. Potential backslope failure in Unit X.

and landscaping of buildings and other structures, are based on the slope of the land. Costs for slope modification increase rapidly for areas where the slope exceeds 5 percent or where bedrock is near the surface.

The topography of St. Louis County varies widely in character, ranging from the flat, almost featureless floodplains of the Missouri and Mississippi Rivers, to the rugged, intensely dissected uplands of the west county area. Relief, percent of land surface in slope, and steepness of slope are common parameters applied to describe land features and have been used in this report to classify the topography for land-use evaluation. The classification ***nearly level*** includes land that is flat or nearly level with little relief and with less than two feet fall per hundred feet distance (0-2 percent slopes). ***Gently rolling*** includes areas with 2 to 5 percent slopes. ***Rolling*** applies to those areas with 5 to 9 percent slopes; and ***steeply rolling*** or ***hilly*** denotes regions where the slopes are 10 percent or more with relief often greater than 250 feet. Figure 1 illustrates the areas of St. Louis County corresponding to these classifications.

LAND-USE INTERPRETATIONS

Evaluation of the geologic environment for land-use planning must consider all aspects of surface and subsurface conditions. The successful development of many projects can be related to the physical properties and engineering behavior of the bedrock formations, soil cover, groundwater flow, or other surface and subsurface features. To assist the planner in evaluating the geological environment a three-level rating system, ***slight, moderate,*** and ***severe*** is used to denote the anticipated degree of influence that the geologic environment will have on land use.

A rating of ***slight*** denotes that the geological materials will exert a limited influence on a particular development or effort. Engineering problems will be minimal both for the short term, such as during construction, and the long term life of the project. A ***moderate*** rating indicates that there have been some problems associated with the geological environment, either short term or long term, but that these problems generally may be eliminated or effectively reduced by proper design criteria. A ***severe*** rating means potentially high risk conditions and indicates areas with a geological setting known to offer extensive problems of a particular nature. Such instances where development proceeds under ***severe*** conditions will usually require extensive remedial measures to prevent failure.

Certain geologic factors such as mineral resources and groundwater are best described by a rating system. A ***poor*** rating denotes little or no economic value as a mineral resource or for groundwater production. A ***good*** rating indicates adequate volumes of groundwater can be expected or that economical deposits of mineral resources are available.

The evaluation of potential problems in land development caused by geologic factors is presented in table 3. Waste disposal, construction, lake development, and mineral resource exploitation have been rated according to the applicable system. These ratings represent general conditions in a regional report such as this and even though more precise boundaries and detailed analysis may be made on larger scale maps, on-site investigations of subsurface conditions are required to obtain detailed information for proper design criteria (fig. 11).

Figure 11. Pre-construction foundation studies can aid in preventing extensive cracking in masonry walls and concrete foundations such as those shown here.

WASTE DISPOSAL

The influence of the geologic environment on waste disposal practice has been evaluated for each of the three common waste disposal methods—sanitary landfills, sewage lagoons, and septic tanks. Favorable sites (***slight*** severity) for waste disposal are situated where the waste can be placed on material with sufficiently low permeability to prevent the movement of contaminants into surface or subsurface waters. A ***moderate*** rating is given where it is possible to operate a waste disposal facility provided that adequate remedial measures such as padding with dirt are employed. ***Severe*** ratings are reserved for those areas where the water table is near the surface or where a combination of slope and subsurface conditions are such that pollutants will move into surface or subsurface waters regardless of customary remedial measures.

Sanitary Landfills

Impermeable bedrock and overburden are necessary for the control of pollutants if the operation of a sanitary landfill is to be successful. Geologic conditions with a ***slight*** severity rating for sanitary landfills are scattered throughout the county. There are suitable areas along the river bluffs where the rugged topography may be converted to more valuable land by filling and leveling in a landfill operation. A ***moderate*** rating has been assigned to much of the county where moderately permeable or limited soil cover exists.

Unit I-a, thick alluvial deposits in the major river valleys, and Unit II-c, limestone bedrock with karst development, have been rated entirely unsatisfactory (***severe***) because of the direct relationship between surface waters and the groundwater system (fig. 3). Groundwater from the Missouri, Mississippi, and Meramec River alluvium is a major source of water supply for county development.

Sewage Lagoons

Geologic factors significant in the successful design and operation of sewage lagoons are essentially the same as those for sanitary landfills, although topography and surface drainage must be considered separately. Rough topography, conducive to landfills, limits lagoon sites. However, floodplain areas (Unit I-a) are considered satisfactory for lagoons if there is a suitable thickness of impermeable soils above groundwater. The hydrologic conditions of the valley must be considered if the proposed lagoon would affect the floodwater profile.

Units with inadequate or unsuitable residual soils in the more rugged western portion of the county have been rated ***severe*** along with the karst areas of Subunit II-c.

Septic Tanks

A satisfactory septic tank and drainage field system requires highly absorbent soil. Impermeable materials will result in the emergence of the effluent at the surface. Because the density of septic tanks must be controlled, there are many areas where septic tanks can be safely used for rural purposes but may cause serious pollution problems in urban areas. The soils of St. Louis County vary greatly in their ability to retain moisture and, therefore, in their suitability for septic tank installation. In addition, a combination of steep slopes and layers of different materials in the soil may lead to slope stability problems when

Figure 12. Erosion of planned development site after vegetative cover has been stripped.

septic tank effluent is added to the natural water contents. Even with suitable soils and favorable geologic conditions, there is a limit to the amount of septic tank effluent that a given area can absorb. If too many septic tanks are installed, none will work properly (fig. 6). Septic tank problems will occur regardless of soil conditions in urbanized areas; it is recommended that they be used for waste disposal in rural areas only.

Units with inadequate or highly permeable soil cover have been designated ***severe***. The shallow residual soils of Units V, VI, and VIII and the highly permeable residual soils developed on limestone bedrock in the western one third of the county are considered in this category. The potential for groundwater pollution from septic tanks is particularly severe in Subunit II-c.

EROSION CHARACTERISTICS

All units and subunits that are covered by loessial derived soils are subject to rapid surface erosion if stripped of their vegetative cover (fig. 12). This erosion leaves unsightly gullies and causes siltation (silt pollution) of receiving lakes and streams. The greatest problems will be along the Missouri River bluff and in Units II, III, VIII, and X.

There is a more insidious type of erosion that occurs in loessial soils: this is piping or underground erosion. When moving water is allowed to percolate under construction projects such as roads, silt and clay-size particles are removed. This process is very small and insignificant at first but rapidly becomes larger and can endanger the entire project.

CONSTRUCTION

The suitability of geologic materials for various construction activities was evaluated with respect to their influence on slope stability, foundation design, excavation, and road performance. Ratings of ***slight, moderate,*** and ***severe*** are assigned.

Slope Stability

Landslides or slope failures are characterized by the downward or outward movement of earthen material, usually along a particular plane of weakness. Movement is commonly along such features as a clay layer, a water lubricated surface, or the boundary between bedrock and overburden. Common factors contributing to the instability of slopes include an increase in water content of the materials, perhaps from septic tanks; removal of the supporting toe of the slope; or addition of excess weight to the top of the slope.

The most serious problem of slope stability ***(severe)*** in St. Louis County occurs in the shales or alternating beds of shale and limestone of Units VI and X. These shales become unstable upon weathering and tend to creep or slide under natural conditions. Slope instability is accentuated if the shales are exposed during excavation or slope modification. Additional slope stability problems are encountered in the karst regions of Unit II-c where unstable conditions develop on the slopes of sinkholes. Indiscriminate change in the geologic environment by land development may lead to unstable slopes during construction or over the long-term life of the project.

Foundations

The criteria for evaluating construction conditions were established primarily on the basis of the bearing strength and swelling characteristics in the surficial materials. Swelling clays are occasionally encountered in Unit VI and along the broad ridge tops in Subunit X-b. These clays can exert pressures greater than 6,000 psf when they are wet; great enough to cause foundation cracking. Additional subsurface conditions that will contribute to foundation problems are the organic deposits in the alluvium of Subunit I-a. These deposits have very low bearing strength and unless the organic materials are removed prior to construction, foundations built on these may require additional support (fig. 12).

Excavations

Excavation, or the difficulty of excavation, was evaluated with respect to the type of equipment and extent of effort required to move the materials. Materials that could be removed by a bulldozer, power shovel, loader, or dragline were considered to offer ***slight*** problems. Materials requiring ripping, special equipment, or limited blasting were classified as ***moderate***. Blasting will be required in most excavations encountering bedrock; and although not specifically noted in table 3, such excavations would be classified as ***severe***.

Road Performance

Road performance was considered as a basis for anticipating durability. Deterioration from frost action, pumping, and swelling, or failure because of unsatisfactory subgrade materials was included in the evaluation. A rating of ***moderate*** suggests that special precautions be taken as a result of one or more of these factors. No ***severe*** conditions were noted.

MINERAL RESOURCES

A rating of ***poor*** was given to an area where little or no economic potential exists at present. A ***good*** rating indicates that this area is conducive to one or more types of natural resource development.

The loss of limestone products through urban expansion is a very important economic problem. Not only is the commercial value of an important natural resource lost, but higher prices for this commodity will be passed on to the consumer as more remote areas are developed as alternate sources.

It is possible to extract limestone by routine underground mining procedures and retain the surface for housing or other developments. Room and pillar dimensions and roof thickness can be designed to insure surface stability. In areas of the county that are not presently urbanized, underground mining of limestone will allow the county to benefit from cheaper mineral products and sequentially use the land for urban development.

LAKE SITES

Geologic features that affect the successful development of a lake or reservoir include impermeable bedrock, adequate soil cover, stable foundations, and a suitable watershed. Water losses into cavernous bedrock, Unit IV; permeable soils, Unit III-c; or the failure of a dam foundation, Unit VI, are considered to cause ***severe*** lake development problems. Much of western St. Louis County has one or more of these problems. Conversely, excellent lakes can be developed when soil and bedrock are suitable, although even the most favorable lake sites can be ruined by poor construction practices or inadequate spillway design.

SUMMARY

Land use in St. Louis County has progressed in the past with little or no consideration being given to the soil and geologic setting of the county. Orderly urban expansion will progress with less difficulty if the engineering parameters of soil and bedrock are known. St. Louis County has been fortunate up to now since geologically the land that has been highly developed is relatively stable and relatively level. However, as urban expansion extends into the western portion of the county, rugged topography, unstable slopes, flood hazards, and important mineral resources should be considered by planners, developers, engineers, and the public.

Engineering geologic maps of 1:63,360 scale present a broad picture of the surface conditions for regional or long-range planning. Engineering geologic maps on the 1:24,000 scale assist in planning local housing developments, industrial sites, and other projects. However, neither map should be used in lieu of on-site investigations. All developments should be preceded by on-site investigations to avoid localized structural damage. The amount and type of investigation will depend on planned use.

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GLOSSARY

ALLUVIUM - clay, silt, gravel, or similar detrital materials transported by and deposited by streams.

AQUIFER - a pervious material which is capable of storing or transmitting groundwater.

ATTERBERG LIMITS - water contents corresponding to the boundaries between the solid, plastic, and liquid states of consistency of cohesive solids.

BEDDING PLANE - surface separating layers of sedimentary rocks.

CHERT - a compact, siliceous rock formed of cryptocrystalline varieties of silica, regardless of color.

COLLUVIUM - materials deposited chiefly by gravity at the base of a hill.

COMPACTION - reduction in pore space between individual grains as a result of pressure from overlying sediments or pressure from earth movements.

EOLIAN - general term applied to earth materials transported and deposited by wind action.

FORMATION - a geologic unit consisting of a succession of strata useful for mapping.

LIMESTONE - a sedimentary rock composed largely of the mineral calcite (calcium carbonate, $CaCO_3$), which has been formed by either organic or inorganic processes.

LOESS - an unconsolidated, unstratified aggregation of small (silt-sized) angular fragments generally believed to be wind deposited.

MOISTURE CONTENT - the ratio of the weight of water to the dry weight of the aggregate soil.

PERMEABILITY - the ease with which a fluid is transmitted through rock or earth materials.

PLASTICITY INDEX - range of moisture contents within which the soil exhibits the properties of a plastic solid.

RESIDUAL CLAY (SOIL) - material formed in place by the chemical decomposition of bedrock.

SANDSTONE - a detrital sedimentary rock formed by the cementation of individual grains of sand size.

SHALE - fine-grained sedimentary rock made up of silt and clay-sized particles.

SHEAR - change of shape without change of volume.

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