GEOLOGY FOR LAND-USE PLANNING OF SOUTHEASTERN OSAGE, EASTERN PAWNEE, NORTHERN CREEK, AND WESTERN TULSA COUNTIES, OKLAHOMA

By

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ABSTRACT

Mapping of geology for land-use planning of approximately 680 sq mi in southeastern Osage, eastern Pawnee, northern Creek, and western Tulsa Counties, Oklahoma was accomplished by interpreting published and unpublished geologic and soil data, and a variety of other information. Four maps show the physical conditions that should have the greatest effect upon the development of the region described above: (1) an environmental geology map, (2) a current land-use map, (3) a combined mineral-energy and water-resources map, and (4) a land-resource capability map. With today's rapid urbanization and emphasis on energy, it is essential for man to understand and to learn to manage the environment in which he lives. These maps and the accompanying text will assist in the making of important decisions about the long-term management of the environment in the study area.

The bedrock of the study area includes most of the Missourian Series and part of the Virgilian Series, both of the Pennsylvanian System. The Quaternary System includes stream-terrace deposits of the Pleistocene Series and alluvium of the Holocene Series. The Environmental Geology Map shows lithologic types of bedrock. Traditional stratigraphic boundaries are not shown. This map is considered to be less confusing and therefore more useful to the layman than traditional geologic maps.

The Land-Resource Capability Map is designed for use in evaluating

land for urban, industrial, and agricultural development. Basic mapping units have been delineated by integrating geologic information with information about various properties of soil and about known hazards. Using this approach, the type of bedrock, its engineering and chemical characteristics, and the thickness and physical properties of the soil are all considered.

The Current Land-use and Vegetation Map provides an inventory of land-use patterns in the study area. The combined Mineral-energy and Water-resources Map shows known locations and the distribution of deposits of some resources, such as petroleum and natural gas, limestone, sandstone, clay, coal, sand and gravel, and surface water and ground water.

The key to proper management of land resources is the evaluation of the impact of man's activities on tracts of land well in advance of development. The proper use of studies such as this one can aid in land-use planning. When properly informed, men will be able to make intelligent decisions in planning for community growth.

INTRODUCTION

Objectives and General Methods

The purpose of this study is to document geologic information in a manner that will make it useful for regional planning. With today's rapid urbanization and emphasis on energy, it is essential that man understands and learns to manage the environment in which he lives. The proper use of studies such as this one can aid in land-use planning. When properly informed, man will be able to make intelligent decisions in the planning of future community growth.

Specific information potentially valuable in the planning process has been compiled and is presented using four maps. These maps are (1) an environmental geology map, (2) a current land-use map, (3) a combined mineral-energy and water-resources map, and (4) a land-resource capability map. An explanation of the purpose, the methods of construction and classification, and of the potential of each map is set out in the text.

The map scale used in the study is intended to furnish information for general planning. The study should be used to provide information for determining specific areas for on-site investigations, but it may not show detail sufficient for final commitment of any tract of land.

Location of Study Area

The study area is located in northeastern Oklahoma a short distance west of Tulsa (Fig. 1). The 680 sq mi include all or parts of T 18, 19, 20, 21, 22 N, and R 8, 9, 10, 11, 12 E (Fig. 1). The larger and rapidly growing communities within the study area are Cleveland, Mannford, New Prue, Prattville, Red Fork, Sand Springs, and Sapulpa (Pl. 1). Smaller communities include Osage, Skiatook, and Terlton. Lake Keystone, only 15 mi from metropolitan Tulsa, is located in the western portion of the study area. With its scenic qualities and proximity to Tulsa, the study area should undergo a great deal of urban and suburban development in the years to come.

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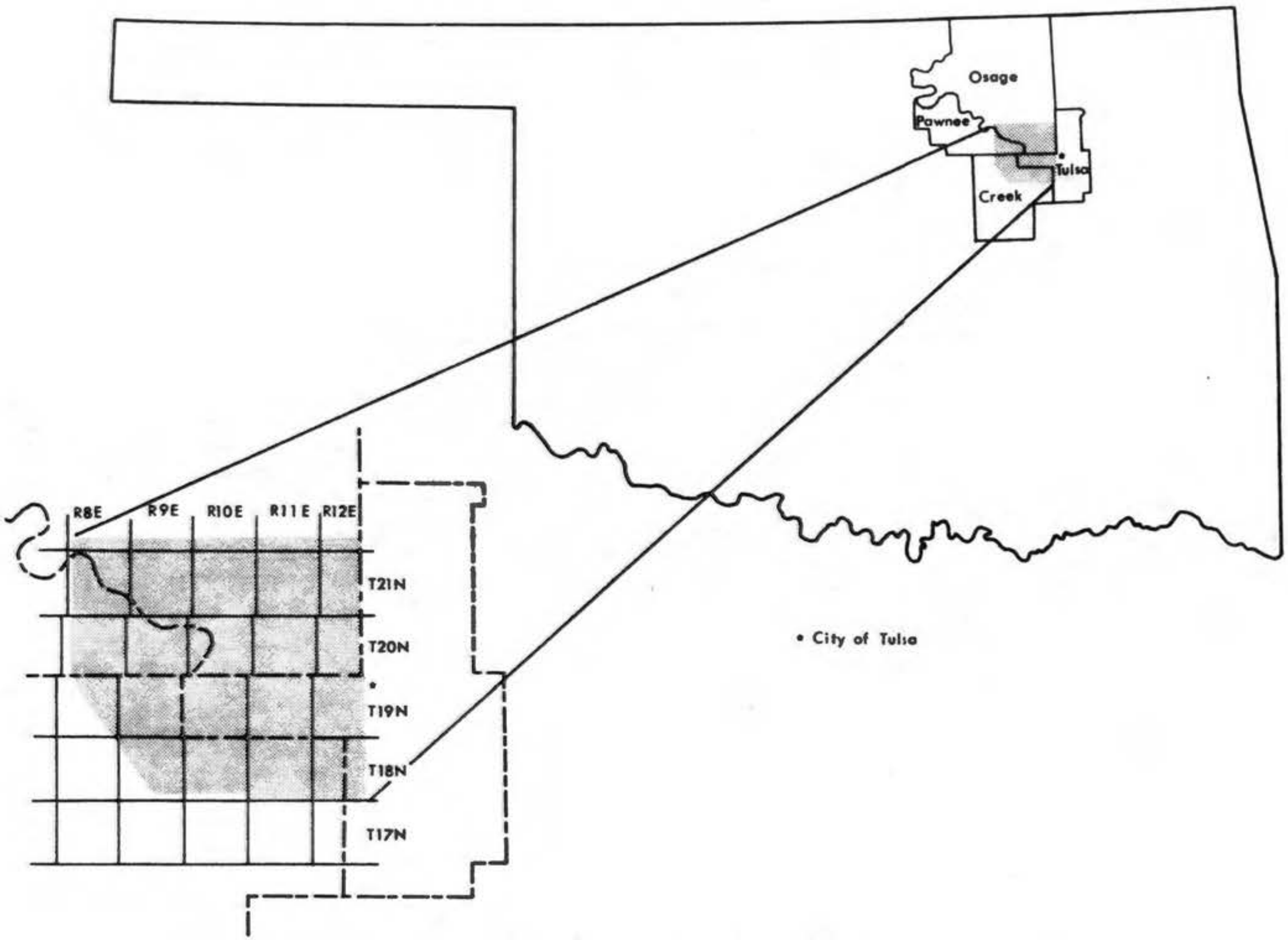

Figure 1.--Location map of study area (modified from Miser, 1954).

Durham, Director, The Environmental Institute, Oklahoma State University; Dr. George A. Gries, Dean, College of Arts and Sciences; Dr. Harold Zallen, formerly Director, Office of Research and Graduate Studies, College of Arts and Sciences, Oklahoma State University; Dr. Jerry J. Crockett, Director of Extension, College of Arts and Sciences; Dr. George S. Abshier, Director, Community Development Institute, University Extension; and Dr. Charles J. Mankin, Director, Oklahoma Geological Survey, The University of Oklahoma.

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Previous Work

Authors who have contributed most recently to the geologic knowledge of the study area are Greig (1959), Pawnee County; Oakes (1952, 1959), Tulsa and Creek Counties; and Russell (1955) and Carl (1956), Osage County. Regional studies have been conducted by Miser (1954) and by Hayes and others (1967, 1970). The most comprehensive study in recent years (Bennison and others, 1972a) presents results of an environmental-mapping project of Tulsa County. Many oil companies have conducted extensive geologic surveys in this area, but in most cases these materials are not available for review.

Data related to classification of soils in this area were obtained from the following Soil Conservation Service reports, which include:

Knobel and Brensing (1942), Tulsa County; Galloway and others (1959), Pawnee County; Oakes and Brensing (1959), Creek County; and from unpublished materials by Bourlier (1973), Osage County.

The Indian Nations Council of Governments (1969) published regional single-purpose maps of most of this area; the maps show general information about slopes, soils, bedrock geology, and mineral resources. Information on studies prior to the 1950's is available for review in papers by Oakes (1952, 1959).

Preparation of Base Map

U. S. Geological Survey topographic quadrangle maps were used in preparing the base map for this study. Available 7-1/2-min quadrangle maps include Avant S. E., Avant S. W., Cleveland, Keystone Dam, Kiefer N. W., Lake Sahoma, Mannford S. E., New Prue, Olive, Sand Springs, Sapulpa N., Sapulpa S., Terlton, and Wekiwa (Fig. 2). The quadrangle maps, published at the scale of 1:24,000 (or 1 in.:2,000 ft), were spliced and reduced photographically to the scale of 1:62,500 (or 1 in.: 1 mi, approximately). Blue-line prints were used for field mapping and for compilation of available data. Transparent mylar copies of the base map were used in preparing the final maps.

General Use of the Map

All maps in this study include a legend designed to explain each map unit that has been delineated. These legends are color-coded so that any specific map unit can be identified readily and traced throughout the map by its distinctive color. Descriptions of units in the legend of each map are purposely brief. However, each unit is

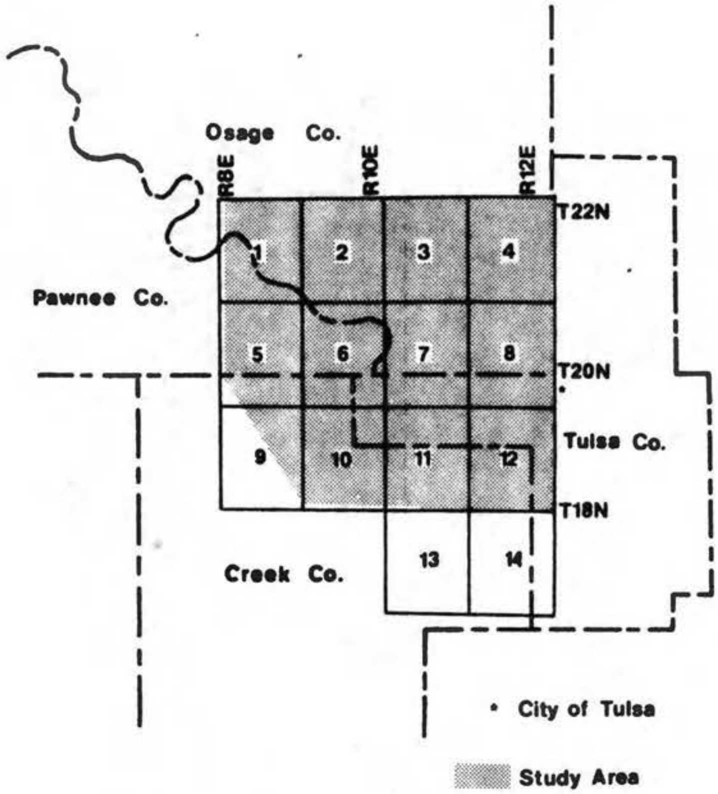

Figure 2.--Locations of topographic maps used for construction of base map (modified from U. S. Geological Survey, 1972).

discussed at greater length within the text.

Combining information from two or more maps may provide additional insight into the nature of an area which would be helpful in land-use planning. For example, evaluation of any tract of land, in terms of its potential for a specific land-use, can be accomplished by comparison of the properties of the area, as they are shown on each of the several maps. This comparison will permit the selection of several smaller tracts of land, of which a detailed on-site investigation may be desired.

Reference to the Land-resource Capabilities Map and the Environmental Geology Map will provide information on areas most suitable for construction and areas where problems related to unstable slopes might be encountered in some uses of land. The Current Land-use and Vegetation Map indicates current land-use and implies the relative value of tracts of land. Locations of airfields, railroads, major highways, pipelines, power-transmission lines and residential areas are shown. The Mineral-energy and Water-resources Map shows locations of oil and gas fields, and the areas in which construction materials and water resources could be available. Details of preparation, interpretation, and use of each map are discussed in the text.

GENERAL GEOLOGY

The bedrock of the study area includes almost all of the Missourian Series and part of the Virgilian Series of the Pennsylvanian System (Fig. 3, 4). The Quaternary System includes surficial materials made up of stream-terrace deposits of the Pleistocene Series and alluvium of the Holocene Series (Fig. 4).

The Environmental Geology Map (Pl. 2) shows lithologic types of bedrock. Traditional stratigraphic boundaries are not shown on the Environmental Geology Map. This kind of map is considered to be less confusing and therefore more useful to the layman than traditional geologic maps. The following discussion will provide the reader with some knowledge of the lithology and the engineering characteristics of the bedrock included in the study area. The discussion ends with a summary description of the engineering characteristics of the formations exposed within the study area (Table I).

Stratigraphy of the Pennsylvanian System

Missourian Series

Skiatook Group

Seminole Formation.-Only a portion of the Seminole Formation (Fig. 3) is exposed in the study area (Fig. 4). The formation consists mainly of sandy shale and nonresistant sandstone (Oakes, 1959, p. 48).

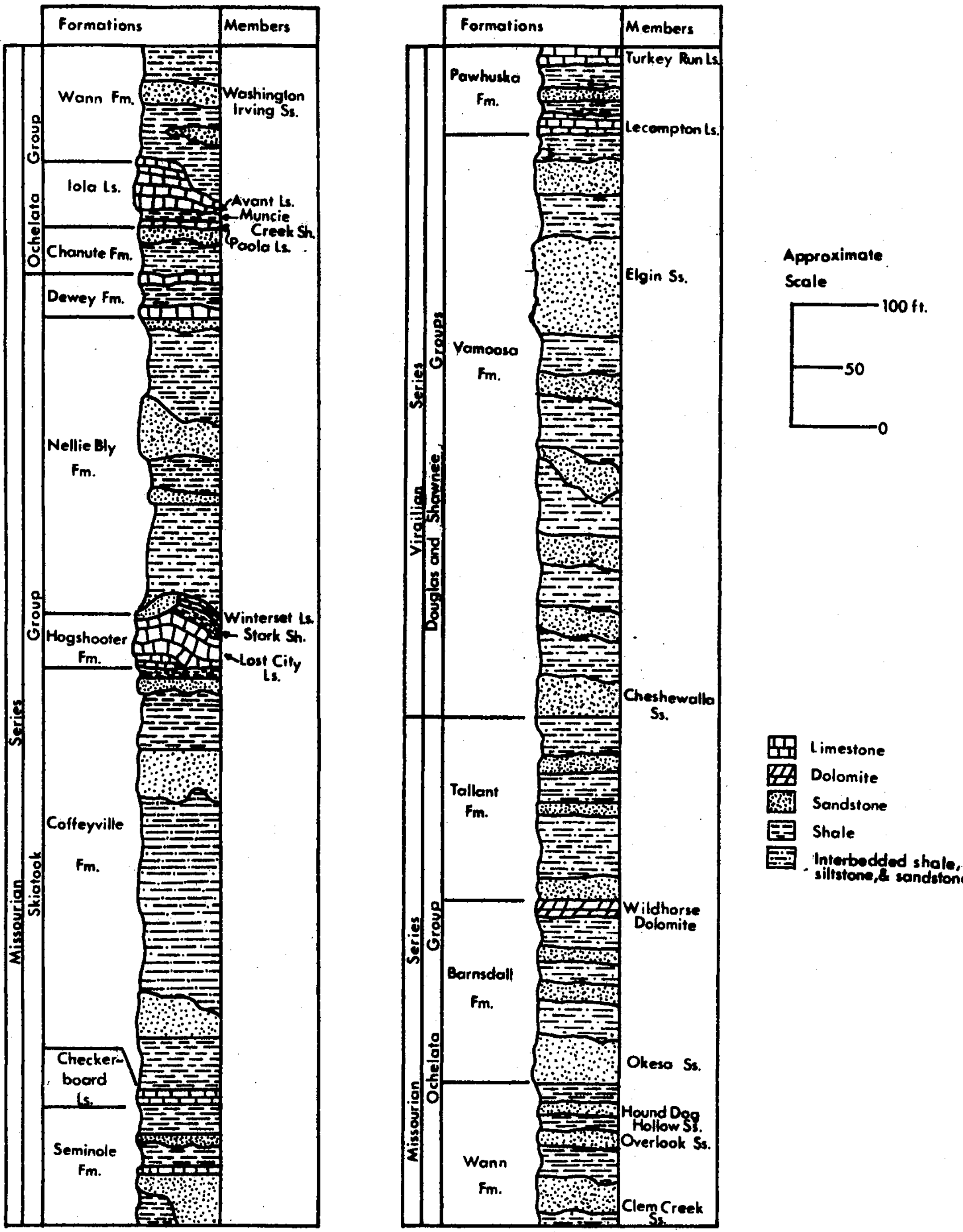

Figure 3.--Generalized stratigraphic section of Pennsylvanian rocks exposed in study area. (Ranks of units after Oakes, 1952; Bennison and others, 1972; Carl, 1957; and Russell, 1955.)

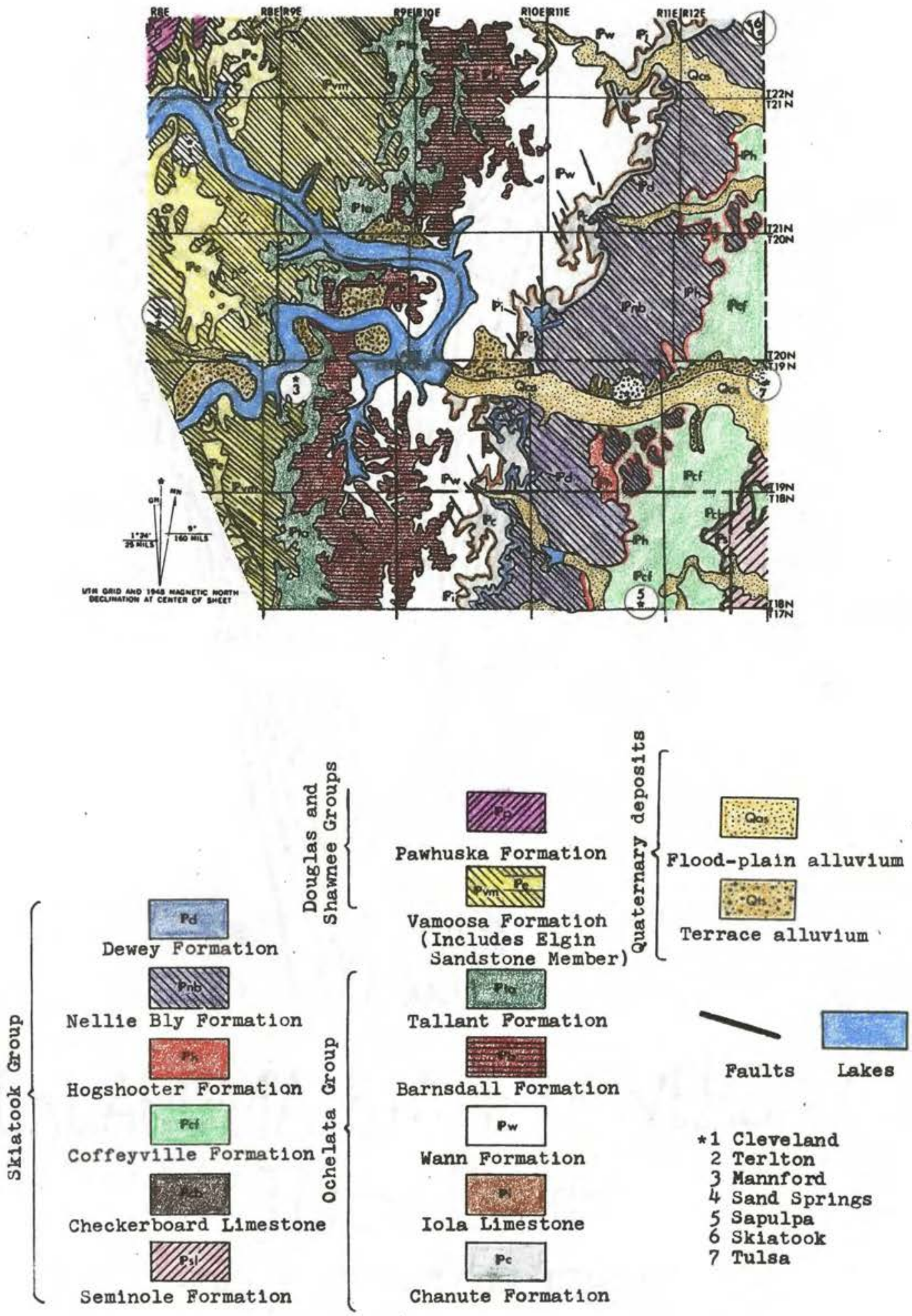

Figure 4.--Generalized geologic map of study area (after Miser, 1954).

TABLE I

ENGINEERING CHARACTERISTICS OF GEOLOGIC FORMATIONS WITHIN STUDY AREA

Unit	County	Approx. Thickness	Suitability	Seepage	Rippability	Landslides or Back-slope Failures	Topography
Seminole Formation	Creek	100-150 ft	Weathered shale units may undergo slow flowage during periods of heavy rainfall.	--------	Rippable	Shale units may undergo movement during periods of heavy rainfall.	
	Tulsa	Less than 100 ft	do.	Locally seeps are present at contacts where shale is overlain by sandstones.	Rippable	do.	Almost flat to slightly rolling with small escarpments formed by resistant sandstones
Checkerboard Limestone	Creek	2-3 ft	May be used as rip-rap.	--------	Minor nuisance because of poor rippability.	----------	
	Tulsa	3 ft	----------	--------		----------	In most areas, the outcrop is covered by soil.
Coffeyville Formation	Creek	375-450 ft	Sandstone may be suitable for subbase, and probably for several other construction purposes.	Seeps occur locally in sandstone units.	Mostly rippable; marginal at base.	----------	
	Osage	240-300 ft	----------	do.	do.	----------	Slightly rolling, sandstone caps prominent escarpments.
	Tulsa	350-440 ft	Sandstone, where soft, seems to be suitable for subbase.	do.	Sandstones may be nonrippable.	Slope failures may occur on slopes steeper than 2:1.	
Hogshooter Formation	Creek	5-20 ft	Where thick enough may be suitable for coarse aggregate and rip-rap.	Seeps along contacts between limestones and shale.	Nonrippable.	----------	Slightly rolling hills to moderately prominent escarpments
	Osage	15 ft	do.	do.	do.	----------	
	Tulsa	20-50 ft	do.	do.	do.	Downslope movement of large blocks occurs locally.	

TABLE I (Continued)

Unit	County	Approx. Thickness	Suitability	Seepage	Rippability	Landslides or Back-slope Failures	Topography
Nellie Bly Formation	Creek	220 ft	Sandstone may be suitable for subbase, and other construction purposes.	Seepage along contacts where sandstone overlies shale.	Rippable.	------------	
	Osage	165-250 ft	do.	Springs.	do.	----------	Tree-covered rolling hills and prominent escarpments capped by massive sandstones.
	Tulsa	280 ft	do.	Seepage along contacts.	do.	----------	
Dewey Formation	Creek	20-50 ft	Calcareous sandstones locally suitable for rip-rap.	None apparent.	Marginal.	----------	
	Osage	15-60 ft	Locally appears to be suitable for coarse aggregate.	do.	Limestone generally nonrippable.	----------	Forms prominent escarpment or bench.
	Tulsa	30-60 ft	do.	do.	do.	----------	
Chanute Formation	Creek	45-60 ft	Sandstone locally suitable for subbase.	None observed.	Rippable.	----------	
	Osage	10-35 ft	----------	do.	do.	Backslope failures may occur locally.	Slightly rolling.
	Tulsa	35 ft	----------	do.	do.	----------	
Iola Limestone	Creek	2-50 ft	Sandstone locally suitable for subbase.	None.	Rippable.	----------	
	Osage	5-70 ft	Limestone suitable for coarse aggregate and rip-rap.	Numerous along contacts of limestones and underlying shales	Limestone nonrippable	----------	Crops out along the front-slopes of escarpments capped by the overlying sandstone of Wann Formation.
	Tulsa	30 ft	do.	----------	do.	----------	

TABLE I (Continued)

Unit	County	Approx. Thickness	Suitability	Seepage	Rippability	Landslides or Backslope Failures	Topography
Wann Formation	Creek	140-180 ft	----------	Springs	Locally sandstone may not be rippable.	----------	
	Osage	200-250 ft	----------	----------	Locally limestone may not be rippable.	----------	
	Pawnee	More than 140 ft entire sec. not exposed	Sandstone appears to be suitable for rip-rap.	----------	Locally sandstone may not be rippable.	----------	Rolling to moderately hilly.
	Tulsa	26 ft	do.	----------	Rippable.	----------	
Barnsdall Formation	Creek	100-200 ft	Sandstone may be good subbase.	----------	Rippable.	Backslope failures noted on slopes steeper than 2:1.	
	Osage	100-160	do., Wildhorse Dolomite Member may be suitable for coarse aggregate and rip-rap.	Numerous seeps from sandstone units overlying shale.	Rippable except for Dolomite.	----------	Almost flat to slightly rolling.
	Pawnee	100 ft (exposed)	Sandstone may be good subbase.	----------	Sandstone may not be rippable.	----------	
	Tulsa	Basal portion present	May be soft enough locally for subbase.	----------	Rippable.	----------	
Tallant Formation	Creek	35-100	Sandstones at base appear to be suitable for subbase.	Numerous along contacts where sandstone overlies.	Rippable	----------	Escarpments with moderately steep sandstone-capped hills and narrow valleys underlain by shale.
	Osage	250 ft	Some sandstones generally suitable for rip-rap.	----------	Sandstone nonrippable locally.		
	Pawnee	150-120 ft	----------	----------	Rippable.	----------	

TABLE I (Continued)

Unit	County	Approx. Thickness	Suitability	Seepage	Rippability	Landslides or Back-slope Failures	Topography
Vamoosa Formation	Creek	?	Sandstones locally suitable for subbase.	Numerous where sandstones over-lie shale.	Rippable; massive sand-stones may require blasting.	Slumps may occur on slopes 2:1 or steeper.	Rugged and hilly.
	Osage	300-630 ft	do.	do.	Lower sand-stone may not be rippable locally.	Slope failures were noted in shale intervals on 2:1 slopes.	The sandstones cap the hills and farm escarpments, with shales forming the steep slopes and valleys.
	Pawnee	390 ft	do.	do.	do.	do.	
Pawhuska Formation	Osage	60-90 ft	Limestones locally are suit-able for concrete aggregate.	----------	Limestones generally nonrippable.	----------	Gently sloping hills with escarp-ments capped by limestone and sandstone.

Several coal seams are in the Seminole; however, the outcrop of only one coal bed has been shown on the Environmental Geology Map (Pl. 2). This unit was strip-mined in sec. 15, T18N, R12E.

Sandstone outcrops in the Seminole Formation are generally rippable (Bennison, 1972a, p. 48). Shale strata are rippable, and when exposed to weathering, have been observed to undergo slow flowage when wet (because of volume changes that take place as water is absorbed).

Checkerboard Limestone.-The Checkerboard Limestone (Fig. 3) crops out in the extreme southeastern portion of the study area (Fig. 4). This unit ranges from 2 to 3 ft thick and consists of light-gray, massive, fossiliferous limestone. The limestone generally weathers to yellow, rounded boulders in the soil profile (Bennison, 1972b, p. 49).

Due to its generally poor rippability, the Checkerboard Limestone may be a minor nuisance during construction work. For example, excavation during recent highway construction has involved the dropping of a huge steel ball to break up the massive limestone (Hayes and others, 1970, p. 37).

Coffeyville Formation.-The Coffeyville Formation (Fig. 3) ranges from 200 to 300 ft thick and is noted for extensive sandstone outcrops and boulder fields (Bennison, 1972c, p. 51). Silty to sandy shale forms about 70 percent of the formation with the remainder consisting of massive, lenticular sandstone beds. Lookout Mountain, located in sec. 15, 16, 21 and 22, T19N, R12E (Pl. 2) and Turkey Mountain, located in sec. 34 and 35, T18N, R12E (Pl. 2) are formed from the Coffeyville. Massive sandstone units cap both of these prominent features; the sandstone is underlain by interbedded shale and sandstone. Shale underlies most of the surrounding lowlands, in which sandstone crops out only locally. These shale units weather to form dark, thick soils with much clayey ironstone rubble (Bennison, 1972c, p. 51). Northward into Osage County, the Coffeyville is a thick unit predominantly of shale.

Massive sandstone units within the formation are generally nonrippable. Foundations of homes and other structures may be unstable locally where weak strata of shale underlie the construction site. Steep, rocky slopes developed on the Coffeyville may cause the costs of building roads and burying utility lines to be increased, as additional costs occur when excessive amounts of cut and fill, or of blasting, are required.

Hogshooter Formation.-The Hogshooter Formation is distributed erratically in the study area (Fig. 3, 4) (Bennison, 1972d, p. 55). Throughout most of the area the Hogshooter is made up of the Lost City Limestone Member, the Stark Shale Member, and the Winterset Limestone Member, in ascending order (Fig. 3). This formation ranges from about 20 to about 50 ft thick near Sand Springs and Prattville, in T19N, R11E (Pl. 1); however, it is only 1 to 2 ft thick about 4 mi south of Skiatook in T21N, R12E (Fig. 4).

At numerous localities, seeps occur along the contacts of the massive limestone units of the formation and the underlying shales. Moisture along these contacts can lead to the downslope movement of large blocks of limestone at some places (for example, see Fig. 5). Gliding of large blocks of limestone has caused problems in maintenance of roads, notably along the south valley wall of the Arkansas River in sec. 18, T19N, R12E, and sec. 13, T19N, R11E (Pl. 2). Massive limestones of the Hogshooter are nonrippable.

Figure 5.--Block glide of part of the Lost City Limestone Member of the Hogshooter Formation, sec. 18, T19N, R12E (Pl. 2).

Nellie Bly Formation.-The Nellie Bly Formation (Fig. 3, 4) consists of interbedded sandy to clayey shales and lenticular sandstones (Bennison, 1972e, p. 57). Thickness of the formation varies from about 200 to about 280 ft. On the Environmental Geology Map (Pl. 2) the formation is shown as shale, sandstone, and interbedded shale, siltstone, and sandstone.

Development of tracts of land for building sites and construction of roads is constrained by the steep, rocky slopes characteristic of topography on this formation. The Nellie Bly is rippable at most localities, but at some places, thick sandstone beds of the formation may be nonrippable.

Dewey Formation.-The Dewey Formation (Fig. 3, 4) is made up of one to three thin strata of limestone separated by dark, calcareous shales (Desjardins, 1972a, p. 60). The thickness of the Dewey varies throughout the study area due to the disconformable contact with the overlying Chanute Formation; a maximal thickness of 45 ft has been recorded in Tulsa County, in sec. 31, T19N, R11E (Desjardins, 1972a, p. 60).

During development of land, calcareous sandstones would be encountered within this formation at some localities. Locally, these sandstones generally would be nonrippable. The Dewey forms an escarpment across much of the study area.

Ochelata Group

Chanute Formation.-The Chanute Formation (Fig. 3, 4) consists of dark gray shales, gray, silty sandstones and several thin beds of coal. Thickness of the formation ranges from less than 15 ft in Osage County, in sec. 4, T21N, R11E, to almost 60 ft in Tulsa County, in T19N, R10E. The average thickness is approximately 35 ft.

The Chanute Formation causes few problems in construction. Because of the abundance of bedding planes and the density of joints, the sandstones of the Chanute generally are rippable (Desjardins, 1972b, p. 63). This unit provides stable foundation conditions for homesites. Only where severe slopes exist will construction be limited.

Iola Limestone.-The Iola Limestone (Fig. 3, 4) is divided into the Paola Limestone Member, the Muncie Creek Shale Member and the Avant Limestone Member, in ascending order. The Paola is an extremely calcareous sandstone, generally less than 3 ft thick. Exposed in the road cut of Oklahoma State Highway 20 in NE 1/4, sec. 24, T22N, R11E (Pl. 2), the member is 1.5 ft of dark gray, extremely calcareous, nonfossiliferous sandstone, which weathers to a dark rusty brown. The Muncie Creek Shale Member thins from north to south across the study area. It consists of dark to light gray, fissile to blocky shale containing small phosphatic nodules. The Avant Limestone Member is about 15 in. thick, on the average, in the study area. In sec. 24, T22N, R11E, it is one bed of gray to light pink, dense to finely crystalline, wavy- to thick-bedded, fossiliferous limestone. Southward it is divisible into three units - a lower bed (4 ft thick) of gray, finely crystalline, sandy limestone, a middle bed (6 ft thick) of buff to gray, fine-grained, medium-bedded sandstone, and an upper bed (2 ft thick) of gray, dense, finely crystalline, sandy limestone.

Locally, the Iola may provide a good source of aggregate. It is generally nonrippable and steep slopes developed on the Iola limit construction in many areas.

Wann Formation.-The Wann Formation (Fig. 3, 4) is made up of three basic units. The lowermost unit is chiefly gray to dark blue, blocky, fossiliferous shale slightly more than 100 ft thick, that contains many lenticular sandstone beds. The middle unit, 100 ft thick, consists of massive sandstones interbedded with shale. The sandstone is mapped as the Clem Creek Sandstone Member and the Washington Irving Sandstone Member (Oakes, 1952, p. 85). The uppermost unit of the Wann is chiefly maroon shale, which is 50 to 60 ft thick, and contains thin beds of sandstone.

Locally, the sandstone strata may not be rippable. Sandstones are generally suitable for use as subbase and rip-rap.

Barnsdall Formation.-The Barnsdall Formation (Fig. 3, 4) is dominantly gray shale and massive sandstone (Hayes and others, 1970, p. 34). The formation is approximately 130 to 170 ft thick. The uppermost unit of the Barnsdall Formation is the Wildhorse Dolomite Member, which is a hard, gray, thin-bedded to massive dolomite (Fig. 3). The Wildhorse crops out only in Osage County.

Except for the Wildhorse Dolomite Member, this formation is generally rippable. Locally, the dolomite may be suitable for coarse aggregate and rip-rap.

Tallant Formation.-The Tallant Formation, a complex of sandstone and shale, overlies the Barnsdall Formation (Fig. 3). The Tallant is approximately 250 ft thick in Osage County; however, it thins to less than 100 ft in northern Creek County.

Locally, massive sandstones may not be rippable. Sandstones generally are suitable for rip-rap and for subbase. Steep slopes may make construction difficult in some areas.

Virgilian Series

Douglas Group and Shawnee Group

Vamoosa Formation.-The Vamoosa Formation consists of approximately 450 ft of thin to massive sandstone strata, gray shales and locally, thin lenticular limestone beds (Fig. 3). Individual sandstone strata may be as much as 35 ft thick. Topography developed upon the Vamoosa is fairly rugged and hilly.

Numerous seeps at localities where sandstone overlies shale and where slopes are steep make slope failures significantly problematic at some places in terrain underlain by the Vamoosa. Sandstones of the Vamoosa generally are suited for use as subbase or rip-rap.

Pawhuska Formation.-The Pawhuska Formation (Fig. 3) is about 50 ft thick and consists of hard, dense, thin-bedded to massive limestone interbedded with sandstone and shale. This formation crops out in the extreme northwestern portion of the study area (Fig. 4).

Limestones of the Pawhuska Formation generally are nonrippable and are suitable for use as concrete aggregate.

Geology of the Quaternary System

A complete investigation of the Quaternary System is beyond the scope of this study; however, the following discussion seems appropriate. Numerous geologists have studied and mapped the Pennsylvanian bedrock of the study area, but few have recognized the actual extent of the Quaternary deposits.

The author has found that a great deal of the study area is mantled with high-level terrace-alluvial deposits. Much of this area previously has been mapped as not being underlain by materials of Quaternary age. These high terrace deposits are old alluvium that consists of clayey silt in the upper part and fine-grained sand, coarse-grained sand, and gravel in the lowermost 5 to 10 ft (Oklahoma Water Resources Board, 1971, p. 94).

Low-level terrace-alluvial deposits in proximity to streams include silt, fine-grained sand, medium- and coarse-grained sand and minor proportions of clay. Deposits of gravel are also in the alluvium along the Arkansas River. These low-level terrace-alluvial deposits probably are late Pleistocene and Holocene in age.

Structural Geology

The study area is within the Prairie Plains Homocline, a regional post-Permian structure composed of Pennsylvanian and Permian strata that dip westward from the Ozark Dome (Greig, 1959, p. 127). The regional dip of the homocline ranges from 20 to 50 ft per mile (Greig, 1959, p. 127). Numerous small domes, anticlines, and synclines are shown in rocks at the surface. Oil fields and gas fields are associated with many of these structural features.

Faults have been shown on the Environmental Geology Map (Pl. 2), although they are believed to be inactive. These normal faults are noteworthy not only because of the approximate parallelism among them, but also because of their grouping into "belts" or sets, which also are approximately parallel (Greig, 1959, p. 128). Individual faults generally trend N 20° to 45° W and are distributed in an en-echelon pattern. Trends of these en-echelon "belts" range from north to N 25° E. The faults are of small size in both vertical displacement and horizontal extent (Greig, 1959, p. 128).

ENVIRONMENTAL GEOLOGY MAP

The Environmental Geology Map (Pl. 2) included in this study is designed to be an inventory of resources of bedrock and sediment. The units shown on this map were derived from interpretation of the geologic maps of Tulsa County (Bennison and others, 1972a; Oakes, 1952), Osage County (Carl, 1957; Russell, 1955), Pawnee County (Greig, 1959), and Creek County (Oakes, 1959). Maps of soils were also found to be quite useful in mapping units of both bedrock and sediments, because at most places the soils seem to have been derived from the underlying parent material. Boundaries of formal stratigraphic units are not shown on the Environmental Geology Map (Pl. 2). The basic mapping units include: (1) shale, (2) sandstone, (3) limestone, (4) sandstone and shale, (5) sandstone, shale, and limestone, (6) limestone and shale, (7) flood-plain alluvium, (8) terrace alluvium, and (9) artificial land (Pl. 2). Faults shown on the map are believed to be exposed at the surface and to be inactive.

The map units are grouped into the following classes, or systems: (1) the sediment-dominant system, consisting of units that were deposited chiefly during the Quaternary Epoch by stream flow or by mass movement; (2) the bedrock (lithologic) system, including units of sedimentary bedrock, Pennsylvanian in age; and (3) the artificial system, made up of deposits resulting from the activities of man.

Sediment-Dominant System

The sediment-dominant system (Pl. 2) includes deposits of unconsolidated clay, silt, sand, and gravel. These deposits border the Arkansas River and other, smaller streams in the area. As mentioned previously, some of these materials are terrace-alluvial deposits that are above the present levels of streams, and others are flood plain-alluvial deposits associated with present levels of streams. Throughout the study area, both units are underlain by Pennsylvanian bedrock.

Bedrock (Lithologic) System

Basic rock types and combinations of them make up the bedrock (lithologic) units shown on the Environmental Geology Map. Figures 6, 7, 8, 9, and 10 are examples of several different associations of bedrock within the study area.

Artificial System

The artificial system includes man-made land resulting from strip-mining of coal. Only one such area is mapped within the study area. It is located in sec. 15, T18N, R12E (Pl. 3). This area has not been reclaimed and would be unsuitable for many land-uses.

Figure 6.--Strata predominantly of shale cropping out along Oklahoma State Highway 51, sec. 15, T19N, R10E. Thin-bedded, lenticular sandstone and limestone strata are included within the gray shale.

Figure 7.--Interbedded sandstone and shale, sec. 6, T19N, R8E. Sandstone strata form benches and shale strata form slopes.

Figure 8.--Ledge of limestone underlain by shale, both included in the Iola Limestone. Exposed on Oklahoma State Highway 51, SE¼, sec. 11, T19N, R10E.

Figure 9.--Ledge of massive sandstone overlying interbedded sandstone and shale, exposed along Oklahoma State Highway 51, NE¼, sec. 17, T19N, R10E.

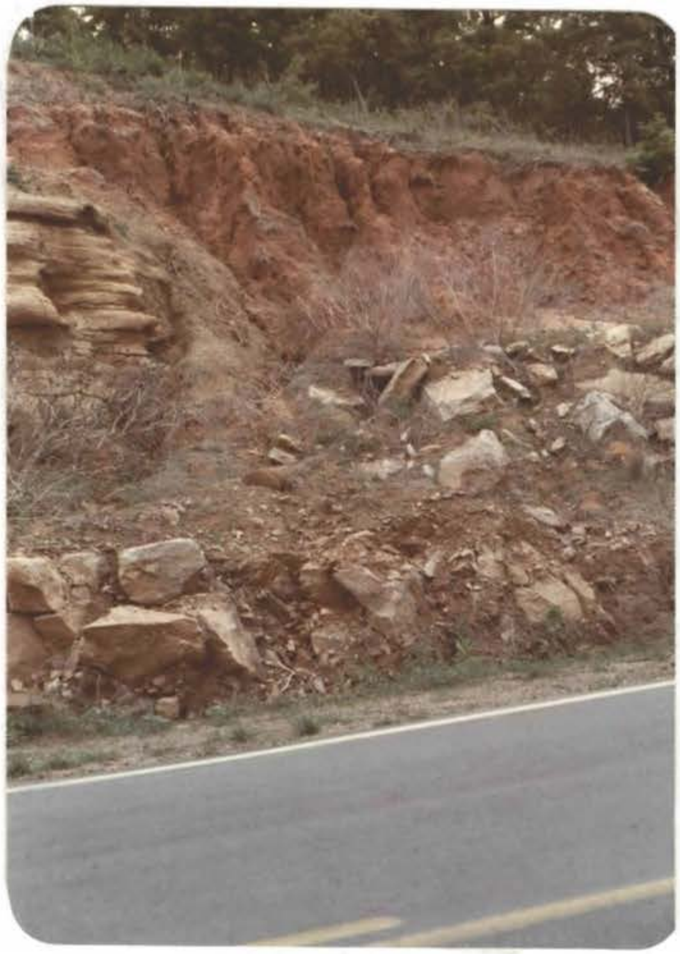

Figure 10.--Quaternary terrace-alluvium overlying limestone of the Hogshooter Formation, SE¼, sec. 1, T19N, R11E.

General Use of the Map

The Environmental Geology Map (Pl. 2) is valuable because it provides: (1) the basic data about kinds of rock that are necessary for generation of the Land-resource Capability Map (Pl. 4); (2) a guide for further development of mineral resources; and (3) a general bedrock map of the study area. Along with other special-use maps, this map can be utilized by builders, civil engineers, planners, economists, legislators, and others to investigate and to evaluate preliminary plans for development of land resources.

CURRENT LAND-USE AND VEGETATION MAP

Initial stages of land-use planning demand that present as well as past land-uses be recognized. Such information may be obtained by using the Current Land-use and Vegetation Map (Pl. 1), which was constructed from the most recent topographic base maps and aerial-photographic mosaics that could be obtained. Characteristic patterns, tones, and spatial arrangements were used to delineate residential, industrial, and agricultural uses of land.

Uses of large tracts of land are classified according to six categories: (1) residential-urban lands, (2) industrial lands, (3) recreational lands, (4) lowland timberlands, (5) upland timberlands, and (6) agricultural lands. Other land-use categories include major pipelines, powerlines, transportation routes, railways, artificial lands, reservoirs, rivers, and airfields.

Uses of Large Tracts of Land

Residential-Urban Lands

A large part of the study area consists of residential-urban lands. Included in this map unit are the communities of Cleveland, Mannford, New Prue, Osage, Prattville, Red Fork, Sand Springs, Sapulpa, Skiatook, Terlton, and Tulsa (Pl. 1). Many commercial areas, minor industrial areas, mobile-home parks, and recent subdivisions around Lake Keystone are delineated.

Industrial Lands

Areas being used for heavy industry, mining of sand and gravel, and for refineries or chemical plants are mapped as "industrial lands." These tracts of land are mostly on the Arkansas River flood plain, where water is plentiful, and where major transportation routes are concentrated (Pl. 1).

Several quarries and gravel pits are inactive and therefore are not included in this mapping unit. Some of these abandoned quarries and pits are used as sites for disposal of solid waste (for example, see sec. 13, T19N, R11E, on Pl. 1).

Recreational Lands

The lakes and streams in this area offer many kinds of recreational facilities to visitors interested in boating, camping, fishing, hunting, and related activities. Lake Keystone alone attracted 2.6 million visitors to the area in 1971. Numerous parks are located on Lake Keystone, including Keystone Park on the south shore, and Walnut Creek Park on the north shore (Pl. 1). Several kinds of recreational areas are shown on Plate 2, including golf courses, athletic fields, playgrounds, boat-access ramps, camp sites, picnic sites and swimming beaches (for example, see sec. 4, T18N, R12E, Pl. 1).

Lowland Timberlands

Hardwoods, including red and black oaks, pecan, walnut, maple, ash, cottonwood, elm, hackberry, and sycamore grow in bottomlands in the mapping area (Pl. 1) (Galloway and others, 1959; Oakes and

Brensing, 1959). This timberland chiefly is used for recreation, wildlife food and cover, and grazing. Because of the limited extent of these woodlands and the present market value of these kinds of wood, timber producers show little interest in exploiting lowland timber. However, commercial harvest of nuts from walnut and pecan trees does provide an additional source of income for many landowners.

Upland Timberlands

Upland timber is the major mapping unit of the "rolling" uplands of Tulsa and Osage Counties (Pl. 1). Timber consists mainly of pin oak, red oak, black oak, post oak, cedar, hickory and persimmon trees. These vast wooded areas provide food and cover for a variety of wildlife. Portions of these areas are used for grazing of cattle.

Other Categories of Land-Use

Numerous other land-uses are recognizable in the study area. Several landing strips are shown that accommodate only small, privately owned aircraft (Pl. 1). Most of these airfields are located atop cuestas developed on strata of sandstone and located short distances from the larger communities.

Major pipelines and power-transmission lines are shown on Plate 1. These lines are operated by several companies, and no attempt was made to designate ownership on Plate 1. However, information about ownership of many of these lines can be obtained from the Oklahoma Water Resources Board (1971, p. 136). Collector pipelines for smaller oil fields are not shown, but these lines should be located prior to any extensive construction that involves excavation.

Section 15, T18N, R12E (Pl. 1) includes the only land mapped as "artificial land." This is an area of abandoned coal strip-mines. These activities of man which have affected only small areas could not be shown practicably on Plate 1. Examples of such areas are dams on farm ponds, small "landfills" and fills for roads. Detailed studies may be necessary prior to construction on some of these small tracts of land.

General Use of the Map

The Current Land-use and Vegetation Map should be of significant value to planners and land developers. Through the recognition of types, locations, and distributions of present and past land uses, a basis for recommendations concerning future development may be established. For example, recommendation of the construction of a residential area in sec. 15, T18N, R12E (Pl. 2) would be undesirable. The development of the abandoned coal strip-mine would be very costly in comparison to development of adjacent tracts of land. Even after a reclamation program, foundations might be damaged by acidic soils or by differential compaction of soils. On the other hand, this location may be "ideal" as a recreational site.

Comparison of all of the maps in this study will help to define the compatibility of projected land uses with the present environment. Such an approach will allow maximal utilization of resources with the least disturbance of the natural environment.

MINERAL-ENERGY AND WATER-RESOURCES MAP

The distribution of all major mineral deposits known to the author, including sand and gravel, oil and gas, clay, coal, limestone, and sandstone is shown on the Mineral-energy and Water-resources Map (Pl. 3). In addition, availability and quality of surface water and ground water have been classified according to the standards outlined by the U. S. Public Health Service (Oklahoma Water Resources Board, 1971, 1972).

Mineral Resources

Petroleum and Natural Gas

Petroleum is the most valuable mineral produced in the region, by far. Oil was first produced commercially in the study area in June, 1901, at Red Fork, in Tulsa County (Pl. 1). Since this initial discovery, hundreds of millions of barrels of oil have been produced from many zones, ranging from Cambrian and Ordovician limestones to Upper Pennsylvanian sandstones (Greig, 1959, p. 146). In several fields, oil has been produced from more than one zone. Many fields are abandoned and others are produced using water-flood operations.

Areas of present and past production are shown on the Mineral-energy and Water-resources Map (Pl. 3). These areas indicate major fields where large quantities of oil have been recovered. However, numerous wells have been drilled outside of these areas, some of which have been productive.

Prospecting will continue as energy demands increase, but production is expected to decline as marginal wells are abandoned (Oklahoma Water Resources Board, 1971, p. 134). Secondary recovery operations will continue to account for the larger portion of oil production.

Limestone

Six limestone units were mapped within the study area (Pl. 3). To the author's knowledge, none of these units are being quarried today. Most of these limestone strata are too thin and impure to be utilized in the production of lime, crushed rock, or building stone (Carl, 1957, p. 70).

The largest operations for production of limestone were located in the vicinity of Sand Springs, in sec. 1, T19N, R11E, sec. 13, T19N, R11E, and sec. 18, T19N, R12E (Pl. 3). Quarries were developed in the Lost City Limestone Member of the Hogshooter Formation (Fig. 4). The facilities for mining and crushing rock and making cement were abandoned after the encroachment of residential areas upon these quarries (Thompson, 1972, p. 230). Stone used in construction of Oklahoma State Highway 20 included limestone quarried from the Avant Limestone Member of the Iola Limestone in sec. 24, T22N, R15E and dolomite quarried from the Wildhorse Dolomite Member of the Barnsdall Formation in sec. 19, T22N, R10E (Pl. 3).

Although large supplies of limestone are not available within the study area, commercial supplies are abundant elsewhere in this region. Therefore, adequate supplies of limestone should be available.

Sandstone

Sandstone used in construction has been obtained from the Nellie Bly Formation in sec. 31, T20N, R11E (Pl. 3). When split along bedding planes into slabs ranging from 1 to 3 in. thick, and sawed into uniform widths, stone has been used in a fashion similar to brick (Carl, 1957, p. 71). Other uses include fill for construction of highways and rip-rap, for stabilization of banks on levees and around reservoirs.

Clay

Several companies in this area have used clay for making cement, brick, tile, light-weight aggregate, pottery, and ceramics. Clays containing abundant illite and chlorite are contained in the Pennsylvanian shales, such as the shales of the Coffeyville Formation (Fig. 3). These shales are suitable as raw materials for products such as those listed above.

Shale from the Vamoosa Formation and from the lower part of the Wann Formation (Fig. 3) has been used for light-weight aggregate, artware, and earthenware (Oklahoma Water Resources Board, 1972, p. 123). The Acme Brick Company and other firms have quarried shale of the Vamoosa Formation southwest of Cleveland, in sec. 18, T21N, R8E (Greig, 1959, p. 138). Other manufacturers of brick and tile obtain clay from shales in the upper part of the Coffeyville Formation. The Frankoma Pottery Company, whose plant is located northwest of Sapulpa (Pl. 1), and the Sapulpa Brick and Tile Corporation probably are the largest users of clay within the study area.

Coal

In comparison to petroleum, coal produced in this region has been a minor commodity. Only one strip-mine is shown on the Mineral-energy and Water-resources Map (Pl. 3). Coal of the Seminole Formation was mined in sec. 15, T18N, R12E. As mentioned previously, this area has not been reclaimed and would be unsuitable for most land-uses.

Sand and Gravel

Flood-plain and channel deposits along the Arkansas River have been a valuable source of sand and gravel for metropolitan Tulsa for many decades. Sand has been produced mostly by dredging in the channel of the river. (Excavation in sand pits is limited by the high water table in the flood plain.) The completion of Keystone Dam has jeopardized this supply of construction materials. A recent survey indicates that the volume of sand being transported by the Arkansas River in the reaches below the dam has decreased significantly (Thompson, 1972, p. 227).

Alluvial terrace deposits along the Arkansas River mostly consist of gravel and fine sand. These materials have been considered to be less suitable for construction purposes than the sands of the younger flood-plain deposits (Thompson, 1972, p. 227). However, terrace materials are suitable for land-fill and for use in construction with asphalt. Most of these deposits are located in residential areas where zoning restrictions and the cost of land would prohibit the development of sand pits (Thompson, 1972, p. 227). Only recently have terrace materials been used for construction. They are currently being used as fill material in construction of a bridge across the Arkansas River south of Sand Springs (Pl. 3).

Asphalt

Asphalt-base petroleum has been produced from shallow sandstones in Osage and Pawnee Counties (Jordan, 1964). In Oklahoma, asphalt has been used chiefly for road-paving. The areas known to have produced heavy oil of high asphaltic content--oil suited for the manufacture of asphalt--are shown on Plate 3.

Water Resources

Surface Water

The primary lakes and rivers within the study area have been classified according to quality of the water contained in them. Three fundamental classes based upon amounts of total dissolved solids include: (1) good water (0-500 mg/l); (2) fair water (500-1,000 mg/l); (3) fair to poor water (frequently exceeds 1,000 mg/l) (Oklahoma Water Resources Board, 1971, p. 106).

Lake Keystone is the largest body of water located within the study area (Pl. 3). Construction of Keystone Dam began in January, 1957 and was completed for flood-control operation in September, 1965. The powerhouse was completed and the second generating unit of the 70,000 kilowatt powerplant went into operation in June, 1968. The average annual energy output is 228 million kilowatt-hours (U. S. Army Corps of Engineers, 1973, p. 5).

The lake provides a high degree of protection against flooding of the Arkansas River downstream from the dam. It also aids in navigation on the McClellan-Kerr Arkansas River Navigation System by the regulation of gate releases. Flow of the river is also regulated substantially by release of water for hydroelectric power generation (U. S. Army Corps of Engineers, 1973, p. 5). Total storage of the lake is 1,879,000 acre-feet, of which 1,216,000 acre-feet are available for the storage of floodwaters. Elevations of the power pool and flood-control pool are 723.0 and 754.0 ft, respectively (U. S. Army Corps of Engineers, 1973, p. 5). In April, 1973, water-level in the reservoir was at least as high as 751.5 ft (Newspaper Printing Corp., 1973, p. 1).

Figure 11.--Keystone Dam, sec. 4 and 9, T19N, R10E. Photo taken looking northwestward from sec. 15, T19N, R10E.

Quality of the water of Lake Keystone is generally fair to poor, frequently exceeding 1,000 mg/l total dissolved solids (based on data published by Oklahoma Water Resources Board, 1969, p. 51). The quality varies seasonally; higher concentrations of total dissolved solids occur in summer and winter. Quality of water in the Arkansas River below Keystone Dam varies from fair to poor. Concentrations of dissolved solids frequently exceed 2,000 mg/l (based on data of U. S. Geological Survey, 1969, p. 75).

Shell Lake, in T20N, R10E, and Lake Sahoma, in T18N, R11E, contain water of good quality (Pl. 3). The total-dissolved-solids contents of these lakes are generally less than 500 mg/l. Shell Lake is a water supply for the community of Sand Springs and Lake Sahoma. Approximately one-fourth of the water used in Sapulpa is drawn from Lake Sahoma.

Tributaries of the Verdigris River classified in this study include Polecat Creek, Delaware Creek, and Hominy Creek. Quality of water in Polecat Creek and Delaware Creek is considered to be fair to poor (Oklahoma Water Resources Board, 1971, p. 106). However, the reach of Hominy Creek that extends through the study area generally is of fair quality (Pl. 3). Authorized by the Flood Control Act of 1963, Skiatook Lake is to be located on Hominy Creek, 5 mi west of Skiatook. It will control the runoff from a drainage area of 354 sq mi (U. S. Army Corps of Engineers, 1973, p. 18).

Ground Water

In this study, ground water has been classified according to quality and availability. Two classes of water quality, based upon total amounts of dissolved solids, include: (1) good to fair (300 to

1,000 mg/l) and (2) fair to poor (500 to 3,000 mg/l) (Oklahoma Water Resources Board, 1971, p. 93). Data were not available for evaluation of quality of water from alluvium in the valleys of Hominy Creek, Delaware Creek, Rock Creek, and Euchee Creek (Pl. 3); therefore, these areas were not classified. Evaluation of the availability of ground water was based on well yields measured in gallons per minute (gpm).

Alluvium of the flood plain of the Arkansas River ranges from 20 to 40 ft thick. The overall water quality is good to fair; an estimate of the typical dissolved-solids content is a value of less than 500 mg/l. Wells completed in the thicker and coarser beds of sand yield from 20 to 80 gpm. Yields of 400 gpm have been obtained along the Arkansas River; however, such yields are uncommon.

Terrace-alluvium along the Arkansas River consists of clayey silt in the upper part of the alluvium, grading downward into fine sand and to coarse sand and gravel in the lowermost 5 to 10 ft (Oklahoma Water Resources Board, 1971, p. 94). The thickness of most terrace-alluvial deposits ranges from about 5 to about 40 ft; the average thickness is 32 ft (Kent, 1972, p. 208). Yields of 20 gpm are common, although yields of 100 gpm are obtainable locally.

The underlying bedrock (shale, sandstone, siltstone, and limestone) is less favorable for development of supplies of ground water. Yields of wells generally are low, ranging from less than 1 gpm to 10 gpm. Quality of water is fair to poor; measurements of total dissolved solids commonly are greater than 500 mg/l. The Vamoosa Formation, which crops out in the western portion of the study area (Fig. 4), has good potential for further development of ground-water supplies. The United States Geological Survey is studying the sandstone units of the Vamoosa Formation in order to evaluate this potential (Joe D'Lugosz, personal communication, 1972).

LAND-RESOURCE CAPABILITIES MAP

The Land-resource Capabilities Map (Pl. 4) is designed for use in evaluating land for urban, industrial, and agricultural development. Basic mapping units were delineated by integrating geologic information with information about various properties of soil and about known hazards. This map (Pl. 4) will provide meaningful information to persons making decisions about land-use by showing units delineated according to capability. These units, however, are not intended to be used as information from which to make final decisions in the evaluation of prospective building sites, or for final commitments of tracts of land. Instead, the Land-resource Capabilities Map is designed to aid in large-scale site evaluation.

Land-resource capability units are classified according to the method shown in Table II of this study. The first-order classification of units is based on the parent material, or geologic material. Second-order classification is based on thickness of soil; third-order classification is based on various other important properties of soil and upon potential hazards associated with the soil, such as salinity, flood potential, susceptibility to erosion, and seepage.

Using these classifications, four broad categories of natural and artificial land units are mapped within the study area (Table III). These units include: (1) the sediment-dominant system (terrace alluvium and flood-plain alluvium), in which properties of stream-deposited

TABLE II

CLASSIFICATION OF LAND-RESOURCE CAPABILITY UNITS

First-order classification based on rock type or parent material

Unit
Limestone
Shale
Sandstone
Sandstone and shale
Limestone and shale
Sandstone, limestone, and shale
Terrace alluvium
Flood plain alluvium
Artificial land

Second-order classification based on soil (depth to base of B horizon)

Subunit
Soil thinner than 30 in.
Soil 30 in. to 45 in. thick
Soil thicker than 45 in.

Second-order classification based on soil texture of B horizon

Subunit
Clay with low plasticity (CL)
Clay with high plasticity (CH)
Silt with low plasticity (ML)
Silt with high plasticity (MH)
Sand, well graded (with silt and/or clay) (SW, SM, SC)
Sand, poorly graded (no silt or clay) (SP)
Gravel, well graded (with silt and/or clay) (GW, GM, GC)
Gravel, poorly graded (no silt or clay) (GP)

Third-order classification based on specific properties and hazards

Subunit
High acidity
High alkalinity
High flood potential
Possible slope failures
Seepage
Steep slopes
Seasonally high water table
High susceptibility to water erosion
Low ripping potential

TABLE III

EVALUATION OF LAND-RESOURCE CAPABILITY UNITS FOR LAND-USE PLANNING

System	Subsystem	Unit	Activities: Liquid Waste Disposal	Solid Waste Disposal	Light Construction	Heavy Construction	Highway Location (Subgrade)	Select or Subbase Material	Base Material	Aggregate	Fill Material	Excavation	Underground Installations	Buried Cables and Pipes	Properties of Soil: Shrink-Swell Potential	Permeability	Erodibility	Water Table Position	Seepage	Acidity	Alkalinity	Ripping Potential	Slope Stability	Flood Potential
Sediment-Dominant System	Flood Plain Alluvium	1	-	-	-	-	0	+	-	X	+	+	-	0	M	L	L	H	L	M	L	H	M	H
		2	-	-	-	-	-	-	-	X	-	+	-	0	H	L	L	H	L	M	M	H	L	H
		3	-	-	-	-	0	+	-	-	-	+	-	0	L	H	H	H	L	M	M	H	M	H
		4	X	X	X	X	X	+	0	+	+	X	X	X	L	H	H	H	H	L	L	H	M	H
	Terrace Alluvium	5	-	-	+	0	+	0	-	-	+	+	-	-	M	L	H	H	L	H	L	H	L	L
		6	-	-	+	0	0	+	0	-	+	+	-	0	M	H	M	H	L	L	M	H	L	L
		7	-	-	+	0	0	0	0	-	0	+	-	0	M	H	H	M	L	L	M	H	M	L
		8	-	-	+	+	0	+	-	-	+	+	-	0	L	M	H	H	H	M	L	H	M	L
Soil-Dominant System		9	-	-	+	+	+	0	-	-	0	0	0	0	M	M	M	L	H	M	L	M	L	L
		10	0	0	-	-	-	-	-	0	-	+	-	0	H	L	M	H	L	L	M	M	L	H
		11	+	+	+	+	+	0	0	X	+	0	0	0	M	L	M	L	L	H	L	H	L	H
		12	+	+	0	0	-	-	-	X	-	+	-	0	H	L	M	H	L	M	M	H	L	M
		13	-	-	+	+	+	0	0	X	0	-	-	0	L	M	M	L	H	M	L	M	L	L
Bedrock-Dominant System		14	-	-	+	+	+	0	0	-	-	-	-	-	L	M	L	L	H	L	L	L	L	L
		15	-	-	-	-	-	0	-	X	0	0	0	-	L	M	M	L	H	H	L	M	L	L
		16	-	-	-	0	0	-	0	-	0	+	-	0	M	L	M	L	L	H	M	H	M	M
		17	-	-	-	-	-	0	-	-	0	0	0	-	L	M	M	L	H	L	L	M	L	L
		18	-	-	+	+	+	0	+	+	-	-	-	-	L	M	L	L	H	L	L	L	L	L
		19	0	0	0	0	0	0	0	0	0	-	-	0	H	L	M	H	H	L	M	L	L	L
Artificial System	Strip Mines	20	-	0	-	-	-	-	-	-	+	0	0	-	M	H	H	L	H	H	L	H	L	L

Anticipated Capability

+ Most favorable capability; minimal problems
0 Moderately favorable capability; moderate problems
- Least favorable capability; maximal problems
X Ordinarily not considered for this use.

Key

H High
M Moderate
L Low

alluvium are of primary environmental significance; (2) the bedrock-dominant system (areas where bedrock is overlain by soil thinner than 30 in.), in which properties of bedrock are of primary significance; (3) the soil-dominant system (areas where soil is thicker than 30 in.), in which properties of soil are of primary importance; and (4) the artificial system (for example, oil-waste lands), in which the effects of man's activities are of primary significance.

Land-Resource Capability Units

Recognition of the various properties of land-resource capability units that may limit or enhance their uses for specific purposes or activities is extremely important in land-use planning. These properties include high shrink-swell potential, high acidity, high alkalinity, steep slopes, susceptibility to water erosion, high flood potential, high or low permeability, seepage, seasonally high water table, and low ripping potential (high induration). Each land-resource capability unit is discussed below with regard to those properties of soil and bedrock that are most significant. Properties of the units are summarized in Table III. Much of the information included in this discussion of capability units was drawn from the work of Bourlier (1973), Knobel and Brensing (1942), and Oakes and Brensing (1959).

Man's activities involving land-resource capability units are evaluated on the bases of dominant system, soil thickness and texture, and other natural properties (Table II). Considering these properties, several of man's activities involving the different land-resource capability units are shown in Table III. Units that are regarded as being unfavorable for a particular activity are designated as "least favorable," whereas units with intermediate potential are designated as "moderately favorable;" those units considered to be favorable are designated as "most favorable." Significant properties of the units are measured in the qualitative terms "high," "moderate," and "low." For ease of recognition of the various units shown on Plate 4, the units are designated by color.

Sediment-Dominant System

Unit 1

In land designated as Unit 1 on the Land-resource Capabilities Map (Pl. 4) the material at the surface is flood-plain alluvium, which consists of unconsolidated silt and clay thicker than 45 inches. These deposits are classified principally as soils of the Verdigris, Breaks-alluvial land complex, and Cleora series. Geologically, they are recent stream deposits, laid down during the Quaternary Period. These materials have low plasticity, low to moderate permeability and are slightly acidic. The water table is commonly within several feet of the land surface. The areas mapped as Unit 1 are subject to occasional flooding. Unit 1 is least desirable for use in waste disposal (because of a high probability of pollution of ground water), construction of some kinds of buildings (because of tendency of material to compact), and underground installations (because of instability of the material during excavation and because of the high water table). Characteristics of Unit 1 make these materials suitable for use as select material and fill material. In the terrain characterized by materials of Unit 1, foundations for buildings are easily excavated, and the terrain would be suited for the locations of reservoirs. Of course, any substantial buildings on this terrain should be flood-proofed.

Unit 2

Land classified as Unit 2 is flood-plain alluvium, which consists of unconsolidated silt and clay, thicker than 45 inches. Soils of the Osage and Lightning series are generally included within this mapping unit. These materials are highly plastic, slightly acidic, and have low permeability. Unit 2 is characterized by a high water table and is subject to occasional flooding. Minimal problems may be expected in digging excavations. However, capabilities are seriously limited with respect to waste disposal, light construction (for example, houses and warehouses) and heavy construction (for example, large office buildings and grain elevators), location of highways, and use of the material for select and fill materials (because of high plasticity), base material (because of high plasticity), and in construction of underground installations (Table III).

Unit 3

Unit 3 consists of flood-plain alluvium thicker than 45 in. located generally along the Arkansas River. The unit includes primarily sandy soils of the Yahola, Port, Lincoln, and Brazos series. The material has moderate to high permeability, low plasticity, and slight acidity. The water table is commonly within several feet of the surface. Areas of Unit 3 are subject to occasional flooding. The unit is least suited for use in waste disposal, light and heavy construction, base material, and in construction of underground installations.

Conditions are generally favorable for use as select material and for general excavation.

Unit 4

Land classified as Unit 4 includes the main channel of the Arkansas River and lies from 2 to 8 ft above the normal water level. These areas generally lack vegetation and consist of medium to coarse sand and gravel. Such areas are subject to almost-continuous change, as they are flooded during each release of water from Keystone Reservoir. At several locations large quantities of these materials are removed from the channel for use in construction. Unit 4 is well suited for use as aggregate, and as fill material.

Unit 5

Unit 5 is terrace alluvium, which consists of silty, clayey soil thicker than 45 inches. This unit is made up of stream deposits, laid down when streams flowed at higher levels during the earlier part of the Quaternary Period. The principal soils associated with these deposits are the Parsons, Taloka and Choteau series. Materials of this unit have low permeability, moderate plasticity, and high acidity. The water table is commonly within several feet of the surface. Areas of Unit 5 are considered to be least suited for waste disposal, for use as aggregate and base material, for construction of underground installations, and for burying pipes and cables. This unit is generally favorable for light construction, location of highways, general excavation, and for use as fill material.

Unit 6

Land designated as Unit 6 is terrace alluvium thicker than 45 in. that consists of well-graded sand and clay with moderate to high permeability, moderate to high plasticity, and moderate alkalinity. Typical associated soils are classified as the McLain, Reinach, and Lela series. Various properties (such as moderate to high plasticity) limit the use of Unit 6 for waste disposal, and for the construction of underground installations. Conditions are generally favorable for activities such as light construction, use as select material and fill material, and for general excavation.

Unit 7

Unit 7 is composed of terrace alluvium made up of well-graded sand and clay thicker than 45 inches. Among the variety of soils included in this unit are the Teller, Vanoss, Norge, Mason, and Minco series. These materials generally have moderate plasticity, moderate to high permeability, slight alkalinity and are susceptible to water erosion. The terrace alluvium is least suited for waste disposal, use as aggregate, and construction of underground installations. Properties generally are favorable for use in light construction and general excavation.

Unit 8

Land classified as Unit 8 is composed of sandy, or sandy and clayey, terrace alluvium thicker than 45 inches. Principal soils developed on this unit are the Dougherty and Eufaula series. These materials are characterized by low plasticity, moderate permeability, and slight acidity. The land is generally steeply sloping, irregular in surficial configuration, and highly susceptible to water erosion. Unit 8 is least suited for use in waste disposal, as base material, as aggregate, and for underground installations. Conditions are generally favorable for light and heavy construction, for use as select material and fill material, and for general excavation.

Soil-Dominant System

Unit 9

Areas included in Unit 9 consist of sandstone overlain by silty or sandy soil thicker than 30 inches. The principal soils classified as Unit 9 include the Dennis-Bates, Stephenville, and Cleburne series. The unit has moderate plasticity, moderate permeability, and low to moderate acidity. Seeps are common where soil thins downslope, and along contacts of the soil with underlying strata. Bedrock at depth is generally nonrippable. Unit 9 is least favorable for waste disposal (because of the probability of pollution of ground water), for use as base material (because of moderate plasticity of the soil), and for aggregate. Minimal problems are expectable in light and heavy construction, and in location of highways.

Unit 10

Uni 10 includes limestone or calcareous shale overlain by clayey soil thicker than 30 inches. Principal soils developed on Unit 10 are the Newtonia and Sogn series. These soils have moderate to high plasticity, low permeability, and local "slick spots" (areas where soil is unusually slick when wet). Limestone units are generally nonrippable where they are thicker than 1 foot. Areas included in this unit are considered to be least suited for light and heavy construction (because of high plasticity of associated soils), highway location, use as base and fill materials, and for construction of underground installations. Properties are generally favorable for excavation.

Unit 11

Thick soil overlying shale strata that locally contain sandstone characterizes land classified as Unit 11. The soil is clayey, thicker than 30 in., and generally is assigned to the Dennis series. Unit 11 has low to moderate plasticity, low permeability, and high acidity. Properties are generally favorable for disposal of liquid and solid wastes, for light and heavy construction, for highway location, and for use as fill material.

Unit 12

Unit 12 includes very clayey soil derived from shale. Principal soils developed in the areas mapped as this unit are the Bates and Okemah series. The unit is characterized by soils thicker than 30 in. with high plasticity, low permeability, slight acidity, and a seasonally high water table. The underlying shale bedrock may be slightly alkaline. Properties are generally favorable for disposal of liquid and solid waste and for excavation. However, capabilities are significantly limited with respect to location of highways (because of high plasticity), use as select materials, base materials, and as fill material (because of low permeability), and construction of underground installations (because of high plasticity of associated soils).

Unit 13

Land classified under Unit 13 includes terrain of interbedded siltstone, shale, and sandstone cropping out at the surface or overlain by silty, clayey, sandy soil thicker than 30 inches. These materials are slightly plastic, highly permeable, and strongly acidic. Seeps are common where the soil thins downslope. The strata of siltstone, shale, and sandstone are rippable, except in areas where the sandstone is thick. Slopes in road cuts and other excavations may be unstable at some locations. Materials classified as Unit 13 are least suited for waste disposal (because of high acidity and the probability of pollution of ground water), for excavation (because bedrock generally is nonrippable), for underground installations, and locally, for buried pipes and cables (because of difficulty in excavation). Properties are generally good for light and heavy construction, and for location of highways.

Bedrock-Dominant System

Unit 14

Sandstone overlain by sandy soil less than 30 in. thick characterizes Unit 14. Soils associated with Unit 14 include the Bates, Collinsville, Hector, Darnell, Stephenville, and Linker series. These sandstones are generally nonrippable except where highly jointed. Seeps are common where soil thins downslope, and along contacts of sandstone and underlying strata. Areas included in Unit 14 are least favorable for waste disposal, for use as sources of aggregate and fill material, for excavation, underground installations, buried pipes and cables, and for location of reservoirs. Properties are generally good for light and heavy construction, and for location of highways.

Unit 15

Unit 15 consists of interbedded sandstone, shale, and siltstone. Typically, soils overlying these areas are thinner than 30 in., sandy, stony, and acidic. Soils of this unit include the Bates, Coweta, Collinsville, Hector, and Linker series. Seepage is common along bedding planes in the sandstone and at places where soil thins downslope. Strata are rippable except in areas where sandstone is thick. Capabilities are seriously limited with respect to waste disposal (because of the potential of polluting ground water), light and heavy construction, highway location (because of steep slopes, locally), use as base material, and for burying cables and pipes (because of difficulty in excavation).

Unit 16

Land classified as Unit 16 is characterized by clayey soil thinner than 30 in. that overlies strata of shale. Soils associated with this unit primarily are assigned to the Niotaze series. These materials are strongly acidic, moderately plastic, slightly permeable, and generally rippable. These areas are least suited for waste disposal (for instance, cells for sanitary landfills would be excavated in shale bedrock), light and heavy construction, for sources of base material and aggregate, and for construction of underground installations.

Unit 17

Unit 17 includes terrain where interbedded sandstone, shale, and limestone are overlain by colluvial soil thinner than 30 inches. Bedrock is exposed mostly as rock benches and in nearly vertical slopes. Units are generally rippable except where individual strata are thicker than about 1 foot. Seepage is common along contacts between strata of limestone and shale. Unit 17 is least suited for waste disposal, light and heavy construction, highway location (because of steep slopes), base material, aggregate, and buried cables and pipes.

Unit 18

This unit includes areas where limestone is at the surface or is overlain by silty or clayey soil thinner than 30 inches. Typically, soils of this unit belong to the Summit series. Strata are generally nonrippable. Seppage is common locally from between bedding planes, along joints, and along contacts of limestone and the underlying units. The weathered surface of the limestone may be quite irregular. Relief on the weathered surface may exceed 45 in. at some locations. Blocks of limestone creeping downslope are common along outcrops. Unit 18 is least suited for waste disposal (because of the potential of pollution of ground water), for fill material, excavation (because of the difficulty of removing limestone), or for underground installations including buried cables and pipes.

Unit 19

Land classified as Unit 19 includes interbedded limestone and shale at the surface or overlain by silty, clayey soil thinner than 30 inches. Creep of limestone blocks occurs along outcrops. Seeps are common locally along contacts where limestone overlies shale. Solution-widened and clay-filled joints may be present in limestone strata. Limestone strata generally are nonrippable where they are thicker than 1 foot. Unit 19 is generally unsuitable for most construction purposes because of the steep slopes that are developed where limestone overlies shale.

Artificial System

Unit 20

Unit 20 is man-made land that resulted from strip-mining of coal. As discussed previously, only one such area exists within the study area, and it is located in sec. 15, T18N, R12E (Pl. 3). Material consists primarily of fragments of sandstone, shale, and limestone mixed with soil in steeply sloping mounds, 20 to 40 ft high. Physical properties are quite variable, and seeps are common.

The use of these materials is restricted to fill material and excavation. However, reclamation programs may make this land available for future development.

General Use of the Map

Land-resource capability units can be used to provide valuable information for persons making decisions about land-use. The key to proper management of land and other resources is evaluation of the impact of man's activities on tracts of land, well in advance of development. For example, Unit 12 (Pl. 4) which is an impermeable clayey material, may provide good sites for location of solid-waste disposal facilities without adverse effects upon the ground water. Within the terrain included in this same unit, however, foundation sites may be very poor because of the high plasticity of the soil and of the underlying weathered shale strata. Information such as this, obtained in advance of development, should aid in land-use planning.

CONCLUSIONS

This study provides geologic information documented in a manner that will make it useful for regional planning. Specific information potentially valuable in the planning process has been compiled and is presented using four maps. These basic maps are accompanied by explanatory legends and descriptive text:

(1) an Environmental Geology Map, which shows distribution of types of bedrock and sediments;

(2) a Current Land-use and Vegetation Map, which shows an inventory of land-use patterns in the study area;

(3) a Mineral-energy and Water-resources Map on which are shown the distributions of current resources, such as petroleum and natural gas, limestone, sandstone, clay, coal, sand and gravel, surface water and ground water;

(4) a Land-resource Capability Map, which can be used for decision-making by delineating units of land according to their capabilities.

The land-resource capability map is designed for use in evaluating land for urban, industrial, and agricultural development. Basic mapping units are delineated by integrating geologic information with information about properties of the soil and about known hazards. This map will provide meaningful information to persons making decisions about land-use, because units are delineated according to capability or suitability. Land-resource capability units are grouped into genetic systems as follows:

(1) The sediment-dominant system consists of four units of terrace alluvium and four units of flood-plain alluvium.

(2) The soil-dominant system includes five units.

(3) The bedrock-dominant system, based on lithology of the rocks and physical properties of the thin soil mantle, is comprised of six distinctive units.

(4) The artificial system is made up of only one unit, which resulted from strip-mining of coal.

The study area contains a moderate amount of mineral resources. Extant oil and natural gas fields are nearly depleted. Clay, sand, gravel, and limestone are plentiful. Water resources are abundant although the quality is often poor.

With today's rapid urbanization and emphasis on energy, it is essential that man understands and learns to manage the environment in which he lives. The proper use of studies such as this one can aid in land-use planning.

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