# THE ENVIRONMENTAL GEOLOGY OF THE RUSSELLVILLE, ARKANSAS AREA

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# ABSTRACT

The natural environment imposes fundamental limitations on the uses of certain areas by man. Therefore, the factors that make up the natural environment must be the subjects of early and thorough studies in an area where urbanization is occurring. All indicators show that Russellville, Arkansas is such an area.

The study area is located in Pope County, Arkansas, 75 mi west of Little Rock in the Arkansas River Valley physiographic province.

In order to develop a more complete understanding of the geologic setting of the area and to evaluate the implications that geology could have for urban planning, 8 basic maps were prepared. These maps deal with areal geology, mineral resources, thickness of sand and gravel deposits, topographic slopes, areas of potential flooding, surficial materials and depths to bedrock, construction properties of soils, and land-use planning.

Sedimentary rocks of the Pennsylvanian System and unlithified sediments of the Quaternary System crop out in the Russellville area. Pennsylvanian rocks consist of the Atoka Formation, the Hartshorne Sandstone, and the McAlester Formation. The Quaternary deposits consist of stream and river terrace alluvium deposited during the Pleistocene Epoch and river alluvium of Recent age.

Rocks of the area are folded into a series of plunging east-west-trending anticlines and synclines, which have been deeply eroded.

Generally, the folds are nearly symmetrical with limbs that dip about 5 to 8 deg. The southern limb of the Shinn syncline, however, dips about 80 deg. The strata are jointed with as many as 3 joint sets being fairly common. Two east-west-trending faults are known in the area.

A mineral-resources map shows the locations of potential resource-recovery areas, not including oil or gas. Sand is abundant in the Arkansas River channel and flood plain. Sandstone also is plentiful and is quarried from several areas in the Hartshorne Sandstone. Coal reserves are located in the Ouita and Shinn basins, however only the Shinn basin deposts are recoverable at the present time because Ouita basin has been flooded by the Dardanelle Reservoir. Ground water is available from the sediments of the Arkansas River flood plain. Another source of ground water is available from the Pennsylvanian bedrock for domestic water supplies.

On the topographic slope map, relief has been converted into percent of grade. These values have been categorized and mapped by symbols. Most of the area is in grades which range from 0 to 7 percent. Generally, slope will present no problems in the development of these tracts. However, grades in excess of 15 percent are present on the escarpments of Norristown and Carrion Crow Mountains, the hogback ridge of the Shinn basic, and the dip-slope of the Pleasant View Mountain.

The potential flooding and drainage map shows areas that the U.S. Army Corps of Engineers includes within the "100-yr" flood plain. Drainage systems and basins are also outlined on the map. The areas most likely to flood are: (1) adjacent to the Arkansas River downstream from the Dardanelle Dam, (2) within the lower part of the Whig Creek drainage basin, (3) along Prairie Creek within the city of Russellville and south of the Russellville Dike, and (4) downstream from the Russellville waterworks dam on the Illinois Bayou.

Types and thicknesses of flood plain alluvium, terrace alluvium, colluvium, and residual soil are shown on the surficial geology map. Extensive deposits of alluvium lie within the Arkansas River flood plain where alluvium may be as thick as about 55 ft at some places. Terrace alluvium covers approximately one-third of the study area with deposits which may be as thick as about 30 ft. Residual soil is present as a mantle overlying bedrock where grades are less than about 8 percent. Colluvium may be present because of soil creep where grades are greater than about 8 percent. Colluvium is located beneath escarpments and along the base of hogbacks, especially where the Hartshorne Sandstone crops out as a ledge above the shale, siltstone, and sandstone of the Atoka Formation. Generally, these colluvial areas are likely to cause site development problems.

The map of construction properties of soils provides a quick reference to the properties of soil that are significant in construction work. The following information is included in the explanation on the map: soil description, parent material of soil, drainage, permeability, shrink-swell potential, plasticity, and acidity.

The land-use map shows proposed uses for tracts within the Russellville area, including these categories of land: (1) commercial, (2) flood easement, (3) industrial, (4) public, (5) residential (low-, medium-, and high-density), (6) resource recovery, (7) scenic vista, recreation, or park land, and (8) undeveloped land (slopes or agricultural land).

The maps and information included within the study are designed to be used for regional planning only. They should not be used for detailed site planning. Additional studies will be necessary for specific development projects.

# INTRODUCTION

## Background

Man's exploitation of nature is no longer acceptable in an era when 4 billion people inhabit the earth, and when the world population's doubling time is approximately 35 yrs. The proper use of land and natural resources is necessary everywhere, but is especially so in cities and developing urban areas.

The environmental problems that man faces today are the fruits of almost 4000 yrs of western man's development of an attitude of self-centered dominance over nature. The full impact of this attitude began to be realized in about 1850 when science and technology were fused into a new and extremely powerful synergistic force which increasingly damaged the natural environment, as man sought the "better life." Another cause of environmental problems has been an ignorance of the interdependence of the elements which together make up the natural environment. Such ignorance is due to the lack (until recently) of interdisciplinary studies. In general, man's place in and impact on the environment has been ignored by the "pure" sciences. Such disciplinary narrowness in scholarship has led the public to the dangerously misleading concept that man's effect on world-wide climate, ecosystems, and environmental quality is insignificant. Now it is known that this is not the case.

Man has enough power at his command to alter the earth's environment drastically and irreversibly. Man can resume a more harmonious place in the natural environment only after he learns to use his appropriated power in conjunction with careful planning. This planning must be based on full understanding of the delicately balanced natural systems with which man is interacting. Properly, man should be a partner with and a protector of the natural environment. He must learn that the earth is a finite body and that its natural resources are exhaustible. He must become a trustee of the natural wealth of the earth, so that future generations will be able to sustain life on this planet. He must learn that conservation and harmony with nature are to be preferred over mindless, uncontrolled growth masquerading as progress.

In order to bring about such harmony with nature it will be necessary for man to understand his natural environment and its interrelationships much more completely than is generally shown by his actions. Such understanding can be derived only by careful interdisciplinary study of the environment. No areas are in greater need of such thorough and careful planning than our urban areas. Urban planning without study can result in disaster. There are numerous examples of "natural" disasters which were the results of, or at least were magnified by, a lack of enlightened environmental planning. An awesome example occurred on March 27, 1964 in Anchorage, Alaska. Landslides that caused massive destruction in the Turnagain Heights subdivision were triggered by the "Good Friday" earthquake.

Turnagain Heights was built upon the Bootlegger Cove Clay Formation which had been studied by the U. S. Geological Survey and the

U. S. Army Corps of Engineers. Their studies indicated that the Bootlegger Cove Clay would be unstable in the event of an earthquake. However, their studies did not lead to wise urban planning, or even to the initiation of a program of correction or additional study of the problem.

Educated urban development depends upon an understanding of the natural environment, sociological and demographic forces and trends, economic systems, engineering capabilities, and aesthetic values. Realizing that the natural environment often will impose fundamental limitations on the uses of certain areas, man must conduct early and thorough studies of the factors that make up the natural environment in an area undergoing urban development. Botanical, zoological, meteorological, hydrological, and geological studies should be included in a comprehensive analysis of an area prior to urban development.

Today, study of the natural environment for the purpose of wise land-use planning is not unusual. It has been done in several noteworthy projects. Such a comprehensive study, however, is unique for an area in the State of Arkansas. Studies of this type are especially valuable in an area that is in the process of urbanization and where a number of diverse environmental factors are likely to be encountered. Russellville, Arkansas is such an area.

## Objectives

This study is intended to provide the geological information which will serve as a basis for urban planning in the Russellville area. There are various opinions concerning the kinds of geological information that should be included in planning, but generally information that deals with the following topics is considered to be essential: stratigraphy and structure of the bedrock and surficial materials, depths to bedrock, topographic slopes, mineral resources, general and construction characteristics of soils, and surface drainage, including flooding potential. Information of these kinds has been compiled and is shown by maps developed for this study. A derivative map also has been prepared showing projected land-use classification.

The writer believes that the information contained within this report will be of value to the Russellville Planning Commission, the Russellville Chamber of Commerce, and various private corporations and citizens. It will assist them in determining the multiple land-use plan that is most compatible with the natural setting of the area.

## Location of the Study Area

The study area is located in west-central Arkansas in the Arkansas River Valley, 75 mi west of Little Rock (Fig. 1). The entire study area of approximately 52 sq mi is located in Pope County. Russellville and Norristown are the only incorporated towns within the study area (Fig. 2).

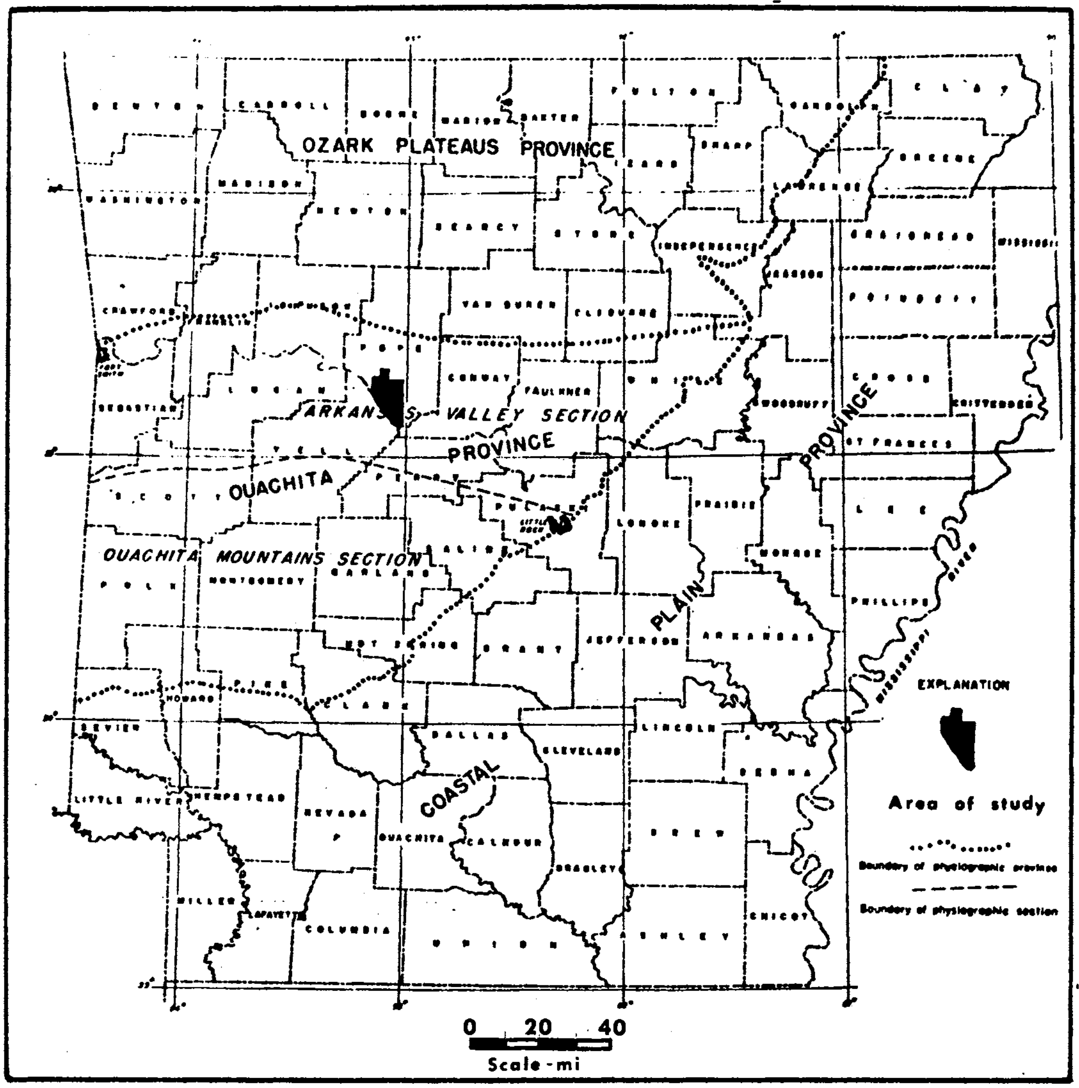


Figure 1. - Index map of Arkansas. (modified from Merewether and Haley, 1961, p. 4).

Figure 2. - Highway system in the Russellville, Arkansas area (Arkansas State Highway Department, 1971).

# COMMUNITY INVENTORY

## Population

In 1970 the population of Russellville was 11,750, whereas the population of Pope County (Fig. 1) was listed as 28,607 (Arkansas Department of Planning, 1973, pg. 49). The population of Dardanelle, south of the Arkansas River in Yell County (Fig. 1), was 3,297 in 1970 (Arkansas Department of Planning, 1973, p. 51). The "urban population" of Pope County (defined as being all persons who live in places of 2,500 or more whether incorporated or not) was 41.1 percent, while the rural population was listed at 58.9 percent of the county's total population (Arkansas Department of Planning, 1973, pp. 57-58).

The population density of Pope County was calculated to be 35.2 persons per sq mi in 1970. The highest density in Arkansas is 375.4 persons per sq mi, in Pulaski County (Fig. 1) where Little Rock, the State Capital, is located. The lowest population density in Arkansas is located in Newton County (Fig. 1) which is north of and adjacent to Pope County. The density in Newton County is 7.1 persons per sq mi (Arkansas Department of Planning, 1973, p. 50).

### Population Change

Pope County had a net population gain of 35 percent during the decade from 1960 to 1970, while the State of Arkansas had a net gain of 7.7 percent (Arkansas Department of Planning, 1973, p. 52). A statistic which is perhaps more meaningful is the "percent of net migration." This figure is derived by computing the difference between the projected population and the actual population at the end of a specified time period. The projected population is the total population at the beginning of the specified time period plus the "natural" increase or decrease in population during the specified time period. The State of Arkansas had a negative net migration of 2.8 percent for the decade of the 1960's. However, Pope County had a positive net migration of 21.3 percent (Arkansas Department of Planning, 1973, p. 54).

### Civilian Labor Force

The total civilian labor force in the "Russellville Labor Area" (Pope and Yell Counties) was 16,950 persons in 1972. The mean number of persons employed in 1972 was 15,850. Therefore, the unemployment rate was about 6.5 percent in the "Russellville Labor Area." The mean number of persons employed in agriculture in the "Russellville Labor Area" was 950, whereas 14,900 were employed in nonagricultural jobs. In 1972, 23.9 percent of the labor force in the "area" was employed in manufacturing and 48.2 percent was employed in non-manufacturing jobs. (All statistics above from Arkansas Department of Planning, 1973, pp. 76-78, 80-82.)

## Growth Potential

Russellville has been designated as a "growth center" by President Nixon's Commission on Population and the American Future (Commercial Appeal Mid-South Magazine, 1972, p. 20). The Commission report recommends creating 121 "growth centers" in the United States, mostly in the southeast, to help limit the flow of population northward and westward. The "growth centers" are visualized as small cities of today which, through annexation and incorporation of surrounding areas would become the bigger cities of tomorrow. Federal money for development would permit these "centers" to develop industry and municipal services to attract migrating people. These "centers" would serve as buffer zones protecting the major metropolitan areas from increased over population. The full significance of the designation of Russellville as a growth center has not yet been fully realized, but it is sure to have a great impact on the future development of the area.

Several criteria were used in determining which towns and cities should be designated as "growth centers". Growth centers were (1) more than 75 mi away from areas of 2,000,000 or more population; (2) in areas where the combined city-county population was less than 350,000 at the time of the last census; (3) areas that had a population increase from 1960-1970 in excess of the national average of 13.5 percent; and (4) geographically suited, with resource potential, to justify federal aid to stimulate growth (Commercial Appeal Mid-South Magazine, 1972, p. 22). The presence of higher-education facilities in an area was also considered to be a positive factor in assessing growth potential. The position of county boundary lines was also considered, due to the governmental complexity of developing an area that lies in two or more counties.

Arkansas will have three such "growth centers", including Little Rock, Forth Smith, and Russellville (Fig. 1).

## Economics of Pope County Including the Russellville Area

In 1972, the total financial resources, including banks and savings-and-loan associations, in Pope County was in excess of $70 million (Arkansas Department of Planning, 1973, p. 86). Retail sales totaled more than $54 million in 1972 (Russellville Chamber of Commerce, 1973, p. 24). Total personal income in 1970 was more than $79 million, but per-capita income was only $3,265 (Arkansas Department of Planning, 1973, p. 62). Of the families in the county, 20.2 percent had incomes of less than $3,000, whereas 20.7 percent had incomes of more than $10,000 (Arkansas Department of Planning, 1973, pp. 63, 64).

In 1972, 23 manufacturing plants were located in Pope County, of which 20 employed fewer than 300 people (Arkansas Department of Planning, 1973, pp. 83-84). In 1967, the value added by manufacturing to the county was in the range of 26 to 50 million dollars (Arkansas Department of Planning, 1973, p. 85). This figure is considered by many experts to be the most significant index of industrial activity in an area. It reflects the difference between the value of the materials as they arrive at the plant, either as raw materials or semi-processed goods, and their value when they leave either to be processed further or to be used as consumer goods.

The principal manufacturing industries in Russellville are shown in Table 1.

## TABLE 1

## INDUSTRIAL DEVELOPMENT OF RUSSELLVILLE

| Name of Firm | Products |
|---|---|
| Firestone | Innertubes |
| Morton Frozen Foods | T.V. Dinners, Pies, Rolls |
| Rockwell | Parking Meters |
| Valmac | Poultry, Poultry Feed, Hatchery Stock |
| International Shoe | Shoes |
| Tabor Metals (formerly Dow Chemical) | Aluminum Extrusions |
| Dow Chemical | Chlorine Cells |
| Ward Manufacturing | Furniture Framing |
| Bibler Brothers | Lumber |

Source: Cooperative Extension Service, 1972, p. 29.

### City Government

The City of Russellville has the Mayor-Councilman form of municipal government. Under this form of government, the city is divided into wards with two councilmen being elected from each ward. The City Council is the governing body, being composed of the councilmen and the mayor, who is the presiding officer.

Department heads, such as the police and fire chiefs, are appointed by the mayor.

## County Government

Pope County is governed by 50 elected Justices of the Peace who constitute the Quorum Court. Other elected officials include: Sheriff, Assessor, Circuit Clerk, County Clerk, Treasurer, Prosecuting Attorney, and County Judge. The County Judge serves as the chief administrative officer of the county.

## City Land-use Planning

A Comprehensive Development Plan was prepared for the city of Russellville in 1969 by the City Planning Division of the University of Arkansas. The plan considers the city's condition as of 1969, its past trends, and its goals for the future. The plan takes into account three major aspects of the city's growth - land-use, streets, and community facilities. The purpose of the plan was to provide a guide for achieving a more orderly, convenient, and attractive community. The "Plan" established the following goals: (1) safety, (2) efficiency and economy, (3) amenity, and (4) balanced land-use. Under the heading of safety the following things were considered: dangers from (1) fire, (2) explosion, (3) dust, (4) noise, (5) odors, (6) vibrations, (7) overcrowding, and (8) unsightly and unsanitary conditions.

The writer is in general agreement with the recommendations in the Plan, but it should be noted that certain "critical areas," where public safety may be endangered due to natural hazards, were not identified. Namely, these areas are in the flood plain of Prairie Creek and along the landslide-prone steep slopes of Norristown Mountain (Pl. 4). These critical areas are discussed later in this report.

The authority for planning is given to first and second class cities and to towns by the General Assembly of the State of Arkansas in Act 186 of 1957, as amended by Act 128 of 1959 (Russellville is authorized to plan under this Act). Paragraph 19-2827 of this Act delegates the responsibility for planning to the Planning Commission (City Planning Division, University of Arkansas, 1969, p. 3).

> The general purpose of the Planning Commission is to prepare or have prepared a plan or plans of the municipality, to receive and make recommendations on public and private proposals for development, to prepare and administer planning regulations, to prepare and transmit to the legislative body recommended ordinances implementing plans and to advise and counsel the City government and other public bodies. The Planning Commission shall have the duty and function of promoting public interest in and understanding of the long-term coordinated municipal planning.

After adoption of the Comprehensive Development Plan by the City Council (adopted Jan. 9, 1969) no public improvement to land or buildings nor any utility installation can be accomplished without being authorized by the City Planning Commission.

The Planning Commission has the primary responsibility for preparing plans and regulations for adoption by the City Council. The Commission must also assist in carrying out the plans through the education of the community as to the benefits of the plans being acted upon. The City Council also has the responsibility to refer all development proposals to the Planning Commission before Council action.

## City Zoning Regulations

Russellville operates under a set of comprehensive zoning regulations. The purpose of these regulations is expressed in the following statement (City Planning Division, University of Arkansas, 1969, ch. 19, p. 1).

> . . . to insure the health, safety, and general welfare of the municipality; by establishing zoning districts; by regulating with such zoning districts the uses, lot area, yards, lot width, lot coverage and parking; and by establishing such other requirements as are necessary for coordinated, adjusted and harmonious development of the municipality.

Detailed zoning regulations are contained in chapter 19 of the Russellville Comprehensive Planning Report (City Planning Division, University of Arkansas, 1969).

## County Planning

County planning was made possible by Act 246 of the 1937 General Assembly of Arkansas, as amended. This Act provides the authority for the County Judge to establish a County Planning Board with the approval of a majority of the Quorum Court. Pope County has such a Planning Board.

The general duties and functions of the County Planning Board are explained in "Guidelines for County Planning" prepared by the City Planning Division, University of Arkansas (1972b, p. 2).

> (1) The Board may prepare and adopt an official plan for the physical development of all or part of the unincorporated territory of the County.
> (2) The Board may promote public interest and understanding of the economic and social necessity for long term, coordinated county planning.
> (3) The Board may confer and cooperate with Federal, State, Municipal, and other county and regional authorities on matters affecting or pertaining to the planning and development of the county.
> (4) The Board may prepare and keep up-to-date a long term coordinated program of public works.
> (5) The Board may prepare zoning regulations.
> (6) The Board may prepare, after adoption of an official highway plan, subdivision regulations and after their adoption shall administer said regulations including approval of plats.

The County Plan is intended to guide a coordinated, efficient, and economical development of the county. The 1937 General Assembly intended that the plan should make recommendations concerning the following: (1) conservation of natural resources, (2) economic distribution of population, (3) efficient transportation facilities, and (4) adequate educational and institutional facilities. However, it was not the intention of the General Assembly that the plan be limited to these subjects.

## County Zoning

The County Planning Board has the authority to establish county-wide zoning. After a public hearing, if the County Court determines that the proposed regulations are desirable and will promote public health, safety, morals, and general welfare and "encourage the use of lands in accordance with their character and adaptability and will limit improper use of lands," the Court must approve the regulations by Court Order and have them filed in the office of the County Recorder (City Planning Division, University of Arkansas, 1972b, p. 5).

Pope County's Planning Board is presently planning a program of public education concerning the need for and value of county-wide planning. Currently, there appears to be much opposition to any form of county planning or zoning in Pope County.

## Joint or Regional Planning

Act 26 of the 1955 General Assembly made statutory provisions for joint cooperation in area planning. The Act provides a mechanism by which local units of government and other public agencies may join to make plans for an area. A joint planning commission may be formed by any combination of cities, counties, or cities and counties, as long as the members have adjoining planning jurisdictions (City Planning Division, University of Arkansas, 1972c, p. 1).

The joint planning commission, when established, will make studies and prepare plans for the development of the region. The plans should guide in the unified development of the area and should eliminate planning duplication. The plans prepared for the region may include recommendations for principal highways, bridges, airports, parks and recreational areas, schools and public institutions, and public utilities. However, such plans need not be limited to these items.

Pope County and Russellville are participating members of such a regional planning district, the West Central Arkansas Planning and Development District. Presently, the West Central District is engaged in studies of population characteristics, geography, existing land-use, economic characteristics, transportation, and land-resource problems (West Central Arkansas Planning and Development District, 1973). It is assumed that such studies will lead to regional planning in the future.

## Transportation

### Highway System

The Russellville area is served by Interstate Highway 40 which has three exits providing access to the city. Interstate Highway 40 provides easy communication with the other "growth centers" of the state, Fort Smith and Little Rock. U. S. Highway 64 parallels "I-40" and now serves as a local traffic distributor. These two highways carry the east- or west-bound traffic through the area. The north-south flow of traffic is carried by Arkansas State Highway 7, which connects the towns of north-central Arkansas with the southern parts of the state. Arkansas State Highway 124 distributes traffic to the northeast of Russellville. Figure 2 shows the highway systems of the area.

### Railroads

The Missouri-Pacific Railroad passes through the center of Russellville and connects with the Dardanelle-Russellville Railroad, which in turn, ties the mainline track with the port facilities of the Kerr-McClellan Arkansas River Navigation System and the industrial sites south of the city (Fig. 2).

### Airport Facilities

The commercial airports nearest to Russellville are located at Little Rock (80 mi east), Fort Smith (77 mi west), and Hot Springs (75 mi south). A general aviation airport with a 3500-ft lighted, asphalt-surfaced runway is located 2½ mi southeast of Russellville (Fig. 2).

### Kerr-McClellan Arkansas River Navigation System

The Kerr-McClellan Arkansas River Navigation System is a 450-mi-long, 9-ft-deep navigation channel extending from the Mississippi River to the Port of Catoosa, near Tulsa, Oklahoma (Fig. 3). There are 17 single-lift locks that raise vessels from an elevation of 112 ft to 532 ft. Each lock is 600 ft long by 110 ft wide, a size that will accommodate tows of eight standard jumbo barges (each 195 ft by 35 ft) in 3-by-3 configuration (including the tow boat). A standard jumbo barge loaded with 1300 tons draws about 8 ft of water. Therefore, a single tow of eight barges will move about 10,000 tons of cargo.

Figure 3. Location map of the Arkansas River watershed (U. S. Army Corps of Engineers, 1969, plate 1).

### Keenan's Port of Dardanelle

Keenan's Port of Dardanelle, a private enterprise, is located at river mi 199.1 at North Dardanelle (Fig. 2). The port is operated as a public facility and is designed for general-purpose cargo. The port includes a warehouse and grain-storage facilities with conveyor loading and unloading between storage and barges at the dock. The port is served by the Dardanelle and Russellville Railroad and State Highway 7.

## Utilities

### Electrical Service

The Russellville area is the site of Arkansas Power and Light Company's Nuclear One and Two electric generating plants. A total output of 1,800,000 kilowatts will be possible by the latter part of 1976. Unit One will produce 850,000 kilowatts and will be in operation during 1974. Three 500KV transmission lines will distribute power from the nuclear plant.

The Russellville area is served by three 161KV transmission lines feeding four substations which step-down the voltage to 13.8KV. The number of transmission lines and substations in the area makes it one of the most reliable electrical systems in the country, since it is very unlikely that all of the system would fail simultaneously (Arkansas Power and Light Company spokesman, personal communication, 1974).

### Natural Gas Service

Natural gas is supplied to the area by a 10-in. pipeline owned and operated by Arkansas Louisiana Gas Company. A 24-in. high-pressure gas pipeline passes across the northern tier of sections in the study area. Russellville's proximity to the gas fields of the Arkansas Valley and to a recently completed pipeline to the Anadarko Basin of Oklahoma insures a reasonably reliable supply of natural gas to the area.

### Water Service

The city of Russellville is supplied with water by the Russellville Water Company, a private enterprise. The company operates a water-supply lake formed by a 32-ft-high concrete arch dam located on the Illinois Bayou about 2 mi north of the city limits (Fig. 2). The dam impounds about 935 acre ft of water at spillway level. The treatment plant can produce approximately 7.5 mgd (million gallons per day). The city is served by a 16-in. transmission main. An in-city storage capacity of 1.6 million gal is presently available.

The treated water quality is shown in Table 2.

TABLE 2

AVERAGE QUALITY OF TREATED WATER

| | |
|---|---|
| pH | 6.5 ppm |
| Chlorine | 0.8 ppm |
| Fluorine | 1.0 ppm |
| Hardness | 10.0 ppm |
| Alkalinity | 10.0 ppm |

Source: Russellville Chamber of Commerce, 1973.

## Sewage-Disposal Service

The Russellville Sewage Treatment Plant was completed in 1964. Plans are being made for enlargement of the plant during 1975. The plant treats 3 to 4 mgd of waste water, on the average. During storm periods the plant may be required to treat from 10 to 12 mgd.

Treatment consists of four steps: (1) screening, (2) grit removal, (3) sedimentation, and (4) filtering. Filtering is accomplished by trickling filters containing organisms which oxidize the solids to form more stable matter. The treated water is released into Whig Creek southeast of the city. Solid waste from the plant is spread on the surface of pasture areas in sec. 22, T7N, R20W (Pl. 1).

## Solid-Waste Disposal Service

Solid waste is collected in the Russellville area by private contractors. It is delivered to a landfill site adjacent to State Highway 7T in the NW¼ sec. 21, T7N, R20W (Pl. 1). The landfill is being placed in a strip-mine which also includes numerous abandoned shaft coal mines.

Contamination of ground water and surface water by the landfill operation may occur, due to the numerous joints in the bedrock and the suspected presence of mine shafts and tunnels. Relocation of the landfill would be desirable.

## GEOLOGY AND THE PAST DEVELOPMENT OF RUSSELLVILLE

Geology, in the formal sense of the word, has not been greatly utilized to guide the development of the Russellville area. However, the valley in which the city is located was known as "Chactas Prairie" by early settlers (Vance, 1970, p. 106). Chactas Prairie was crossed by two trails that crossed at what is now the intersection of Main and Denver streets. The north-south trail followed the course of the Illinois Bayou and led to a natural ford on the Arkansas River. It is believed that this trail was first established by buffalo and later was used by Indians. White men made it into a wagon road. The east-west trail crossed the prairie lengthwise and became a major transportation link from Little Rock to Fort Smith. The completion of the Little Rock and Fort Smith Railroad in about 1873, across this flat region, served to stimulate the development of Russellville.

In the early development of the Russellville area, "common sense" led man to avoid building on flood plains or extremely steep slopes. Furthermore, once he learned by trial and error where the best wells could be dug and which soils were best suited to certain crops, he began to apply his knowledge to other nearby areas. Good judgement led the pioneers of the area to build their roads and railroads in areas of low slope, away from landslide-prone areas. The engineering properties of soils were largely unknown to these early settlers, but this did not matter so much because most of the early structures were small and foundation loading was low.

In the 1870's, local residents became aware of the coal-producing potential of areas near Russellville and a mining industry developed which stimulated local economic growth. Stone, gravel, and sand were needed for construction and it was soon learned where the best areas were for obtaining these raw materials.

Only in the last few decades has the pressure to acquire more land for urban and industrial development led men to ignore such "land-use common sense."

## PREVIOUS GEOLOGIC WORK IN THE RUSSELLVILLE AREA

The general geology of the Russellville area was of interest in the 1880's because of coal production which developed along the Arkansas River Valley during this period. Winslow (1888) discussed briefly the physiography and general geology of the Arkansas coal basin. His report contains a few specific comments regarding the Ouita coal basin located on the northern edge of Russellville.

The first truly comprehensive study of the geology of the area was the work of Croneis (1930). His work includes detailed stratigraphic descriptions of the formations that crop out in the Russellville area. The major structural features of the region are also described adequately. Because the study includes the entire terrain of Paleozoic rocks in Arkansas, a section dealing with any specific local structure is brief.

During the planning of the Dardanelle Lock and Dam project the U. S. Army Corps of Engineers conducted many detailed surface and subsurface geological investigations. The records of these investigations contain much valuable information that is not published. The earliest of these investigations was prepared in 1951 and is a general geologic analysis of the area to be affected by the project. This affected area not only included the terrain surrounding the dam site, but also areas on the margin of the reservoir and a canal-alignment tract from the dam site to a site several miles to the east. This line of investigation crossed the southern portion of the area included in this report. The U. S. Army Corps of Engineers' (1957) "Design Memorandum Number 8 - Geology and Soils" provides a brief review of the regional geology, mineral resources, construction materials, and geology of the dam site. "Design Memorandum Number 15 - Protection of Russellville" (U. S. Army Corps of Engineers, 1961) describes the geology and soils of the flood plain of the Illinois Bayou in the Ouita coal district, which includes the northern part of the city of Russellville.

Hahn (1954) of the U. S. Bureau of Mines studied the coal deposits of the Ouita and Shinn basins (Pl. 2) in the Russellville area. These unpublished reports are useful in the evaluation of the coal production which could be expected from the area. Stroud (1969) summarized the natural resources of the Russellville area. Haley (1964) of the U. S. Geological Survey remapped the geology of the area on the Russellville East and West quadrangles at a scale of 1:24000. These maps are unpublished but are kept on "open file" at offices of the Arkansas Geological Commission in Little Rock. Haley's studies in the Russellville area are parts of a thorough re-examination of the Arkansas coal basin by the U. S. Geological Survey. Reports in this series contain much information that is pertinent to the geologic analysis of the Russellville area.

The U. S. Army Corps of Engineers (1969) prepared "Floodplain Information" for the Russellville and Dardanelle area. This analysis projects flood levels for a "100-yr" or greater flood and, therefore, is an exceptionally valuable tool for rational urban planning.

Cordova (1963) and Bedinger, Emmett, and Jeffery (1963) prepared studies of the ground-water resources of the Arkansas River Valley.

Garver and Garver, Inc. (1970) published a study of "Opportunities for Development of River Ports . . . Dardanelle - Russellville, Arkansas". This report provides information concerning population and area economy, general geology of the proposed industrial sites, industrial development, and current port and industrial sites.

# GEOLOGY OF THE RUSSELLVILLE AREA

## Stratigraphy

Sedimentary rocks of the Pennsylvanian System and unlithified sediments of the Quaternary System crop out in the Russellville area. The Pennsylvanian rocks consist of (1) the Atoka Formation which is mostly shale but which also contains sandstone and shale; (2) the Hartshorne Sandstone; and (3) the McAlester Formation, which is mostly shale but which contains siltstone in the Russellville area. The Quaternary deposits consist of terrace alluvium deposited during the Pleistocene Epoch and flood plain alluvium of Recent age.

### Pennsylvanian System

#### Atoka Series

Atoka Formation.-The Atoka Formation (Table 3) was named by Taff and Adams in 1900 from exposures in Oklahoma (Merewether and Haley, 1961, p. 6). The formation was defined as the rocks that overlie the Morrowan Wapanucka Limestone and that underlie the Desmoinesian Hartshorne Sandstone (Merewether and Haley, 1961, p. 6). In the Arkansas River Valley the Atoka Formation has been defined as the rocks that lie above the Jackfork Sandstone (Mississippian) and below the Hartshorne Sandstone (Croneis, 1930, p. 116).

TABLE 3

SELECTED STRATIGRAPHIC UNITS IN AND NEAR THE RUSSELLVILLE, ARKANSAS AREA

| System | Series | Group | Formation | Member |
|---|---|---|---|---|
| Pennsylvanian | Desmoines | Krebs | McAlester Formation | Lower Hartshorne coal bed |
| | | | Hartshorne Sandstone | |
| | Atoka | | Atoka Formation | |

Generally, the formation is more than 50 percent shale, about 30 percent siltstone and commonly less than 20 percent sandstone. The Atoka also contains lenticular coal beds, most of which are too thin to be mined. In the Arkansas Valley the formation ranges from less than 1500 ft thick adjacent to the Ozark Plateaus province, to more than 9000 ft thick in Perry County in the frontal belt of the Ouachita Mountains (Fig. 1) (Croneis, 1930, p. 116).

The shale of the Atoka generally is not well exposed. It generally underlies valleys or crops out beneath Hartshorne sandstone ledges, where it is mostly covered by colluvium. The shale is weathered deeply, commonly showing change in color from dark gray to light gray to a limonitic yellow-brown where it is thoroughly weathered.

The Atoka Formation commonly is micaceous, containing both muscovite and phlogopite (Croneis, 1930, p. 117). This feature serves as a distinguishing characteristic of the formation that is helpful in field mapping (Haley, 1973, personal communication). Many of the micaceous shales contain finely divided carbonaceous material and carbonized plant fragments.

The highly variable lithologic character of the Atoka Formation long has been recognized. Croneis (1930) noted that lateral variations within 1 mi were sufficient to make correlation between some measured sections impossible. Ripple marks, which are quite abundant in the silty and sandy facies, current cross-bedding, and thin coal beds together suggest an environment of deposition similar to the type found on broad deltas with isolated shallow lagoonal areas.

The extraordinary variation in lithology across short distances is quite important in controlling the accumulation and transmission of liquids in the Atoka Formation. This fact will be discussed more fully in the section on ground water.

The upper portion of the Atoka Formation crops out in the Russellville area. It is separated from the Hartshorne Sandstone by a surface of disconformity. The base of the Atoka is not exposed in the study area; therefore the Atoka ranks as the oldest bedrock in the area. The formation probably is about 6,000 ft thick in the Russellville area (estimated by extrapolation of data from Merewether and Haley, 1969, p. 15).

The exposed upper portion of the Atoka is mainly shale and silty shale, but thin strata of siltstone also are included. One coal bed about 6 in. thick crops out in a cut on State Highway 7 about 2 mi south of Russellville.

The shale is light-to dark-gray, fissile to splintery, silty to clayey, and as mentioned above, is micaceous. It weathers to a limonitic yellow-brown, indicating that the unweathered shale contains very finely crystalline, unoxidized iron sulfide. The uppermost portion of the Atoka contains numerous closely spaced, thinly laminated strata of carbonaceous material. The shale is generally ruptured by joints, faults, and bedding plane cleavage.

Some silty, noncohesive strata of Atoka shale "slake" or disintegrate readily when placed in water. This quality could make the Atoka an unsatisfactory material for use as surfacing road metal. However, the utilization of the shale for road building and surfacing and other types of construction requiring fill material is common because it is available from several borrow pits in the area. This practice should be studied carefully in projects where the stability of a fill is important or the lack of cohesion of a road surface might be critical. Sliding of an automobile into a ditch or into the path of an oncoming vehicle could result from the "slaking" of Atoka shale used as road-surfacing material.

The siltstone of the Atoka Formation is generally light to dark gray or tan, argillaceous to sandy, micaceous, and well lithified.

Sandstone in the formation is gray but weathers to a limonitic yellow. It generally ranges from silty to fine-grained, but some strata are argillaceous. The sandstone generally is quartzose and well indurated. Pyrite is a fairly common accessory mineral. Fossil plant residue is present on many bedding surfaces. Ripple marks and cross-bedding are abundant in the sandstone facies of the Atoka Formation. These primary sedimentary structures are also present in the siltstones and silty shales of the formation.

## Desmoinesian Series

Only the Hartshorne Sandstone and the McAlester Formation of the Krebs Group crop out in the Russellville area.

Hartshorne Sandstone.-The Hartshorne Sandstone is defined in Arkansas as, "the first continuous sandstone layer underlying the 'Hartshorne coal bed'" (Hendricks and Parks, 1950, p. 73). The Hartshorne Sandstone of Hendricks and Parks correlates with the lowermost sandstone in the Hartshorne Sandstone type section in Oklahoma (Merewether and Haley, 1961, p. 7).

The Hartshorne is widespread in the Arkansas Valley region where it is a ridge-forming unit. Generally, it crops out on the flanks of anticlines that have been breached by erosion. This produces long cuesta-like ridges which have gently dipping, outward-facing dip slopes and steeply sloping, inward-facing escarpment slopes.

Several characteristics noted by Merewether and Haley (1961, p. 9) distinguish the sandstone of the Hartshorne from sandstones in the Atoka and McAlester formations. Sandstone of the Hartshorne is generally coarser grained (very fine to medium), less silty and clayey, and lighter in color (grayish white to light gray). Additionally, the Hartshorne forms more prominent ridges. However, distinction of the Hartshorne is not straightforward in every instance, and the difficulty of recogning the Hartshorne at some localities has been described by Merewether and Haley (1961, p. 9) and by Croneis (1930, p. 139).

> At most exposures it consists of very irregularly bedded, massive strata, which make a prominent ridge wherever the dip is moderately high. At some places, however, the formation consists of two thin beds of sandstone and an intervening bed of arenaceous shale, and at other places

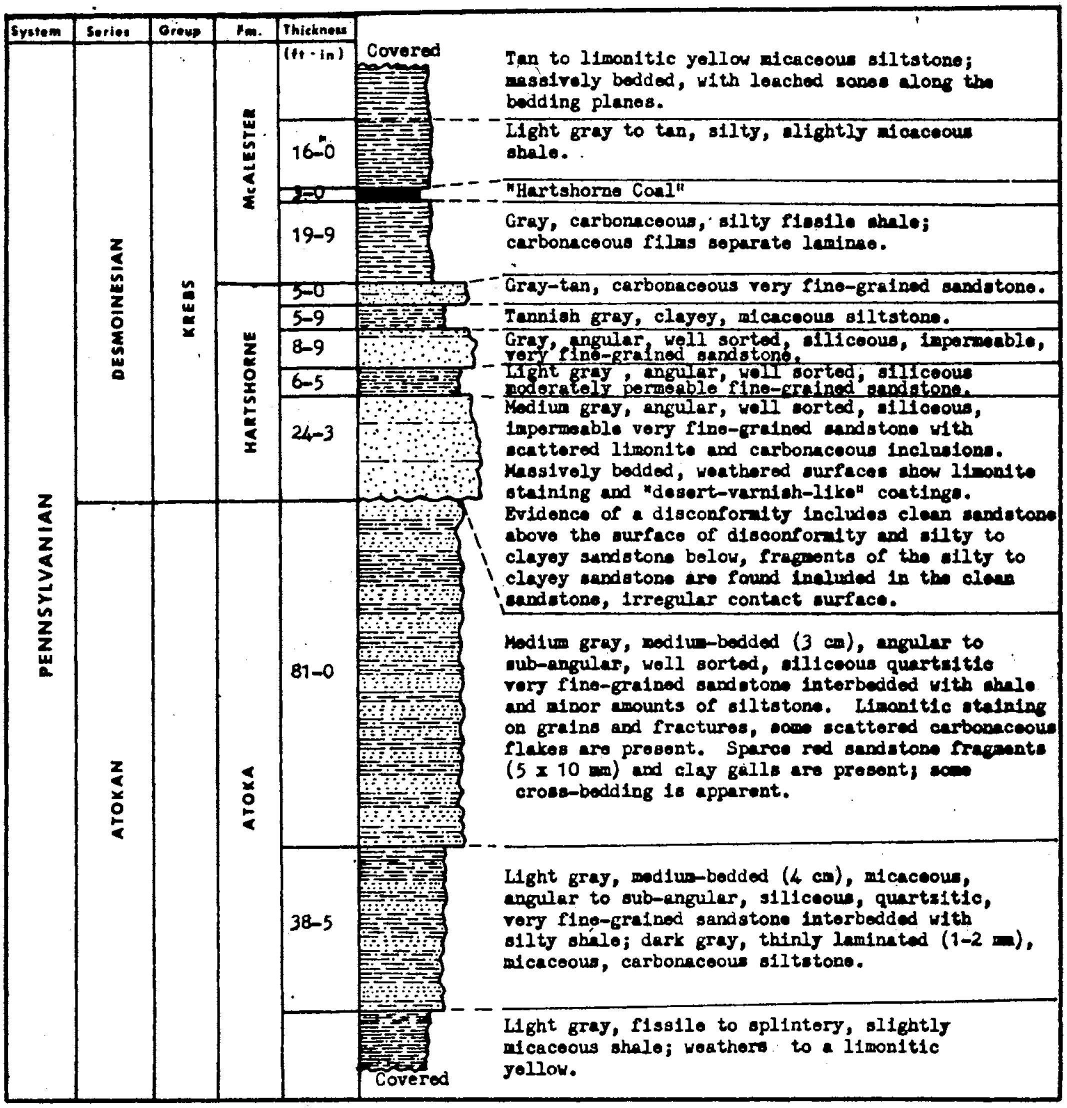
> it consists of a single bed of sandstone. At a few places, as at Russellville, on the north side of the Shinn basin, the Hartshorne is made up entirely of beds of soft sandy shale, which do not appear in the topography despite their rather high dip. On the south side of the Shinn basin, less than a mile away, the formation consists of 75 feet of sandstone, thinner bedded and less irregular than usual, which makes a prominent ridge.

As mentioned previously, the Hartshorne overlies the Atoka Formation disconformably. The Hartshorne-Atoka contact has been identified as being at the base of the massively bedded fine-grained siliceous sandstone exposed in the roadcut on State Highway 7 (NE¼ NE¼ sec. 29, T7N, R20W) approximately 1½ mi south of Russellville. At this locality the Atoka Formation is predominately a shale which includes an appreciable amount of fine-grained, thinly bedded sandstone and siltstone. Figure 4 describes a stratigraphic section measured in this roadcut.

In the Russellville area, the Hartshorne sandstone is light to medium gray or tan, commonly carbonaceous, generally well sorted, slightly permeable, siliceous, quartzose, fine - to very fine-grained sandstone interbedded with siltstone and minor amounts of shale.

The Hartshorne shows current ripple marks and cross-bedding within several sandy or silty horizons. It is thin-bedded to massive, regularly to irregularly bedded and lenticular at some localities. The base of the formation is generally sharply defined and at some places is irregular due to channeling into the underlying Atoka Formation (Merewether and Haley, 1969, p. 18).

<u>McAlester Formation</u>.-The McAlester Formation is the youngest Pennsylvanian rock unit that crops out in the Russellville area. The formation as described and mapped in this report is equivalent to that described by Hendricks and Parks (1950). Rocks of this formation were



Tan to limonitic yellow micaceous siltstone; massively bedded, with leached zones along the bedding planes.

Light gray to tan, silty, slightly micaceous shale.

"Hartshorne Coal"

Gray, carbonaceous, silty fissile shale; carbonaceous films separate laminae.

Gray-tan, carbonaceous very fine-grained sandstone.

Tannish gray, clayey, micaceous siltstone.

Gray, angular, well sorted, siliceous, impermeable, very fine-grained sandstone.

Light gray, angular, well sorted, siliceous moderately permeable fine-grained sandstone.

Medium gray, angular, well sorted, siliceous, impermeable very fine-grained sandstone with scattered limonite and carbonaceous inclusions. Massively bedded, weathered surfaces show limonite staining and "desert-varnish-like" coatings. Evidence of a disconformity includes clean sandstone above the surface of disconformity and silty to clayey sandstone below, fragments of the silty to clayey sandstone are found included in the clean sandstone, irregular contact surface.

Medium gray, medium-bedded (3 cm), angular to sub-angular, well sorted, siliceous quartzitic very fine-grained sandstone interbedded with shale and minor amounts of siltstone. Limonitic staining on grains and fractures, some scattered carbonaceous flakes are present. Sparse red sandstone fragments (5 x 10 mm) and clay galls are present; some cross-bedding is apparent.

Light gray, medium-bedded (4 cm), micaceous, angular to sub-angular, siliceous, quartzitic, very fine-grained sandstone interbedded with silty shale; dark gray, thinly laminated (1-2 mm), micaceous, carbonaceous siltstone.

Light gray, fissile to splintery, slightly micaceous shale; weathers to a limonitic yellow.

Figure 4. - Stratigraphic section on Arkansas State Highway 7, 1½ mi south of Russellville (NE¼ NE¼ sec. 29, T7N, R20W).

originally divided into three separate formations, the Spadra Shale, the Fort Smith Formation, and the Paris Shale. However, this usage has been discontinued in recent years.

The McAlester Formation overlies the Hartshorne Sandstone conformably. The base of the McAlester is placed below the "first Hartshorne coal bed," generally at the top of the relatively clean sandstones of the Hartshorne Sandstone. In the Russellville area the contact is very sharply defined because the McAlester Formation consists almost entirely of gray clayey shale. Coal and some thin siltstones are also included in the formation.

The shale is medium gray to grayish black, silty, micaceous, and commonly contains pyrite and plant fossils. The siltstone is gray to tan, micaceous, and some strata are argillaceous or sandy. Locally, the siltstone is massively bedded with leached zones that provide secondary porosity along the bedding planes. No sandstone beds were observed in the McAlester Formation within the study area.

Generally, the McAlester is poorly exposed in the area of this report because it crops out in two synclinal valleys that form lowlands. In a large part of the area, the shale is masked by river and stream alluvium and by terrace alluvium.

The lower "Hartshorne Coal" is the thickest and most widespread coal bed in the report area. The bed is located from 2½ to 19 ft above the top of the Hartshorne Sandstone in the Coal Hill, Hartman, and Clarksville Quadrangles, Johnson County, Arkansas (Fig. 1), according to Merewether and Haley (1969, p. 19). The coal is normally separated into two "benches" by a shale or siltstone that ranges from about 1 in. to 20 ft thick, but that is less than 12 in. thick throughout much of the area where the coal is developed (Merewether and Haley, 1969, p. 19). Total thickness of the two "benches" of coal in the extensively mined areas of Johnson County is from about 32 to about 63 in.

In the Russellville area the "Hartshorne Coal" was reported to be about 30 in. thick in the Ouita basin (Branner, 1888, p. 25). It was also noted by Branner that two main coal strata are present in the Shinn basin, the upper being about 30 ft above the lower. The upper coal ranges from 18 to 20 in. thick but is generally divided into two parts by 4 to 8 in. of shale (Branner, 1888, p. 25). The lower coal, ". . . rests upon the upper surface of the underlying sandstone. It is about 18 in. thick and is said to strongly resemble the Ouita coal." (Branner, 1888, p. 25).

Upon inspection of the roadcut on Highway 7 south of Russellville, a single greatly weathered coal bed 36 in. thick is noted 19 ft 9 in. above the Hartshorne Sandstone. During the summer of 1973 State Highway 7 was widened and the freshly exposed material revealed an additional coal seam about 44 in. thick. However, it was severely weathered and its boundaries could not be established precisely. Six mo later it could not be located in the exposure.

## Quaternary System

### Terrace Alluvium

Generally, terrace deposits adjacent to the flood plain of the Arkansas River can be divided into two distinct types: (1) higher, older bodies of alluvium with bases above the top of flood plain alluvium; and (2) lower, bodies of terrace alluvium with bases below the surface of the flood plain alluvium (Bedinger and others, 1963, p. 5). Older terrace deposits have been observed at a height of 150 ft above the Arkansas River in Crawford County (84 mi upstream from Russellville) (Fig. 1), but the average height above the river flood plain is approximately 50 ft. Croneis (1930, p. 148) noted that deposits of terrace alluvium generally occur at heights from 75 to 200 ft above present water levels. Generally, the younger terraces lie from 20 to 40 ft above the flood plain (Bedinger and others, 1963, p. 5).

Generally, a zone of pebbles and cobbles lies near the base of the older high terrace deposit. The pebbles and cobbles are composed of siltsone, sandstone, or quartz. Above this coarse zone are layers of sand, silt, and clay (Merewether and Haley, 1969, p. 21). Some of the material composing the terrace alluvium is from local bedrock, but a portion is foreign to the surrounding area. Color of the older terraces generally is reported to be red (Bedinger and others, 1963, p. 5).

The oldest river terrace deposit and a few of the older stream terraces are probably equivalent to the Gerty Sand (Pleistocene) in Oklahoma (Merewether and Haley, 1969, p. 21).

### River and Stream Terraces in the Russellville Area

Several terraces can be recognized in the Russellville area. Field examination of the areas delineated on the topographic maps, aerial photographs, and soil maps, indicates that possible four terrace levels can be identified. However, evidence is not abundant in several areas and a differentiation of terrace levels was not attempted at these localities. The approximate elevations of the suspected terrace levels are from: 320 to 340 ft, 340 to 360 ft, 360 to 400 ft, and over 400 ft.

An exposure of the highest terrace deposit is in the SW¼ sec. 20, T8N, R20W (Pl. 1) where an open cut has been made exposing the terrace gravels. The gravels are as long as 6 in. The material has been used locally as road metal. This terrace is approximately 80 ft above the flood plain of the Illinois Bayou. Material which appears to be of the same deposit also crops out in the NE¼ sec. 30, T8N, R20W (Pl. 1) at an elevation of approximately 400 ft.

The intermediate terrace levels ranging from 340 to 400 ft in elevation are widely exposed in the Russellville area. These deposits cover the majority of the tract including secs. 2, 3, 4, 8, 10, and 11, T7N, R20W (Pl. 1). The terrace deposits are generally composed of tan, sandy silt. Grains larger than sand are rarely found in this material. Generally, these deposits are less than 10 ft thick (Pl. 6).

Another well exposed outcrop of these intermediate terrace deposits (elevation 350 to 370 ft) is in the SE¼ sec. 34, T7N, R20W and the S½ sec. 35, T7N, R20W (Pl. 1). Erosion of this area is distinctive due to the vertical-walled gullies in the fields underlain by the terrace material. The gullies are recognizable on aerial photographs as white linear "streaks" surrounded by mottled gray tones. The unusual erosional character and microscopic examination of the material shows that it contains a high proportion of angular silt grains, perhaps derived from loess.

A gravelly, intermediate-level (elevation about 360 ft) terrace deposit is exposed in the NE¼ sec. 29, T7N, R20W in a road cut along

State Highway 7 (Pl. 1). In this location, a thin deposit of terrace alluvium overlies the dipping Atoka Formation exposed in the road cut. The pebbles in this terrace deposit range from less than 1 in. to 3 in. in diameter; larger pebbles probably are included in the material. The pebbles, which were collected at "random" are all chert, a fact that indicates that they were transported from outside the local area.

The lowest terrace (approximately 320 ft) is best preserved adjacent to the modern flood plain of the Arkansas River (elevation about 318 ft) in secs. 2 and 3, T6N, R20W and in secs. 20, 28, 29, and 33, T7N, R20W (Pl. 1). These deposits are mainly silt. Gravel is not known to be preserved in these terraces.

### Flood Plain Alluvium of the Arkansas River

Alluvium of the Arkansas River consists of gravel, sand, silt, and clay. Generally, it grades from gravelly at the base to clayey at the surface. The log of a test hole drilled in the alluvium of the Arkansas River near Dardanelle, Arkansas is shown in Table 4.

The log appears to describe the typical sequence of sediments in the alluvium of the Arkansas River Valley, because it correlates closely with other logs of river alluvium from sites both upstream and downstream.

Additional comments concerning the alluvium of the Arkansas River are included in the section of this report that concerns sand and gravel resources.

TABLE 4

LOG OF TEST HOLE, YELL COUNTY
NW¼ sec. 35, T6N, R20W

| Surface Elev. 316 ft | Depth to water: 17 ft | |
|---|---|---|
| Description | Thickness (ft) | Depth (ft) |
| Soil; sandy | 1.3 | 1.3 |
| Sand; fine, brown; contains trace of medium to coarse sand | 6.7 | 8.0 |
| Clay; silty, brown | 2.0 | 10.0 |
| Sand; fine, brown; contains some very fine sand | 10.0 | 20.0 |
| Sand; medium, brown; contains much fine sand, some very coarse sand, and some very fine gravel | 15.0 | 35.0 |
| Gravel and sand; brown, contains much fine gravel, some medium sand, and some very coarse sand | 24.0 | 59.0 |

Source: Bedinger and others, 1963, p. 7.

## Flood Plain Alluvium of Major Tributaries of the Arkansas River

Alluvium is extensive in the valleys of the major tributaries of the Arkansas River, such as the Illinois Bayou. Generally, the alluvium can be divided into two distinct parts: (1) an upper zone composed mainly of clay and silt with minor amounts of very fine to medium sand; and (2) a lower zone composed of gravel and boulders enclosed in a matrix of clay, silt, or sand. The general relationship of the terraces and the flood plain is shown in Figure 5.

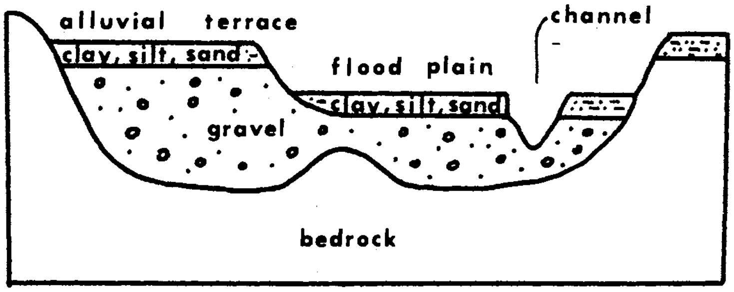


Figure 5. - Generalized cross-section of alluvium in tributaries of the Arkansas River (Cordova, 1963, p. 13).

Auger borings and core holes were drilled in the N½ sec. 31, T7N, R20W and NW¼ sec. 32, T7N, R20W by the U. S. Army Corps of Engineers in preparation for the construction of the Russellville Dike (Pl. 5). Records of these borings and cores show that a graveliferous unit of boulders, sand, and clay, ranging from about 2 to about 12 ft thick overlies the Atoka Formation. Two lenses of sandy silt and silty sand overlie portions of the gravel zone. The uppermost part of the alluvium in this valley (Prairie Creek, a tributary of the Illinois Bayou, Pl. 5) consists of a "lean" clay (silty clay of low plasticity). It overlies the sand lenses in some places; elsewhere it overlies the gravel. Average thickness of alluvium cored in this area is 26 ft (U. S. Army Corps of Engineers, 1961, Pl. 7).

# Structural Geology

## Anticlines

### Knoxville Anticline

The Knoxville anticline was named by Croneis (1930) and was defined as extending from the SE¼ sec. 31, T9N, R22W, northeast of Knoxville in Johnson County to the SE¼ sec. 19, T8N, R20W, approximately 1 3/4 mi northwest of Russellville in Pope County (Fig. 6). Merewether (1967) pointed out that the structure, as defined, is composed of two anticlinal axes which were offset. Therefore, Merewether renamed the eastern subdivision of the Knoxville anticline the Eastern Knoxville anticline. He noted that this renaming reflected details in a large single anticline. The anticline is bounded on the north by the Clarksville syncline and on the south by the Ouita syncline (Fig. 6). The structure, as exposed in the study area, plunges to the east at an angle of approximately 5 deg. The anticline is almost symmetrical, but the south limb generally dips about 8 deg, whereas the north limb, which is not exposed in the study area, dips about 5 deg. Erosional activity has "breached" the axial portion of the structure and exposed older rocks; of course, younger rocks are exposed on the flanks of the anticline.

### Russellville Anticline

The axis of the Russellville Anticline is difficult to locate precisely because most of the eroded axial portion of the structure is masked by terrace alluvium. However, the axis can be defined

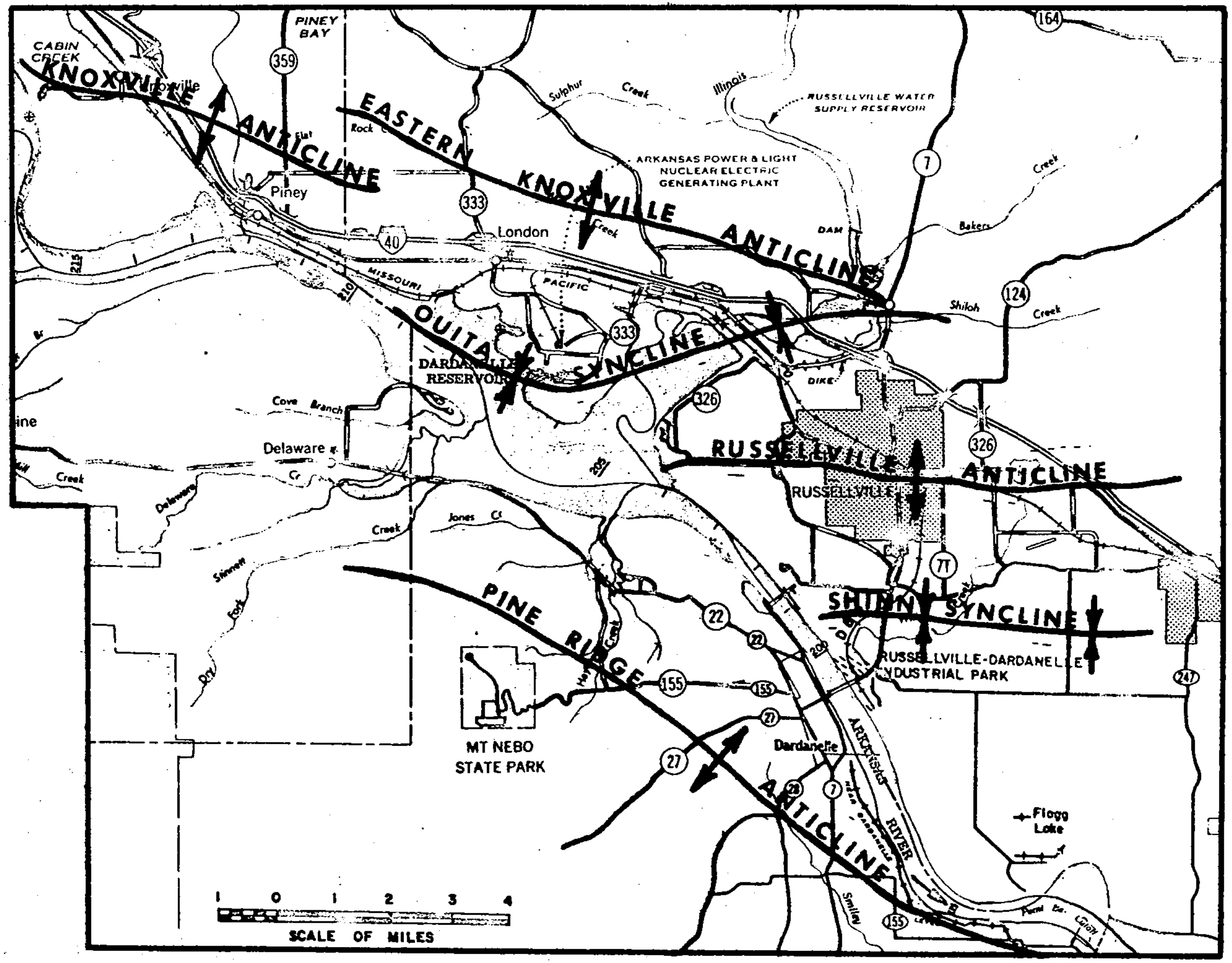


Figure 6. - Location map of the geologic structures in the Russellville, Arkansas area (base map modified from Garver and Garver, 1970, Fig. 3).

approximately as extending from the SE¼ sec. 35, T8N, R21W, on the western end, to the SE¼ sec. 11, T7N, R20W on its eastern end (Fig. 6). The broad, almost symmetrical anticline is approximately 4 mi wide, plunges westward, and lies between the Ouita syncline on the north and the Shinn syncline on the south (Fig. 6).

### Pine Ridge Anticline

The Pine Ridge anticline lies to the south of the Shinn syncline (Fig. 6). Only rocks of the northern limb of the anticline crop out in the study area. The sandstones of the Atoka Formation compose a series of three low, narrow, parallel, east-west-trending ridges which dip northward about 5 deg. The Pine Ridge anticline is obscured by the terrace and river alluvium of the Arkansas River in secs. 28, 29, 32, 33, and 34, T7N, R20W and secs. 2, 3, 4, 9, 10, 11, 12, 13, 14, and 15, T6N, R20W (Pl. 1). The shales of the Atoka Formation generally form rolling uplands between the sandstone ridges.

## Synclines

### Ouita Syncline

The easternmost portion of the Ouita syncline is exposed in secs. 28, 29, and 30, T8N, R20W north of the city of Russellville (Fig. 5). The syncline lies between the Eastern Knoxville anticline on the north and the Russellville anticline on the south. Much of it is presently covered by the waters of the Dardanelle Reservoir. Its axis generally trends northeastward, but in sec. 28 it appears to turn due east and thence slightly southeast. The fold plunges to the west and is generally symmetrical, with dips averaging about 5 deg. The McAlester Formation is exposed in the eastern portion of the syncline, whereas to the west (outside of the study area) the Fort Smith Formation crops out over several sq mi of the syncline.

### Shinn Syncline

The Shinn syncline lies between the Russellville anticline on the north and the Pine Ridge anticline on the south. The axis of the syncline trends from the NE¼ sec. 19, T7N, R20W eastward to the SE¼ sec. 23, T7N, R20W (Pl. 1). The syncline plunges westward and is partially obscured in secs. 19, 20, and 21 by terrace and stream alluvium. The asymmetry of the structure is readily discernible by noting the relatively broad outcrop pattern of the Hartshorne Sandstone north of the axis, and the narrow outcrop pattern of the sandstone south of the axis (Pl. 1). Dips on the northern limb are approximately 15 deg and they are as much as 80 deg on the south limb. Dips decrease eastward to approximately 7 deg on the eastern "nose" of the structure. The McAlester Formation is exposed locally along the axis of the syncline where it is not masked by terrace and stream alluvium.

## Faults

### Pleasant View Fault

This previously unnamed fault is located in secs. 23, 24, T8N, R21W and sec. 19, T8N, R20W (Pl. 1). It generally lies close to and parallels the axis of the East Knoxville anticline. The trend of the fault changes from northwest-southeast in sec. 24, to almost due east-west in sec. 19 where it is concealed beneath the terrace alluvium of the Illinois Bayou.

### Shinn Syncline Fault

This previously unnamed fault lies in sec. 23, T7N, R20W where it almost coincides with the axis of the Shinn syncline. The fault trends almost due east-west in the SW¼ sec. 23, but the trend changes in the SE¼ of sec. 23 to a direction nearly northwest-southeast (Pl. 1). It is primarily recognized by topographic discontinuities to be discussed later in this report. Near the fault plane the shales of the Atoka Formation show extensive fracture cleavage. Measurement of dip or displacements was not possible to achieve, because at no outcrops were recognizable bedding planes exposed.

### Joints

Most of the Paleozoic rocks exposed in the Russellville area are thoroughly jointed. The thin sandstones show the most regular and well developed joint systems, while the massively bedded sandstones show less jointing. Shales are extensively jointed, but apparently lack the competency necessary to develop an orderly joint pattern.

The joint system, where best developed, consists of two, and at some places, three joint sets. The major joint set in the study area trends about N5°W and the joints are almost vertical. A sub-major set trends nearly east-west and is also almost vertical. The minor set, which is developed at a few localities, trends northeast- southwest.

Joints are spaced from less than 1 in. to more than 10 ft apart. During weathering and erosion these discontinuities cause the thin sandstone to break into rectangular blocks a few in. to a few ft in width. Much of the colluvial material in areas of sandstone outcrop contains numerous such blocks.

Many of the major joints show the effects of differential weathering and erosion along their traces. Replacement of the original cementing material of the sandstone, probably a siliceous hematite, by nearly pure silica has occurred along some joints. The zones of replacement are about ¼ in. wide, on the average. As noted in a later part of the report, jointing significantly influences the production of ground water and the migration of liquid waste and effluent from solid waste in the study area. The joints generally act as conduits along which ground water and polluted water may travel rapidly.

## Geomorphology

### Introduction

The Arkansas River Valley subprovince of the Ouachita physiographic province varies in width from 25 to 35 mi and extends from the Oklahoma border eastward to the Gulf Coastal Plain near Searcy, Arkansas (Fig. 1). It lies between the Boston Mountains on the north and the Ouachita Mountains on the south (Fig. 1). The Arkansas River Valley is a gently undulating plain, interrupted by numerous long ridges and several broad-topped synclinal mountains, all trending slightly north of east (Croneis, 1930, pp. 12-13). Topography of the province is generally controlled by structure of the bedrock. Regional structure is that of a synclinorium (Croneis, 1930, p. 13). Close folding and thrust faulting are characteristic of the southern portion of the valley near the Ouachita boundary. Open folding and normal faulting are typical of the northern portion of the valley (Croneis, 1930, p. 13) in which the study area is located.

## Topographic Expression of Anticlines

### Eastern Knoxville Anticline

The Eastern Knoxville anticline extends from sec. 19, T8N, R20W to sec. 23 and 24, T8N, R21W (Pl. 1). The anticline is shown by a cuesta, known locally as Pleasant View Mountain. Its escarpment slopes are oriented to the north and to the west (on the eastern nose of the structure where the anticlinal axis plunges east). The dip slope faces southward and the Hartshorne Sandstone is well exposed in an area known as "Forty-Acre Rock" (SW¼ sec. 24, T8N, R21W; Pl. 8). This tract is of particular interest because the sandstone is case-hardened and weathers to a "waffle-iron" surface (Fig. 7). Differential weathering and erosion appear to be controlled by a system of two intersecting joint sets that are zones along which gully erosion has been concentrated.

Inversion of topography is not as prominent on this structure as elsewhere in the region because the Atoka Formation, which is exposed along the axial portion of the anticline, also contains ridge-forming sandstone strata.

### Russellville Anticline

The Russellville anticline is best exposed in sec. 31, T8N, R20W; sec. 36, T8N, R21W; secs. 1, 2, and 12, T7N, R21W; and secs. 6, 7, 17, and 18, T7N, R20W (Pl. 1). The western nose of the structure forms a broad, gentle dip-slope which plunges beneath the Dardanelle Reservoir. The "cuesta-like" landform, known locally as Norristown Mountain, has steep eastward- and northward-facing escarpment slopes, where Hartshorne Sandstone ledges overlie Atoka Formation shale slopes. Due to their commanding view, the escarpment slopes offer tempting but hazardous tracts for low-density residential development. Problems which would be encountered in such development will be discussed later in this report.

Figure 7.-"Waffle-iron" surface of Forty-Acre Rock near Russellville, Arkansas (SW¼ sec. 24, T8N, R21W).

The southwestern side of the anticline in secs. 12, 17, and 18, T7N, R20W (Pl. 1) has been deeply eroded by the superposition of the Arkansas River across the Hartshorne Sandstone. This has produced very steep and high cliffs, known locally as River's Bluff (Pl. 8). The cliffs are about 300 ft high and are very nearly vertical or overhanging in several areas. The footslopes of the cliffs are littered with massive blocks (as large as 50 ft x 40 ft x 30 ft) of sandstone rubble. The smaller debris forms talus slopes at the bases of the cliffs. Due to the flooding of the river channel by the Dardanelle Reservoir, several large blocks of sandstone now appear as small islands near the shoreline.

The interior portion of the Russellville anticline has been deeply eroded and is mostly occupied by stream terraces. However, the Atoka Formation is exposed in several places, especially where the formation's three uppermost sandstone beds are present. These sandstones form low ridges in the interior of the structure, especially along the southern margin in secs. 14, 15, 16, 17, and 23, T7N, R20W (Pl. 1).

## Topographic Expression of Synclines

### Ouita Syncline

Shale of the McAlester Formation underlies lowland topography north of the city of Russellville in secs. 28, 29 and 30, T8N, R20W (Pl. 1). Most of this lowland, originally the flood plain of the Illinois Bayou, is now covered by the waters of the Dardanelle Reservoir. The north flank of the synclinal valley is formed by Pleasant View Mountain, while the south limb has been mostly eroded away by the superposition of the Illinois Bayou upon the north flank of the Russellville anticline, except on the western end of Norristown Mountain (Pl. 1). The alluvium that masks part of the eroded interior of the Russellville anticline probably came from the Illinois Bayou.

### Shinn Syncline

The Shinn syncline is exposed south of the Russellville anticline. The syncline is asymmetrical, a fact that is readily apparent in its topographic expression. The northern limb of the syncline dips about 15 deg and is very poorly exposed. A low northwest-trending ridge can be seen, but in general, the area tends to be one of low rolling landscape. However, the southern limb of the structure, which dips up to 80 deg, is expressed as a hogback, especially on its western end in secs. 20, 27, 28, and 29, T7N, R20W (Pl. 1). Toward the eastern end of the ridge the hogback grades into a cuesta as the dips decrease to less than 10 deg. The cuesta development is most pronounced in secs. 26 and 27, T7N, R20W (Pl. 1) where the escarpment slopes face southward. The axial portion of the Shinn syncline forms a lowland where shales of the McAlester Formation and stream and terrace alluvium are exposed.

## Expression of Faults

### Pleasant View Fault

The Pleasant View fault, located in secs. 23 and 24, T8N, R20W (Pl. 1), has little topographic expression. The trace of the fault is marked by erratically dipping strata exposed in the bed of a small eastward-flowing stream (SE¼ sec. 19, T8N, R20W). The fault is probably the cause of the inverted "Z" offset in Pleasant View Mountain in sec. 19, T8N, R20W (Pl. 1).

### Shinn Syncline Fault

The Shinn syncline fault is recognized by its topographic expression. The Hartshorne Sandstone ridge shows a marked change in topography in the SW¼ sec. 23, T7N, R20W. In this area the elevation of the ridge crest abruptly drops approximately 120 ft. An alternate explanation of this discontinuity could be that it is due to radical change in lithology of the Hartshorne Sandstone. Such a change could be caused by change from a facies of massive siliceous sandstone to thinly-bedded, silty, ferruginous sandstones and siltstones. Such lithologic changes have been proposed by Croneis (1930), as previously mentioned. However, the writer favors the explanation of the discontinuity being due to a fault, because three Atoka Formation sandstone ridges show pronounced offsetting in secs. 23 and 26, T7N, R20W and beyond the eastern boundary of the study area. A north-northwest-trending linear feature (probably a fault) seems to terminate the Shinn syncline on an ERTS (Earth Resources Technology Satellite) photograph of the area. This additional evidence supports the hypothesis that a fault causes discontinuity of the ridge.

## Drainage Patterns

### Mill Creek Tributary

The unnamed creek in secs. 23 and 24, T8N, R21W (east fork of Mill Creek) is a subsequent stream having become adjusted to weak rock belts by differential erosion. Its drainage pattern could be best described as "annular" because it follows a more-or-less circular course. However, its annular character is best shown in the sections immediately north of the northern boundary line of the study area. The stream has become adjusted to the hard and soft strata of the Atoka Formation, which drop out in the axial portion of the Pleasant View anticline.

### Illinois Bayou

The Illinois Bayou probably is a superposed stream (one which extends across a geologic structure that antedates the stream valley, but that was not exposed at the time valley cutting began; see Thornbury, 1969, p. 116). North of the study area the Illinois Bayou shows partially entrenched meanders and generally flows transverse to the folds of the region. A linear feature (probably a fault) visible on an ERTS photograph of the area appears to have the same general trend (N25E) and coincides with the channel of the Illinois Bayou about 15 mi north of the study area. This relationship suggests that the drainage pattern may be, in part, structurally controlled.

### Prairie Creek

Prairie Creek has a dendritic drainage pattern which reflects the fact that it flows mostly across stream and terrace alluvium, which by its nature, cannot exert structural control on the pattern.

### Whig Creek

Whig Creek has a complex drainage pattern. In its headwaters (secs. 10, 11, 14, and 15, T7N, R20W and beyond the eastern boundary of the study area) it shows a dendritic drainage pattern. This area is primarily underlain by terrace alluvium. In its middle portion it is superposed across sandstone ridges of the Atoka Formation and the Hartshorne Sandstone (secs. 15 and 22, T7N, R20W). In the lower portion, Whig Creek (secs. 20, 21, and 29, T7N, R20W) appears to revert to a dendritic pattern, except where it is deflected by the Hartshorne Sandstone hogback ridge in the SE¼ sec. 20, T7N, R20W and the NE¼ sec. 29, T7N, R20W (Pl. 1). Therefore, Whig Creek is fundamentally a superposed stream. Its true character is best shown in secs. 15, 16, 21, and 22, T7N, R20W where the terrace alluvium is thinnest due to its deposition upon the ridge-forming units of the Hartshorne Sandstone and the Atoka Formation. In the headwaters and lower portion of the drainage system the alluvium is thicker.

### Drainage South of the Shinn Syncline

The area south of the Shinn syncline (south of the Hartshorne Sandstone hogback ridge in secs. 26, 27, 28, and 29, T7N, R20W; Pl. 1) has a "rolling" topography which is typical of a surface underlain by the Atoka Formation. Drainage patterns are generally dendritic and appear to be mostly superposed north of the Arkansas River flood plain (Pl. 1).

The presence of nearly vertical-walled gullies in the terrace alluvium of this area has been noted earlier in this report. Units of loess in the terraces would explain the steep-walled character of the natural gullies and road cuts (Fig. 8) in the area, especially the one located in the SE¼ sec. 34, T7N, R20W (Pl. 1).

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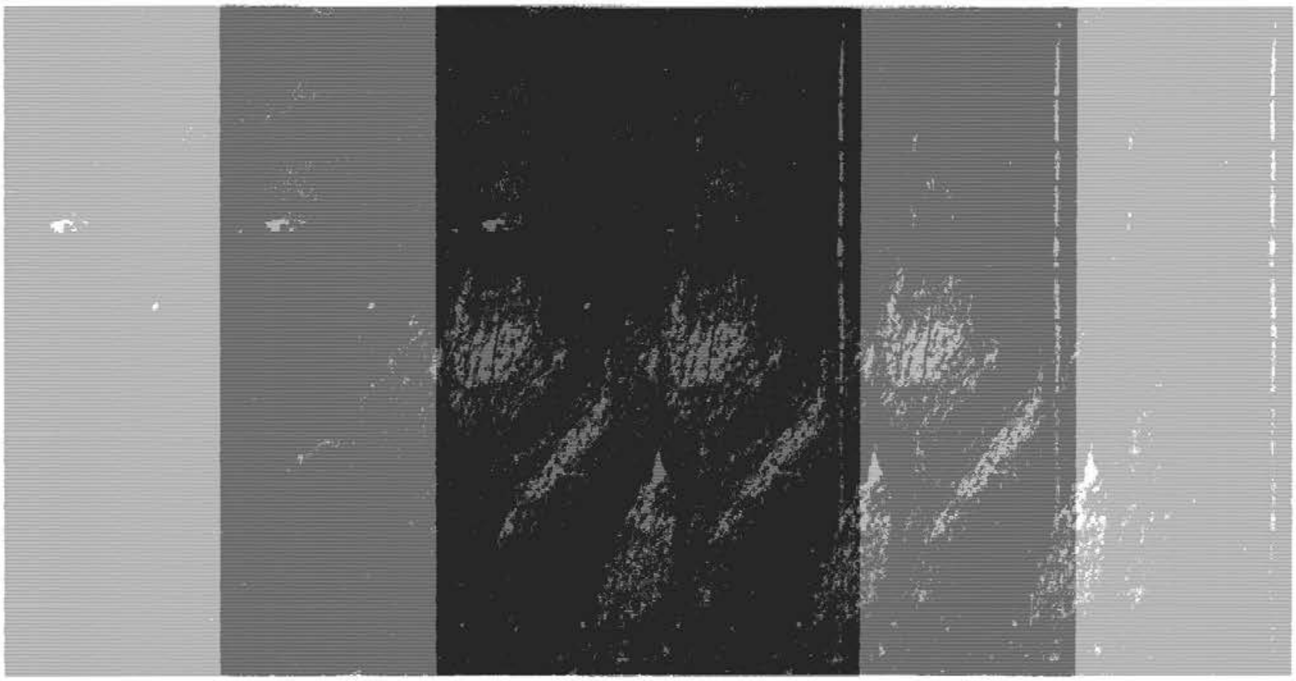


Figure 8. Steep-walled roadcut in terrace alluvium (SE¼ sec. 34, T7N, R20W).

## rkansas River Flood Plain

The flood plain of the Arkansas River occupies the majority of 2, 3, 4, 9, 10, 11, and 12, T6N, R20W, and sec. 33, T7N, R20W 5). These areas are flat (Pl. 5). However, there are "channel where relief may be as much as 20 feet. Along the edge of the sas River dunes are developed and a few small sand pi ncluded in the area (Pl. 2).

## Surficial Deposits

The surficial materials that overlie the bedrock in the Russel area consist of stream and terrace alluvium, colluvium, resid mine spoil, and urban waste landfill.

## Stream and Terrace Alluvium

The positions of the stream and terrace alluvial deposits are shown on Plate 1 and Plate 6. These materials have been described earlier in this report in the section entitled "Stratigraphy"; however, a brief summary is included here for completeness. The alluvium is generally silty and sandy clay, clayey to sandy silt, fine to coarse sand, and gravel. The gravelly alluvial zones are located mostly in the Arkansas River flood plain, especially near the contact with bedrock. Some gravelly terrace deposits have been recorded in the area.

## Colluvium

Colluvium is described by Way (1973, p. 27) as follows:

> . . . soil material that has moved downslope by a process of mass wasting, such as creep, aided by frost action and erosion. . . . Its materials are not stratified or exhibit poor stratification . . . it is hard to distinguish in residual soils. . . . All regions of residual soil materials contain zones of colluvium fringing the bottoms of significant slopes. It is important to identify these because of their unstable, unpredictable characteristics.

Colluvium in the Russellville area has been mapped as 3 units: (1) shale and siltstone colluvium, (2) sandstone colluvium, and (3) mixed (footslope) colluvium.

### Shale and Siltstone Colluvium

The shale and siltstone colluvium (mostly from the Atoka Formation) is composed of silty and sandy lean (low to moderate plasticity) clays that contain numerous fragments of sandstone and siltstone less than 6 in. in diameter. The material is unstratified and is difficult to distinguish from residual soil, especially where the grades are less than 5 percent.

### Sandstone Colluvium

At many places the Hartshorne Sandstone colluvium is mixed with residual soils developed on sandstone, because of the low slope (3 to 7 percent grade) - especially on Norristown Mountain (Pl. 4). The mixed sandy colluvium and residual soil commonly includes sandstone fragments. It is not unusual to find bedrock exposed in the stream channels in terrain where this type of colluvium is developed, because the colluvium is only 2 to 3 ft thick at most places.

### Mixed Colluvium (Footslope Colluvium)

Mixed or footslope colluvium is developed below escarpments, especially where the Hartshorne Sandstone overlies the Atoka Formation. The material is composed of boulder-, cobble-, and pebble-sized fragments of sandstone and siltstone in a matrix of sand, silt, and clay. Organic debris is also likely to be present, mixed with detrital material.

### Residual Soil

Residual soils are present on the outcrop of sandstone (Hartshorne Sandstone) and shale (McAlester and Atoka formations). In the sandstone terrain the soil horizons are fine sandy loam over stony to very stony loam subsoil. Many rock fragments can be found throughout the soil profile. In areas where shale outcrops, the soil is silty clay loam that grades downward into a shaly clay subsoil. The lowermost part of the soil profile commonly contains numerous siltstone and sandstone fragments due to the thin (2 or 3 in.) siltstone and sandstone strata that are abundant in the Atoka Formation.

### Mine Spoil

Mine spoil probably covers less than 1 sq mi in the Russellville area. It contains an extremely heterogeneous mixture of sandstone, shale, coal fragments, and alluvium, including sand and gravel. Generally, the spoil has not been reclaimed, but a few areas have been leveled and reseeded. Natural reseeding has caused vegetation to become established on most of the unleveled spoil piles.

### Urban Waste Landfills

Urban-waste landfills probably occupy less than 40 acres in the study area. The material is composed of all forms of urban solid waste, which was burned prior to 1970. Since then, solid waste has been placed in the landfills without burning. The "completed" landfills have been leveled and covered with about 1 ft (Fig. 9) of silty terrace alluvium.

Figure 9. "Completed" urban landfill near Russellville, Arkansas (NE¼ sec. 21, T7N, R20W).

# MINERAL RESOURCES

## Sand and Gravel

Extensive deposits of sand and gravel occur along the Arkansas River in secs. 19, 20, 29, 31, 33, T7N, R20W and secs. 4, 9, 10, 11, and 12, T6N, R20W. Several sand and gravel pits are located in secs. 29, 32, 33, T7N, R20W and sec. 11, T6N, R20W. Large quantities of sand and gravel also are dredged from the Arkansas River and are available from a washing and screening plant located in the SE¼ of sec. 29, T7N, R20W at the Port of Dardanelle (Pl. 2).

River deposits average about 25 ft in thickness and reserves are estimated at 6 million tn per mi of river bed. An estimated 4 million tn of sand and gravel have been produced from these deposits to date (Stroud and others, 1969, pp. 336-337).

Sand bars along the river channel are composed of approximately 85 percent sand and 15 percent gravel. The quartz particles in the sand are clear to frosted, gray, hard, dense, subangular to subrounded and make up 77 percent of the total sample of sand. Some particles of quartz contain incipient fractures. Other constituents of the sand are feldspar, 15.0 percent; chert, 4.0 percent; granite, 2.5 percent; and other rocks and minerals, 1.5 percent (U. S. Army Corps of Engineers, 1951, p. 78). About 5 percent of the sand is composed of unsound (cracked) particles. Normal washing and classifying of the bulk and will yield a product which is slightly deficient in fines (U. S. Army

Corps of Engineers, 1951, pp. 78-79). The gravel consists mainly of chert pebbles, but pebbles of limestone, sandstone, and quartz are also present (Stroud and others, 1969, p. 337).

Damming the river has sharply reduced the natural replenishment of the sand and gravel, and thus depletion of the deposits is possible; but reserves are vast and are considered to be adequate for the development of the Russellville area for many years to come. The relatively low cost of barge transportation will provide the region with adequate sand and gravel resources even after depletion of local reserves.

In 1972, 212,961 tn of sand and gravel were produced in Pope and Yell counties (Fig. 1) (Arkansas Tax Commission, 1972). Projecting this rate of production into the future and comparing it against an estimated reserve of 6 million tn per river mi, approximately 28 yr will be required to deplete each mile of river channel sand and gravel deposit.

In addition to these large reserves there are extensive sand and gravel deposits in the valley, contained in flood plain alluvium and terrace alluvium. These deposits extend from the present channel to the valley walls. The materials are thicker than 60 ft near the present channel. Therefore, reserves of sand and gravel are considered to be more than adequate for the future development of the area.

## Sandstone

Massively bedded sandstone of the Hartshorne Sandstone crops out over about one-quarter of the area covered by this report. Several quarries have been operated in the region and several are currently in operation. The most important of these are located as follows:

(1) NW¼ sec. 30, T8N, R20W, (2) NW¼ and NE¼ sec. 28, T8N, R20W, (3) SE¼ sec. 22, T7N, R20W, and (4) C, SE¼ and SW¼ sec. 18, T7N, R20W (land controlled by U. S. Army Corps of Engineers).

Total production of sandstone from sec. 22, T7N, R20W, has been estimated at 600,000 tn (Stroud and others, 1969, p. 337) and reserves are at least several million tons. Most of the stone is used as road metal, aggregate for concrete, and rip-rap on embankments. Total crushed stone production in Pope County in 1972 was 380,984 tn (Arkansas Tax Commission, 1972). Reserves of sandstone in the Russellville area are virtually inexhaustible.

## Coal

The history of coal mining in the Russellville area dates back a hundred years. The first known mine opened in 1873 west of Russellville. In 1883 coal mining became a well established industry and by 1887 production from the Ouita and Shinn basins (Pl. 2) was 4,200 short tn. The highest annual production was in 1913 when 79,608 tn were produced. Total production from 1887 to 1963 is estimated at 3 million short tn, valued at $13.7 million (Stroud and others, 1969, p. 336).

Before 1953 most of the coal in the study area was mined by underground operations. There was no production between 1953 and 1956. Strip mining began in 1957 and continued until 1962. There has been no significant production since that date.

The coal which was mined in the Russellville area was known by the trade name "Arkansas Anthracite". It is a semianthracite with the range of composition shown in Table 5.

TABLE 5

COMPOSITION OF THE COAL MINED IN THE RUSSELLVILLE AREA

| Constituent | Range (in percent) |
|---|---|
| Sulfur | 1.27 - 2.49 |
| Ash | 6.43 - 12.31 |
| Volatile matter | 12.87 - 14.41 |
| Fixed carbon | 85.59 - 87.13 |
| BTU per pound | 15,250 - 15,930 |

Source: Stroud, 1969, p. 336.

## Future of Coal Mining in the Russellville Area

Coal has been mined from two basins in the area. The Ouita basin in secs. 19, 20, 21, 28, 29, and 30, T8N, R20W (Pl. 2) is located north and northwest of Russellville. The Shinn basin lies about 1 mi southeast of the city in secs. 19, 20, 21, 22, and 23, T7N, R20W (Pl. 2). The main coal seam in the Ouita basin is about 26 in. thick on the average, and it underlies an area of approximately 3 sq mi. The Corps of Engineers drilled two core holes in the basin prior to building the Dardanelle Dam. One hole located in the NW¼ sec. 30, T8N, R20W (Pl. 2) encountered a 30-in.-thick coal seam at the depth of 84 ft. The coal is overlain by 53 ft of shale and 31 ft of alluvium. A second hole drilled in the NW¼ sec. 26, T8N, R21W (Pl. 2) (about 1½ mi west of the first hole) did not locate the coal during the drilling of 30 ft of alluvium and 117 ft of shale. The opinion of the writer is that because the Ouita syncline plunges westward at about 4 deg, the hole was not drilled deep enough to penetrate the coal. However, there is some evidence to indicate that the plunge is not constant, and that it decreases westward (B. R. Haley, 1973, personal communication).

The areas around the periphery of the basin where the coal is near the surface have been mined extensively and some moderately deep stripping (70 ft) has been accomplished. However, the great majority of the center portion of the basin, where the overburden exceeds 70 ft, has not been mined. Most of this coal is now unrecoverable by stripping due to the construction of the Dardanelle Dam and the flooding of the Ouita basin area by the Dardanelle Reservoir. In the past, underground mining encountered water-seepage problems due to the extensive development of joints and other fractures which permitted surface and ground water to enter the mines. Therefore, it is not likely that underground mining beneath the Dardanelle Reservoir would meet with much success.

The Shinn basin is about 1¼ mi wide, in the north-south direction, and is about 3 mi long. The basin contains two seams of the "Lower Hartshorne Coal" which are separated by about 30 ft of interbedded sandstone and shale (Stroud and others, 1969, p. 336). Two coal beds crop out in a road cut (NE¼ NE¼ sec. 29, T7N, R20W), but they are separated by about 10 ft of shale. The upper seam has been mined extensively, especially around the margins of the basin where dips are as much as 80 deg. Owing to the steep dip of the coal into the syncline, the lower seam lies beneath more than 600 ft of overburden at the center of the basin (Stroud and others, 1969, p. 336). In the past, the deepest coal mine in Arkansas (480 ft) was located in the Shinn basin. [Today a mine more than 600 ft deep is located in Sebastian County, Arkansas (Fig. 1)(B. R. Haley, 1973, personal communication)]. The lower seam of coal has been mined only to a minor extent, but the great thickness of overburden will make its recovery difficult and expensive.

To date, the Shinn basin area has not been entirely committed to "high value" land-development activities. The eastern part of the basin in secs. 22 and 23, T7N, R20W (Pl. 2) is used primarily for grazing land, farm home sites, and garden plots. One active stone quarry is located in the SE¼ sec. 22, T7N, R20W (Pl. 2). The center portion of the basin, primarily in sec. 21, T7N, R20W (Pl. 2) is occupied by an active city landfill, a "completed" city landfill, farmland, automobile salvage yards, and mine-spoil piles. The land adjoining State Highway 7 and the Dardanelle and Russellville Railroad tracks (secs. 20, 21, T7N, R20W; Pl. 2) has been developed into light-industrial and commercial tracts. The part of the basin that lies to the west of Highway 7 is generally considered to be prime agricultural river-bottom land. Heavy industry has also developed in the area due to the proximity of the Arkansas River Navigation System. The U. S. Army Corps of Engineers also has title to much of the acreage in the western part of the Shinn basin. Thus, the eastern and central part of the Shinn basin could be mined in the near future, before urban growth prohibits such an operation.

The U. S. Geological Survey and the U. S. Bureau of Mines estimate that the coal reserves in the Russellville area are approximately 17 million short tn (Stroud and others, 1969, p. 336). That is, about

5½ times more coal remains than has been mined. In the past, mining losses of coal in the Ouita and Shinn basins have about equaled the production. The Ouita basin probably should not be considered to be a coal-resource area in the near future due to the presence of the Dardanelle Reservoir. Therefore, subtracting an estimated one-half of the potential reserves from the total leaves slightly more than 4 million tn of recoverable coal in the Shinn basin, an important obtainable resource of the area.

## Ground Water Resources

### Ground Water in the Alluvium and Terraces of the Arkansas River Valley

The greatest ground-water resource in the Russellville area is in the alluvium of the Arkansas River. If properly evaluated and developed, this source of water could provide municipal and industrial water supplies of significant volume.

The stratigraphy of the Arkansas River flood plain and terrace deposits in the Russellville area has been studied utilizing the core logs of 23 observation wells drilled for the U. S. Geological Survey in the Arkansas flood plain south of Russellville (Pl. 3).

The thicker, more uniform deposits of sand are generally found near the present river channel. Thinner deposits of sand, which contain a greater proportion of silt and clay, are located near the edge of the flood plain. The proportion of gravel and gravelly sand is very small in comparison to the amount of sand in the alluvium. The gravel and gravelly sand is generally located near the bedrock contact.

Complex stratigraphic relationships are common where channel deposits are encountered. Clay and silt layers are interbedded with sand in an unpredictable manner using the data available. Sediment types change markedly within distances of only a few feet vertically or laterally. Therefore, the channel deposits are considered unlikely to yield large volumes of ground water for any one location. However, there is a potential for production where the net thickness of sand and gravel is great.

In the flood plain in secs. 28, 29, 33, and 34, T7N, R20W and secs. 2, 3, 4, 9, 10, 11, and 12, T6N, R20W (Pl. 3) the water table is about 21 ft below the surface. The depth at which water is encountered is much less where clay lenses form aquitards and the water table is perched. Such a perched water table was recorded at several locations on the flood plain and terraces (Pl. 3).

Water-saturated deposits of sand that are 29 ft thick on the average are located near the present river channel (see Panel Diagram, Pl. 3). The average grain-size distribution in these sand deposits is shown as Table 6. Yields of 325 to 535 gpm (gallons per minute) could be expected from a 12-in. diameter well that penetrated 29 ft of water-saturated sand and that operated at 100 percent efficiency (estimate based on Bedinger and others, 1963, p. 10).

Water-saturated sand and gravel 42 ft thick were encountered in a well which was drilled in Yell County, near Dardanelle, Arkansas in sec. 35, T6N, R20W. Pumping tests conducted on this well are considered to be important in the evaluation of prospects for water production in the Arkansas River flood plain in the area under study. Pumping tests of the well produced the following information:

(1) Coefficient of transmissibility (gpd per ft) = 120,000, (2) Coefficient of permeability (gpd per sq ft) = 3000, and (3) Coefficient of storage = $3.8 \times 10^{-3}$ (Bedinger and others, 1963, p. 8). In the writer's opinion, these results could be assumed to be typical of the wells drilled in the study area because the hydraulic factors mentioned above are typical of areas both upstream and downstream from the Russellville area.

TABLE 6

AVERAGE GRAIN-SIZE DISTRIBUTION OF SEDIMENT IN THE ARKANSAS RIVER FLOOD PLAIN, SOUTH OF RUSSELLVILLE, ARKANSAS

| Grain Size | Percentage of Total Sand and Gravel Recovered From 23 Observation Wells |
|---|---|
| very fine sand | 28 |
| fine-medium sand | 9 |
| medium sand | 20 |
| medium-coarse sand | 10 |
| coarse sand | 6 |
| coarse-very coarse sand | 9 |
| very coarse sand | 9 |
| gravel | 9 |
|  | 100 |

## Shapes and Position of the Water Table

According to Bedinger and others (1963, p. 13), the water table generally slopes toward the river during low- and normal-water river stages causing an effluent condition to exist. During high-water river stages the conditions are reversed and the river becomes influent in which case the water table slopes away from the river channel. Locally, "mounds" in the ground-water table occur beneath areas where recharge is identified with permeable surface material and greater-than-average rates of infiltration.

The average rate of recharge in the 280 sq mi area of alluvium between Little Rock and Fort Smith probably is about 130 mgd (million gallons per day) (Bedinger and others, 1963, p. 15). Although more ground water is being used today than ever before, the potential yield of the aquifer still exceeds the utilization by a large factor.

## Chemical Quality of Ground Water

The water is generally of the calcium-magnesium bicarbonate type which may show wide variations in the dissolved-solids content. These variations are most clearly related to the inflow of water from adjacent or underlying formations. The chemical quality of the ground water from the Arkansas River alluvium in Pope and Yell counties is shown in Tables 7 and 8.

## TABLE 7

## CHEMICAL QUALITY OF THE GROUND WATER FROM THE ALLUVIUM OF THE ARKANSAS RIVER IN POPE AND YELL COUNTIES, ARKANSAS

| County | Iron (Fe) ppm | | Bicarbonate ($HCO_3$) ppm | | Sulfate ($SO_4$) ppm | | Chloride (Cl) ppm | | Nitrate ($NO_3$) ppm | | Calcium Magnesium (Ca, Mg) ppm | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| Pope | 29 | .08 | 508 | 31 | 150 | 0.8 | 187 | 2.2 | 148 | 0.0 | 510 | 42 |
| Yell | 51 | .09 | 526 | 23 | 132 | 1.0 | 208 | 2.0 | 270 | 0.0 | 688 | 35 |
| Median for area | 1.4 | | 245 | | 18 | | 11 | | 5.2 | | 253 | |

Source: Bedinger and others, 1963, p. 20.

TABLE 8

CHEMICAL QUALITY OF THE GROUND WATER FROM MUNICIPAL WELLS PRODUCING FROM THE ALLUVIUM OF THE ARKANSAS RIVER

| Constituent (ppm) | Atkins | Dardanelle |
|---|---|---|
| Iron (Fe) | 3.9 | 0.02 |
| Manganese (Mn) | 0.0 | 0.0 |
| Aluminum (Al) | 0.0 | 0.0 |
| Calcium (Ca) | 54.0 | 68.0 |
| Magnesium (Mg) | 9.8 | 18.0 |
| Chlorine (Cl) | 6.5 | 208.0 |
| Sulfate ($SO_4$) | 8.0 | 28.0 |
| Fluoride (F) | 0.3 | 0.3 |
| Total solids | 230.0 | 690.0 |
| Total hardness as $CaCO_3$ | 176.0 | 243.0 |
| Total alkalainity as $CaCO_3$ | 178.0 | 129.0 |
| pH | 7.3 | 6.9 |

Source: Bedinger and others, 1963, p. 26.

### Future Use of the Ground Water of the Arkansas River Alluvium

Generally, the water is usable domestically and also in some selected industries, but the hardness and the presence of both iron and nitrate may make it unsuitable for certain industrial uses. The

U. S. Geological Survey rates most of the water as "excellent to good" and the rest as "good to permissible" for irrigation use (Bedinger and others, 1963, p. 27).

From the studies reported by Bedinger and others, it seems that where the saturated thickness of Arkansas River alluvium ranges between 30 and 60 ft, wells should produce 300 to 700 gpm.

## Ground Water in the Consolidated Rocks

Ground water not only occurs in the alluvium of the Arkansas River and its tributaries but also is contained in the consolidated sedimentary rocks that crop out in the area. However, the unweathered consolidated rocks tend to have very low intergranular porosity due to the presence of iron-oxide or silica cement. The zone of soil and weathered rock above the ground-water table is more porous and may contain vadose water in both intergranular and secondary openings.

The unweathered bedrock of the area contains ground water in secondary openings such as fractures, joints, fracture cleavage, and interbed passageways. Figure 10 shows a generalized cross-section of the porosity zones present in the outcrop areas of consolidated sedimentary rocks. Joint sets and systems are best developed in massively bedded rocks, such as sandstones and siltstones.

The shales of the upper portion of the Atoka Formation are sandy and silty and therefore are competent enough to have been thoroughly jointed. Joints exposed at the surface are less than ¼ in. wide, on the average, where weathering and erosion have not enlarged them. They are closed at depth. Joints may be filled with iron oxides or silica, which also greatly reduce their capacity to contain and transmit water.

Nevertheless, joints are still considered the most important factor influencing ground water storage and flow in the consolidated rocks of the area. Therefore, a thorough study of their distribution should be undertaken in ground-water investigation (Cordova, 1963, p. 18).

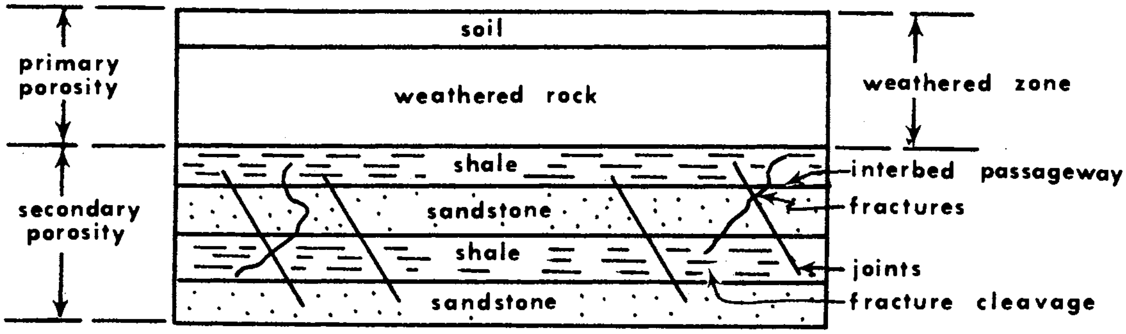


Figure 10. - Porosity zonation in consolidated rocks of the Arkansas Valley (diagrammatic and modified after Cordova, 1963, p. 17).

### Well Yields

In the consolidated rocks, no apparent relationship exists between the amount of water produced and the rock unit encountered or the depth of the well. This circumstance can normally be expected where ground water occurs in secondary porosity. The yield of a well is controlled by the number, size, openness, and the interconnection of the fractures, joints, and bedding plane fractures intercepted by the well, and these openings vary remarkably within short distances. The yields of wells in the consolidated rocks of the area range from about 30 gph (gallons per hour) to about 6,000 gph. Most wells yield less than 600 gph.

### Water in the Atoka Formation

The maximum yield in the Atoka Formation is about 3,600 gph. Large capacity wells from 100 to 300 ft deep supply the town of Ola in Yell County (Fig. 1). Numerous rural homes, farms, and small commercial establishments have wells in the Atoka Formation that produce less than 600 gph at depths less than 100 ft. Water is recovered from weathered zones, bedding planes, joints, and fractures in shale and sandstone.

The Atoka Formation is considered to be a major aquifer because of its large areal extent, even though the yields are small and difficult to predict (Sniegocki and Bedinger, 1969, p. 5). At some places, naturally flowing wells have been completed.

At the top of the Atoka Formation, along the contact with the Hartshorne Sandstone, small cavities have been recorded at one location (U. S. Army Corps of Engineers, 1957, p. 8). Where this zone was penetrated by core drills, water was lost in the hole and the drill rods dropped approximately 1 in. During pressure testing the intake of water exceeded 600 gph. Inspection of the zone by bore-hole camera showed the vertical extent of the zone to be about ½ in.

According to the driller, a well drilled on Carrion Crow Mountain (Pl. 2) in 1972 was "The best producing well on Crow Mountain" (Jess J. Carpenter, quoted by State of Arkansas, Report of Water Well Construction). The yield was 2,400 gph and the water-producing zone was encountered at from 65 to 66 ft. The driller's log showed the following data: (1) yellow sandy clay = 0-3 ft, (2) soft sandrock = 3-15 ft, (3) hard sandrock = 15-66 ft, and (4) grey sandrock = 66-100 ft. The water probably is being produced from the unconformable contact between the Hartshorne Sandstone and the Atoka Formation. Secondary and perhaps "cavernous" porosity are likely to be present at the unconformity. This horizon is a possible source of ground water in the area.

In 1970, the State of Arkansas Committee on Water Well Construction established rules that require among other things, that the driller keep a log of the rock being drilled, the depths to the water-producing formations, and the yield of the well. Comments which follow are based on an analysis of these reports.

Several small rural communities near Russellville utilize the Atoka aquifer for home- and farm-water supplies. In the South New Hope area (secs. 26, 27, 28, 34, and 35, T7N, R20W; Pl. 2) water may be recovered from two zones. The shallower zone extends from about 24 to about 33 ft deep. The second zone extends from about 47 ft to about 120 ft. The thickness of this zone and its lack of lateral continuity seem to indicate that the water is produced mainly from fracture porosity. In addition to the aquiclude (rock strata that will not transmit water) from -33 to -47 (-33 ft means 33 ft below the ground surface), a second aquiclude probably occurs from -55 ft to -72 ft. Only one well of ten located water in this zone. Water is produced at various depths below -72 ft. Yields range from 360 to 1,200 gph.

In the vicinity of the Russellville airport (secs. 14 and 15; Pl. 2) water occurs in a shallow zone from -18 ft to -27 ft. A barren zone is found from -27 ft to -47 ft and water production is found at various depths ranging to -106 ft. Yields range from 180 to 1,500 gph in this area.

In the areas to the north and northeast of Russellville, ground water is produced under similar circumstances. A water-bearing zone typically occurs from -20 ft to -35 ft, underlain by a barren zone about 6 ft thick. A deeper water-bearing zone occurs between about -41 and -94 ft. This deeper zone probably also produces from secondary porosity. Production ranges from about 120 to about 600 gph.

### Water in the Hartshorne Sandstone

The Hartshorne Sandstone crops out over about 10 sq mi of the report area. It has been developed as an important aquifer for home, farm, and small-business uses, especially in the area of the Russellville Marina (sec. 2, T7N, R21W) and Lakeview Estates subdivision (sec. 36, T8N, R21W; Pl. 2).

In the Marina area, water is produced from a depth of 23 ft to 96 ft with yields ranging from 300 to 6,000 gph. No water-producing zone is clearly defined in this area, indicating that secondary porosity is responsible for the containment and transmission of ground water. However, one zone from -28 to -38 ft produced some water in all wells for which data were available.

In the Lakeview Estates area water is produced from depths ranging from 21 to 114 ft. Yields range from 500 to 3,000 gph. Natural flow is not continuous and tends to cease in the late summer and fall. Zonation of the water-producing formations is evident in this area. The four distinct water-bearing horizons are at -20 to -24 ft, -31 to -39 ft, -45 to -50 ft (a common water-bearing horizon in this area), and -80 to -114 ft. Such well-defined barren zones and sometimes artesian zones probably indicate that secondary porosity has been developed along bedding planes. The production of water from a fractured zone at about 85 ft deep in this area was reported by driller Nyle Leonard in May, 1971.

### Water in the McAlester Formation

The only well in the McAlester Formation in the study area for which data were available is located in the SW¼ sec. 21, T7N, R20W. This well produces water from -50 to -59 ft in fractured, steeply-dipping shale. The well yields 30 gph.

Generally, wells in the McAlester Formation yield less than 50 gpm (Cordova, 1963, p. 30). The water supply is considered to be adequate for small farms, rural homes, small commercial establishments, livestock farms, and small towns.

## Chemical Quality and Temperature of Ground Water in Consolidated Rocks

Chemical characteristics of water produced from the Atoka Formation are strongly similar to that of water produced from the McAlester Formation. The Atoka and McAlester both produce water which is unusually high in sodium bicarbonate. The hardness value may exceed 1,000 ppm (parts per million), but generally the average hardness is less than 500 ppm. Only 14 percent of the 64 wells tested in the Arkansas Valley by Cordova (1963) contained more than 4 ppm of iron, but 66 percent of these wells were producing from the Atoka Formation. The writer has no chemical analyses available for water from the Atoka

Formation in the area of this report, but analyses are available from nearby areas (Table 9). Analyses of water from the McAlester Formation are shown in Table 10.

As shown in Tables 9 and 10, quality of the ground water in the Atoka and McAlester formations is highly variable and the presence of "bad" water cannot be predicted before drilling. The water from shallow wells is generally softer and has less iron and hydrogen sulfide than water from deep wells. Because supplies of water for homes and small-farm uses are found at depths less than 75 ft, it is not recommended that deeper wells be drilled. Two shallow wells are likely to produce more water of better quality than one deep well.

Water in the Hartshorne Sandstone has some significant differences in composition from the water produced from the Atoka and McAlester formations. Table 11 shows the chemical analyses of water from five wells located outside the study area.

Water produced from the Hartshorne Sandstone generally contains more iron and silica, but less calcium, magnesium, and sodium than water from the Atoka. Water from the Hartshorne is not as hard as water from the Atoka nor is it as alkaline.

Figure 11 is a comparison of the average water quality from the Atoka, Hartshorne, and McAlester formations of the Arkansas River Valley. As can be seen from this chart, the Atoka is high in chloride, sulfate, and total dissolved solids, while the other parameters included in Figure 11 do not show striking differences in water quality of the three formations.

# TABLE 9

## CHEMICAL ANALYSES OF WATER FROM WELLS IN THE ATOKA FORMATION IN THE ARKANSAS RIVER VALLEY

| Location | Content (ppm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | Fe | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | $NO_3$ |
| 6N, 17W, 7dcb | 5.7 | 0.04 | 19 | 8.3 | 38 | 8.5 | 110 | 0 | 22 | 32 | 0.3 | 15 |
| 6N, 20W, 18aab | 11 | 1.2 | 78 | 53 | 100 | 5.1 | 288 | 0 | 237 | 102 | 0.5 | 0.5 |
| 8N, 17W, 36ccd | - | 8.8 | 11 | 15 | 51 | - | 114 | 0 | 4.5 | 106 | - | 0.2 |
| 9N, 20W, 21cbb | 7.1 | 0.83 | 37 | 10 | 28 | 0.8 | 220 | 0 | 6.6 | 4.5 | 0.3 | 0.1 |

(continued)

| Location | Content (ppm) | | | pH | Temp. °F | Water Level Below Surface (ft) |
|---|---|---|---|---|---|---|
| | Dissolved Solids | Hardness as $CaCO_3$ | Non-carbonate hardness | | | |
| 6N, 17W, 7dcb | 240 | 82 | 0.0 | 7.2 | 65 | 28.5 |
| 6N, 20W, 18aab | 870 | 412 | 176 | 7.6 | 66 | 60.8 |
| 8N, 17W, 36ccd | 317 | 137 | - | - | 65 | 141 |
| 9N, 20W, 21cbb | 341 | 134 | 0.0 | 7.1 | 71 | 28.5 |

Source: Modified from Cordova, 1963, pp. 24-25.

## TABLE 10

## CHEMICAL ANALYSES OF WATER FROM WELLS IN THE McALESTER FORMATION IN THE ARKANSAS RIVER VALLEY

| Location | Content (ppm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | Fe | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | $NO_3$ |
| 7N, 20W, 20cda* | 13 | 0.29 | 19 | 18 | 15 | 0.8 | 144 | 0.0 | 0.4 | 23 | 0.5 | 8.4 |
| 7N, 28W, 1dad | - | 0.04 | 14 | 0.3 | 110 | 3.1 | 290 | 0.0 | 39 | 18 | - | 0.2 |

(continued)

| Location | Content (ppm) | | | pH | Temp. °F | Water Level Below Surface (ft) |
|---|---|---|---|---|---|---|
| | Dissolved Solids | Hardness as $CaCO_3$ | Non-carbonate hardness | | | |
| 7N, 20W, 20cda | 181 | 122 | 4 | 7.4 | 65 | 44 |
| 7N, 28W, 1dad | 354 | 64 | 0.0 | 7.8 | - | 150 |

*Located in the study area.

Source: Modified from Cordova, 1963, pp. 24-25.

## TABLE 11

## CHEMICAL ANALYSES OF WATER FROM WELLS IN THE HARTSHORNE SANDSTONE IN THE ARKANSAS RIVER VALLEY

| Location | Content (ppm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | Fe | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | $NO_3$ |
| 6N, 32W, 21aaa | 16 | 0.0 | 15 | 10 | 16 | 1.4 | 81 | 0.0 | 22 | 16 | 0.4 | 1.2 |
| 6N, 32W, 21aaa* | - | 3.7 | 19 | 10 | 13 | 0.8 | 96 | 0.0 | 18 | 14 | - | 2.8 |
| 6N, 32W, 21acc | - | 0.22 | 40 | 18 | 76 | 5.1 | 158 | 0.0 | 156 | 41 | - | 1.0 |
| 6N, 32W, 21add | - | 1.4 | 37 | 17 | 27 | 0.9 | 106 | 0.0 | 87 | 30 | - | 0.6 |
| 6N, 32W, 21bcc | - | 8.4 | 39 | 23 | 49 | 1.1 | 220 | 0.0 | 82 | 22 | - | 0.6 |

(continued)

| Location | Content (ppm) | | | pH | Temp °F | Water Level Below Surface (ft) |
|---|---|---|---|---|---|---|
| | Dissolved Solids | Hardness as $CaCO_3$ | Non-carbonate hardness | | | |
| 6N, 32W, 21aaa | 176 | 78 | 12 | 6.3 | 61 | 110 |
| 6N, 32W, 21aaa* | 139 | 88 | 10 | 6.5 | - | 110 |
| 6N, 32W, 21acc | 433 | 174 | 44 | 7.3 | - | 45.5 |
| 6N, 32W, 21add | 278 | 162 | 76 | 6.7 | - | 120 |
| 6N, 32W, 21bcc | 343 | 192 | 12 | 8.2 | - | 86 |

*Same well as one listed on live above, sample collected 4 months after the first sample was taken.

Source: Modified from Cordova, 1963, pp. 24-25.

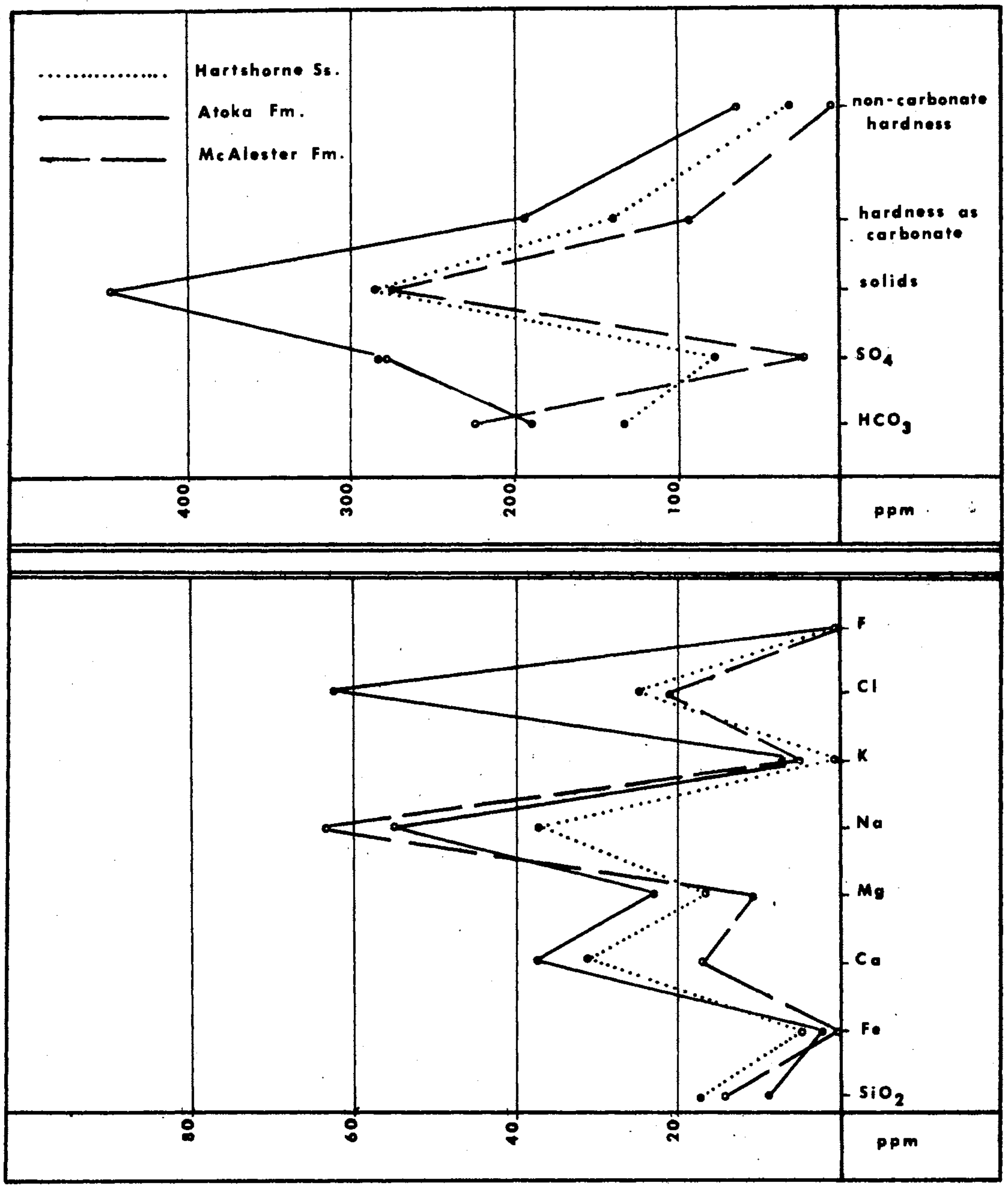


Figure 11. - Comparison of average water quality from the Atoka and McAlester formations and the Hartshorne Sandstone in the Arkansas River Valley.

The Use of Water in Pope County, Arkansas

The daily use of water in Pope County in 1970 was 6.18 million gal. Ground water provided 2.79 mgd and surface water accounted for 3.39 mgd (Halberg, 1972, p. 8). Various categories of use are shown below as Table 12.

TABLE 12

USE OF WATER IN POPE COUNTY, ARKANSAS IN 1970
(mgd = million gal per day)

| Use | Ground Water | Surface Water | Total |
|---|---|---|---|
| Public supply | 0.45 | 2.97 | 3.42 |
| Self-supported industry | 0.02 | 0.0 | 0.02 |
| Rural use | | | |
| domestic | 0.94 | - | 0.94 |
| livestock | 0.38 | 0.31 | 0.69 |
| irrigation | 0.51 | - | 0.51 |
| fish and minnow farms | 0.30 | 0.11 | 0.41 |
| Wildlife impoundments and national fish hatcheries | 0.19 | 0.0 | 0.19 |
| County total | 2.79 | 3.39 | 6.18 |
| Percent of increase over 1965 | 90% | 60% | 68% |

Source: Halberg, 1972, p. 8.

## Potential Development of Ground Water Supplies

The Atoka, Hartshorne, and McAlester formations are aquifers which produce water due to secondary porosity that is generally caused by fracturing, jointing and irregularities along bedding planes. Therefore, yields tend to be small. These aquifers will be adequate for rural homes, farms, and small commercial-establishment uses. However, any development requiring large amounts of ground water from these would be difficult and expensive.

The alluvium of the Arkansas River has large water-production capacity and, with the properly planned well-field, could provide large industries with continuous adequate water supplies unless their rate of withdrawal exceeds the rate of natural recharge estimated by Bedinger and others (1963, p. 17) to be 130 mgd.

# GEOLOGY AS RELATED TO CONSTRUCTION AND DEVELOPMENT

## General Climatology of the Russellville Area

The climatological data included in this report were abstracted from Arkansas Power and Light Company's "Preliminary Safety Analysis Report for Russellville Nuclear Unit" (Arkansas Power and Light Company, 1967, p. 2A.1-2A.13). Climatological data are included in this part of the report because of the close relationship between weather and certain construction practices and its significance to slope stability.

The annual mean daily temperature at Russellville is 73F, minimum is 49.4F. The highest temperature on record is 113F and the lowest is -15F. Russellville has 93 annual mean number of days with temperature equal or greater than 90F and 74 days equal to or less than 32F. A table of temperatures and precipitation is shown as Table 13.

Rainfall is ample for farming. Late spring and early summer is the wettest period of the year, but rainfall is reduced almost 35 percent in the period from May to August. Annual precipitation extremes range from approximately 23 in. to about 80 in.

Spring rains are common and the probability that precipitation in May will be at least 3 in. is 90 percent. Probability that precipitation during any fall or winter month will be less than 1 in. is 10 percent. Weather records for a 7-yr period show 70 mean number of days with precipitation equal to or greater than 0.1 in. and an additional

32 mean number of days with precipitation equal or greater than 0.05 in. Single-storm totals of more than 5 in. of precipitation are common. Average annual snowfall in the area was 4.1 in. from 1951 through 1960. The mean annual number of days with thunderstorms at Russellville is about 55. Eleven tornadoes have been seen in Pope County in 35 yrs (between 1916 and 1950).

Annual evaporation in the Russellville area is 53 in. (measured in an evaporation pan). The maximum amount evaporated in a 1-month period averages 7.66 in. during July.

### TABLE 13

### TEMPERATURES AND PRECIPITATION AT RUSSELLVILLE, ARKANSAS

| Month | Mean temperature (deg F) (30-yr normal) | Mean precipitation (in.) (30-yr normal) |
|---|---|---|
| January | 42 | 4.04 |
| February | 46 | 4.24 |
| March | 53 | 4.84 |
| April | 63 | 5.06 |
| May | 70 | 5.61 |
| June | 78 | 4.14 |
| July | 82 | 4.17 |
| August | 81 | 3.79 |
| September | 74 | 3.53 |
| October | 64 | 3.28 |
| November | 51 | 4.13 |
| December | 44 | 3.47 |

mean monthly temperature = 62F    mean annual precipitation = 49.74 in.

Source: Arkansas Power and Light Company, 1967, p. 2A.1.

## Topography and the Potential of Landslides

The term "landslide" is used by the general public to mean the downslope movement of rock and soil. However, geologists or engineers generally use the term as it is defined by the Highway Research Board (1958, p. 20):

> . . . downward and outward movement of slope-forming materials composed of natural rock, soils, artificial fill or combinations of these materials. The moving mass may proceed by any one of three principle types of movement: falling, sliding, or flowing, or by their combination . . . . Normal surficial creep is excluded.

Landslides are not produced by any single cause, but are due to a combination of causes, such as: (1) rocks with unstable structural or mineralogic properties, (2) climate, (3) erosion, (4) weathering, and (5) triggering forces (man's activities, earthquakes, and violent storms). Landslides are correlated with climatic changes. An area that was prone to sliding in the past may be stable today because the climate may be drier now. Therefore, the presence of ancient landslides does not necessarily indicate that landslides in the near future are highly probable. However, ancient landslides do indicate that several factors are favorable for sliding and that perhaps only a wetter climate or an exceptionally wet year is needed to reactivate landsliding.

One of the best ways of identifying old or modern landslides is to examine stereoscopic pairs of aerial photographs. Landslides may be recognized by the presence of some or all of the following features: (1) hummocky ground (low-mounded ground surface), (2) scalloped escarpments (cliffs with crescent-shaped recesses), (3) abnormally steep cliffs with mounds at their bases, (4) bowl-shaped headwater regions of creeks, and (5) constrictions in canyons (Highway Research Board, 1958, p. 50).

Field examination of a suspected landslide may reveal additional evidence that sliding is active. Cracks in the ground, either deep-seated ("stretching") or superficial, are excellent indicators of recent movement. Minor failures in structures may also be indicators of initial movement. Such minor failures may consist of spalling in concrete, closure of expansion joints, loss of alignment in structures, and minor rock or soil falls.

Another excellent method for determining the potential of an area for landsliding is to study nearby areas of known landslide activity. Generally, numerous slides are available for study along highway right-of-ways. If these are nearby and if they occurred within the same geologic formation, then one can assume that rock properties and climate are similar, and inferences can be drawn about areas of potential landsliding.

## Landslides Outside of the Research Area

An area of modern landslides is located on Interstate Highway 40 approximately 10 mi east of Russellville. At this site sandstone-and-shale colluvium was cut to form an embankment about 50 ft high with a grade of 23 percent. The slide, probably best described as an earthflow, developed during the spring of 1973, approximately 8 yrs after construction of the road cut. The upper part of the earthflow included several slump blocks which showed backward rotation; several small scarps (less than 3 ft high) were formed around their margins. The form of the lower portion of the slide suggested that the material flowed during movement.

The area was regraded in the Fall of 1973 by the Arkansas Highway Department, so it is no longer available for study. However, the fact that such an earthflow occurred in the colluvial footslope beneath the Hartshorne Sandstone escarpment - under conditions which are little different from those at several sites in the Russellville area - does suggest the potential instability of natural or man-made slopes of similar material and steepness. However, a careful examination of the characteristics of the strata at each site is necessary before the stability of a slope can be evaluated.

A second site is also instructive. This slide area, known locally as "Potato Hill" is located in Logan County, approximately 20 mi west of Dardanelle (Fig. 1). On April 25, 1973 a large section of the shale hill slid across the highway, tearing down trees and cracking the asphalt pavement and roadbed (Fig. 12). The earthflow was about 30 ft thick where it crossed the road. Examination of the area above the "toe" of the slide revealed massive slump blocks (approximately 50 x 150 ft) that dropped as much as 4 ft; the tops of the blocks showed the backward movement characteristic of a rotational slump.

Potato Hill is composed of the grayish-black shale of the McAlester Formation which dips approximately 3 deg toward the highway. Relief of the hill is about 240 ft; slope of the hillside is more than 30 percent. The shale is thoroughly fractured by north-south and east-west trending sets of joints. The slide was preceded by 17.41 in. of rain in a period from March 1 to April 25, 1973. During the 10 days immediately preceding the slide, 6.01 in. of rain fell. Thus, under the proper combination of conditions, shale of the McAlester Formation is unstable. Conditions favoring development of landslides were: (1) heavy rainfall, (2) steep slope, (3) fractured shale, (4) expanding clays in shale, (5) toe of the hill steepened by highway construction (within the last 10 yrs), and (6) traffic vibration.

Figure 12. - Potato Hill earthflow, Logan County, Arkansas (April 25, 1973).

The information obtained by a study of this "natural experiment" could be applied to other areas with similar features. There are no areas in the Russellville study area where the McAlester Formation shale is exposed under similar circumstances. However, the example does show that earthflows can occur, that planners and developers should insure that areas to be developed are carefully examined for potentially dangerous landslides, and that construction methods should not intensify the instability of slopes.

## Ancient Landslides in the Russellville Area

The author believes that at least two ancient landslides can be identified in the Russellville area. They are most easily recognized on the aerial photographs of the area. Both are located at the foot of Norristown Mountain in the NW¼ and SW¼ sec. 6, T7N, R20W (Pl. 4). The area shows hummocky ground at the foot of the escarpment and a scalloped ridge crest. Both of these features, as mentioned previously, are excellent indicators of landslide activity. Surface evidence for the slides is lacking, except for hummocky ground at the foot of the ridge. Neither of the areas shows evidence of modern movement. These slides probably occurred under a more humid climate during the Pleistocene Epoch.

A more real danger along the escarpment of Norristown Mountain is the potential for rock slides and talus creep due to the steep slopes (about 30 percent grade). Development of this slope must be limited to a low-density residential pattern (if it is developed at all) and these structures must be well designed with carefully engineered foundations, in order to avoid the structural problems that are likely to occur on unstable slopes.

## Improper Development of a Portion of the Norristown Mountain Escarpment

A roadcut was begun on the north face of Norristown Mountain escarpment during the summer of 1972. Until September, 1972 was a very dry year. Only 20.76 in. of rain had fallen, 13.79 in. below normal.

The cut and fill was made by bulldozers "ripping" the shale and siltstone of the Atoka Formation from the slope and pushing it over the edge of the cut to form an embankment (Fig. 13). The fill was placed on top of colluvium at the foot of the escarpment. No special effort was made to compact the material, and in its dry state it could not attain a maximum density (a condition which is obtained by adjusting the water content during compactive effort). The fill material was left, therefore, in a state of loose to medium compactness (density). The slope was examined by the author during August, 1972, and it was noted that the slope angle on the front of the embankment was more than 50 deg (110 percent grade). According to Carson and Kirkby (1972, p. 183), a stable slope for fractured and jointed rock that is almost cohesionless and in a high density packing arrangement is about 45 deg (100 percent grade). The same material in a loosely packed arrangement should be stable on grades of only 73 to 84 percent (Carson and Kirkby, 1972, p. 183).

Under natural conditions, grades on colluvium at the foot of Norristown Mountain in this area are about 25 percent. These slopes have become stabilized by hundreds of years of exposure to weathering and erosion and thus are in equilibrium with natural processes. Therefore, grades of more than 25 percent should be considered as "unnatural" to the materials and climate of the escarpment, and thus potentially unstable.

Figure 13. - Construction of the roadway on the Norristown Mountain escarpment (NE¼ sec. 17, T7N, R20W).

The instability of the slope on Norristown Mountain was demonstrated during the late summer and fall of 1972. The unusually dry weather became unusually wet as 23.76 in. of rainfall occurred in only 4 mo. (9.75 in. above the amount expected during a "normal" year). Once the fill material became partially soaked, it showed signs of movement. Prior to the rainy season, concrete curbing had been poured on both sides of the roadbed. During the rainy period, movement of the slope caused misalignment between sections of curbing, with vertical offsets of as much as 3 in. (Fig. 14).

Figure 14. - Vertical misalignment of curbs due to slope instability on the escarpment of Norristown Mountain (NE¼ sec. 17, T7N, R20W).

Lateral alignments were also disturbed. Early in the rainy season tension cracks appeared trending parallel to the leading edge of the embankment (Fig. 15). The cracks were as much as 3 in. wide and 70 ft long. Tension cracks were also developed in the bench below the upper level of the embankment. Above the roadcut, tension cracks and "stretching" were also observed in shale of the Atoka Formation and in residual soil by the author and by Mr. Bill Goddard (soil scientist, U. S. Forest Service). The removal of the lower material and increase of the slope angle have also had the effect of causing the upper face of the backslope to become unstable (Fig. 16).

Figure 15. Tension cracks along the front edge of the upper embankment of the road built on the escarpment of Norristown Mountain (NE¼ sec. 17, T7N, R20W).

Figure 16. - Tension cracks in the Atoka Formation shale exposed in the backslope of the roadcut across the Norristown Mountain escarpment (NE¼ sec. 17, T7N, R20W).

The fill material is also highly susceptible to erosion (Fig. 17). Inadequate storm drains became overloaded during almost every rain. Water overflowed the curbing (pavement had not been applied), causing very rapid erosion of the fill, and resulted in low-level flash-flooding of homes and home sites located immediately below the roadbed embankment. Sediment also was deposited in the street, driveways, carports, and in the interiors of a few homes.

Figure 17. - Erosion caused by inadequate storm drains in the roadway built on the escarpment of Norristown Mountain (NE¼ sec. 17, T7N, R20W).

In addition to all of the physical problems related to this road-building project, it is an "eyesore." It could be considered to be "visual pollution." Heretofore, the north- and east-facing escarpment of Norristown Mountain has been a beautiful backdrop for the city of Russellville. Now the "scar" of the roadcut is visible for miles, and it degrades the visual richness of the local setting.

## The Future of the Slope

The roadway has been paved and drainage has been improved, but the problem almost certainly will never be completely solved. Carson and

Kirkby (1972, p. 149) point out that experience has shown that many new slopes, which were stable at the end of construction, became unstable with passage of time, due to reduction of shear strength of the fill. It is a simple fact that the road should never have been built on this escarpment. Now that it exists, however, several actions are required to prevent it from becoming a landslide. As has been shown previously, water is the "catalyst" that makes seemingly stable slopes become active. The actual stability of colluvial material depends on pore pressures (pressure exerted on rock and soil grains by water which permeates the mass) to which it is subjected. When perched water tables exist in the colluvial mass, its stable angle is reduced to about 25 deg (55 percent) (Carson and Kirkby, 1972, p. 182). As mentioned previously, the angle presently held by the slope is more than 110 percent! With this fact in mind, it becomes obvious that water must be kept out of the fill material. This can best be done by placing an impervious covering over the exposed portions of the head and toe of the potential slide area. Drainage must also be improved so as to divert as much water away from the area as possible. Slope loading and vibration must be kept at a minimum. Heavy truck traffic must not be permitted on the road. Construction of dwellings or other structures must not be permitted on the man-made "benches" or natural slope above the roadway.

This particular road-building project has been an excellent example of how not to plan properly within the natural limitations of a site. Perhaps the numerous mistakes made at this site will prove to be a good object lesson and lead to planning and development in the Russellville area that is more in harmony with the natural environment.

## Soil Creep

Soil creep is defined as any movement in soils which is imperceptible except by measurements over a long period of time (Sharpe, 1938; quoted by Carson and Kirkby, 1972, p. 272). Soil creep may be caused by: (1) reworking of soil surface layers as temperature and moisture varies, (2) random movement by organisms, (3) micro-seisms, and (4) steady application of downhill stress. According to Carson and Kirkby (1972, p. 273), creep movement may occur on slopes as low as 9 deg (20 percent) at rates not more than about 0.2 to 0.4 in. per yr.

### Soil Creep in the Russellville Area

Direct evidence of soil creep is present in the NE¼ sec. 28, T7N, R20W (Pl. 4). At this locality, on the hogback ridge which forms the south limb of the Shinn syncline, soil creep is evident in a roadcut. The steeply-dipping (77 deg north) shales of the Atoka Formation show soil creep in the colluvial layer near the crest of the ridge. The surface grade is approximately 17 percent toward the south. Soil creep is evident in the upper 4 ft of shale and colluvium (Fig. 18). The shale and thin siltstone strata show a pronounced decrease in dip near the surface and essentially become parallel to the slope about 2 ft below the surface. The author believes that the rate of soil creep is very slow, because other evidence of creep is not apparent.

From the observation of the generally rounded and subdued topography of the hills in the Russellville area, it is suspected that soil creep may also be occurring on grades of less than 17 percent, and where shale and interbedded siltstone crop out. However, direct evidence to support this proposition was not found during this study. Mr. Bill Goddard (soil scientist, U. S. Forest Service) estimates that soil creep occurs on grades in excess of about 8 percent in the Russellville area (personal communication, 1974).

Figure 18. - Soil creep in the colluvium on the Atoka Formation (NE¼ sec. 28, T7N, R20W).

## Soil Creep and Construction

Soil creep can be very damaging over the lifetime of a structure. Unless the foundation of the structure goes below the creep zone (residual soil and colluvium) into bedrock, foundation failures and resulting structural misalignment problems occur after several years (doors will not close, window frames are "out-of-square," floors are warped, etc.). Roads built on creeping slopes generally fail by cracking of the pavement surface as the sub-base creeps.

Many otherwise excellent building sites may be subject to soil creep, but a little extra planning, design, and careful construction can overcome these problems at small expense, compared to the expense of repairing structural failure at a later date.

## Flooding in the Russellville Area

### Drainage Basins

The Arkansas River's drainage basin has an area of 160,645 sq mi, 95.6 percent of which lies upstream from the Dardanelle Dam.

Flooding in the Dardanelle-Russellville area is caused primarily by rainfall which occurs east of Hutchinson, Kansas (Fig. 3). The average downstream flow at Hutchinson is only about 375,000 acre-ft per yr (Stewart, 1973, p. 109) due to evaporation, infiltration, and irrigation losses upstream. From Hutchinson eastward, flow increases due to increased runoff, less evaporation, and less water being drawn off for irrigation. Storms in eastern Oklahoma and western Arkansas are particularly important in determining flood conditions on the Arkansas River in the area of study.

The Illinois Bayou River drains an area of approximately 395 sq mi of Pope, Searcy, and Van Buren counties, Arkansas (Fig. 3). The majority of the basin lies in Pope County to the northeast of Russellville. The terrain in the Illinois Bayou basin is rugged, consisting of ridges underlain by sandstone and valleys underlain by shale. The elevation varies from about 300 ft to about 2,000 ft above mean sea level.

Prairie Creek (Pl. 5) has a basin of only 12.6 sq mi in area. All of the basin lies within the city limits of Russellville, except for about 1 sq mi. The northeastern headwaters are located on the southern face of Carrion Crow Mountain (Pl. 5). The western edge of the basin is formed by the eastward- and northward-facing escarpments of Norristown Mountain (Pl. 5). The southeastern boundary of the basin lies near South Arkansas Avenue (Pl. 5). This divide continues eastward along U. S. Highway 64 (Pl. 5). The smallness of Prairie Creek's drainage basin is not an indicator of its importance to the city of Russellville. Intense local storms produce rapid runoff and flash-flooding in its basin. This is due to the shortness of channels, high gradient in its headwaters, and low gradient in the center of Russellville. The stream's natural mouth is blocked by a dike which keeps Dardanelle Reservoir from flooding the city of Russellville. The waters of Prairie Creek are pumped over the dike by a pumping station located in the NE¼, sec. 31, T7N, R20W (Pl. 5). This station is operated and maintained by the U. S. Army Corps of Engineers.

The drainage basin of Whig Creek (Pl. 5) generally lies to the southeast of Russellville. Its drainage area is approximately 11.2 sq mi. On its northern boundary Whig Creek adjoins the Prairie Creek basin and on its southwestern end its flood plain merges with that of the Arkansas River.

## Main Flood Season

The seasons during which flooding is most likely to occur on the

Arkansas River are winter, spring, and early summer. The higher floods on the Arkansas River are the results of general heavy rains over thousands of square miles, in conjunction with intense local storms.

Floods on the Illinois Bayou and Prairie and Whig Creeks are due to heavy local storms. Storms of this type may occur at any time; therefore, there is no particular seasonal frequency of flooding in these drainage basins.

## Histories of Flooding

### Arkansas River

The levels of the Arkansas River have been recorded in the Russellville area since June 1886, when the U. S. Weather Bureau started observations near the site of Highway 7 bridge. A knowledge of the flood history of the river prior to 1886 has been developed by the Corps of Engineers through reference to historical documents, public records, and newspaper files (U. S. Army Corps of Engineers, 1969, p. 19).

Table 14 shows statistics of the largest 10 floods that have occurred since 1896.

### Illinois Bayou

The U. S. Geological Survey maintains a gaging station on the Illinois Bayou at Scottsville, Arkansas (Fig. 3) approximately 13 mi northeast of Russellville. The drainage area upstream from this station is 242 sq mi. Table 15 shows statistics of all known floods above bankfull stage of 16 ft.

TABLE 14

HIGHEST 10 KNOWN FLOODS - ARKANSAS RIVER AT DARDANELLE, ARKANSAS*

| Order | Date of Crest | Gage Height | | Estimated Peak Discharge (cfs) |
|---|---|---|---|---|
| | | Stage (ft) | Elevation (ft) | |
| 1 | May 25, 1943 | 34.0 | 324.2 | 683,000 |
| 2 | May 30, 1957 | 33.4 | 323.6 | 471,000 |
| 3 | April 1945 | 33.2 | 323.4 | 578,000 |
| 4 | April 18, 1927 | 33.0 | 323.2 | - - |
| 5 | November 5, 1941 | 31.9 | 322.1 | 433,000 |
| 6 | January 1916 | 29.8 | 320.0 | - - |
| 7 | February 20, 1938 | 29.6 | 319.8 | 396,000 |
| 8 | June 21, 1935 | 29.5 | 319.7 | - - |
| 9 | May 14, 1950 | 29.2 | 319.4 | 382,000 |
| 10 | May 1896 | 28.9 | 319.1 | - - |

*All known floods which had a gage height of 22 ft or more, were considered to be flood stage at the Dardanelle gaging station near the bridge on Highway 7. Zero on the gage is 290.16 ft above mean sea level.

Source: U. S. Army Corps of Engineers, 1969, p. 22.

TABLE 15

FLOOD CRESTS ABOVE BANKFULL STAGE - ILLINOIS BAYOU, SCOTTSVILLE ARKANSAS - 1948 TO 1968

| Date of Crest | Gage Height | | Estimated Peak Discharge (cfs) |
|---|---|---|---|
| | Stage (ft) | Elevation (ft) | |
| May 10, 1943 | 24.6 | 472.1* | - - |
| January 24, 1949 | 24.6 | 472.1 | 77,000 |
| May 2, 1954 | 16.5 | 464.0 | 23,500 |
| April 3, 1957 | 17.9 | 465.4 | 24,600 |
| November 4, 1959 | 17.9 | 465.2 | 24,000 |
| May 6, 1961 | 19.2 | 466.7 | 29,500 |
| March 9, 1964 | 16.5 | 464.0 | 20,500 |
| February 9, 1966 | 18.1 | 465.6 | 25,300 |

*May 10, 1943 stage is from high water mark. Gage height is 447.54 ft above mean sea level.

Source: U. S. Army Corps of Engineers, 1969, p. 24.

## Prairie and Whig Creeks

No records of stages or discharges are available for Prairie or Whig Creeks. High water marks (elevation 345.5 ft) are present on a number of buildings in the downtown section of Russellville as a result of several recent floods along Prairie Creek. Less information is available concerning flooding on Whig Creek.

In its 1969 study of the flood situation in this area, the Corps of Engineers determined that major floods occur on these creeks on the average of about once in 10 yrs. Minor flooding can be expected every year.

## Descriptions of Floods

### Arkansas River

In April, 1927 general rains in eastern Kansas and Oklahoma and in western Arkansas during the latter part of March caused ground saturation and caused high stages to develop on local streams. Between April 7 and April 21 there were three separate storms in the same general area.

The flood on the Arkansas River was not unusually large upstream from the confluence with the Verdigris River in Oklahoma (Fig. 3), but large flows from tributaries between Webbers Falls, Oklahoma and Fort Smith, Arkansas caused flooding to be unusually great downstream. Downstream from Fort Smith the flow from tributaries further increased the flood proportions. The crest stage at Dardanelle was 33 ft.

In May, 1943 heavy rains centered over northeastern Oklahoma, southeastern Missouri, and northwestern Arkansas combined to produce disastrous flooding along the Arkansas. Intense local rains of more than 15 in. in southwestern Missouri and 20 in. south of Tulsa were prime factors in causing the flood.

The stage at the Dardanelle gage reached 34 ft and the peak discharge was 682,000 cfs (cubic ft per second). The _Dardanelle Post Dispatch_ of May 13, 1943 reported:

> ARKANSAS RIVER RAGING IN GREATEST FLOOD EVER KNOWN
>
> In a most sudden and greatest Arkansas River flood within the knowledge of living man, the raging river is expected to reach a crest of between 34 and 34.5 feet here tonight or early tomorrow morning. The previous high mark, 33 feet, occurred in April 1927. . . . All highways leading out of Dardanelle are or will be closed by nightfall. Water is over the highway at one of the Whig Creek bridges to a depth

> of 12 inches or more. The D. and R. Railroad discontinued train operation this morning (U. S. Army Corps of Engineers, 1969, pp. 28-29).

In the vicinity of Whig Creek the flood reached elevations of about 322 ft.

### Illinois Bayou

In January, 1949 a storm centered several miles outside of the Illinois Bayou basin caused the worst flood on record at the Scottsville gage (Fig. 3). Rainfall of 13.1 in. occurred in a period from January 23rd to January 27th. The Russellville Weekly Tribune, January 27, 1949 reported as follows:

> . . . . Highways 64, 22, and 7 were closed temporarily due to the flood waters. A bridge on the Missouri Pacific railroad washed out and traffic was delayed 12 hours on the railroad. . . . The base of the antenna [elevation about 334 ft] at radio KXRJ [known today as KARV] was covered with water from the Illinois Bayou . . . . Many Dover residents were forced to spend the night in Russellville due to flooding of Highway 7 at Shiloh Creek . . . . Water supply of Russellville was endangered for a while Monday and Monday night . . . due to high water (U. S. Army Corps of Engineers, 1969, pp. 30-31).

### Prairie Creek

Prairie Creek caused one of the largest local floods in Russellville's history on August 13, 1957. Generally heavy rains (more than 6 in.) fell on several northwestern Arkansas counties, while the Russellville area received 9.93 in. of rain in a 24-hr period. This caused rapid rising of Prairie Creek, which overflowed its channel flooding areas in "downtown" Russellville. Flood damage was estimated to be in excess of $200,000.

Flood waters reached both north and south of the Missouri-Pacific railroad tracks and water was at least 3 ft deep at both North Arkansas

Avenue and East "D" Street (north of the railroad) and in the 100 block of East Main Street (south of the railroad) (Fig. 19). Flooding extended as far west as North Muskogee Avenue and West "B" Street where homes and a church were damaged (Daily Courier Democrat; August 13, 1957, p. 1).

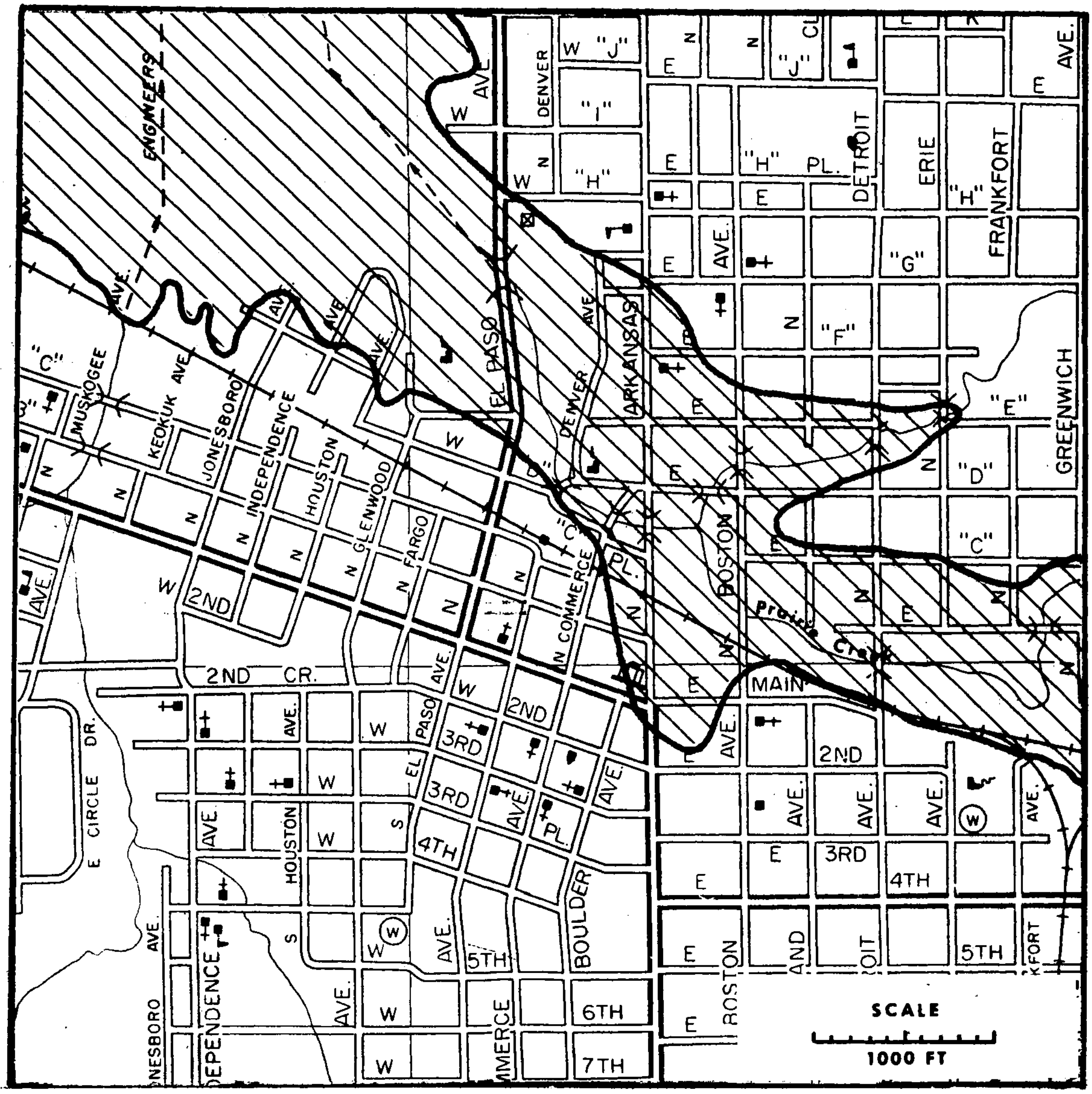


Figure 19. - Area subject to the "Standard Project Flood" (indicated by diagonal lines) in "downtown" Russellville (U. S. Army Corps of Engineers, 1969, pl. 29; base map from the Arkansas Highway Dept., 1965).

## Development on Flood Plains

### Arkansas River and Whig Creek

The flood plains of the Arkansas River and of Whig Creek have not been utilized to any great extent for industrial or commercial development. Development has been concentrated at the Dardanelle Lock and Dam and the Dardanelle Bridge. The development adjoining the Dam is under the direction of the U. S. Army Corps of Engineers. Industrial and commercial development is located in the SW¼ sec. 20 and the SE¼ sec. 29, T7N, R20W (Pl. 5).

Dow Chemical Company operates a chlorine-cell carbon-plate fabricating plant in sec. 20. The access roads to the plant were completely blocked by several feet of water from two tributaries of Whig Creek during the flood of April 1973 (Fig. 20). Alternate access routes are being planned for this plant, since maintenance of a high temperature, carbon-reduction furnace is essential to the safety of the plant and surrounding area.

Flooding may not be the only concern of industries located in this general area. Bank erosion was noted to be quite severe during the April, 1973 flood. A roadway in sec. 22 along the bank of the Arkansas River was partially destroyed by undercutting and slumping (Fig. 21). Planning for facilities to be located near the bank of the river should include stabilization of the bank by rip-rapping prior to development.

Other developments near the Dardanelle Bridge consist of the Port of Dardanelle - Keenan River Warehouse, D. and R. Railroad yard, Mobley Construction sand and gravel washing and screening plant, and Valmac Industries Inc. (a poultry-feed mixing plant). According to data secured from the Corps of Engineers, all of the developments mentioned above, except the Keenan River Warehouse, would be subject to flood damage during a "Standard Project Flood" (largest flood expected from the most severe combination of conditions).

Figure 20. Flood waters across the access road to Dow Chemical Co. (NE¼ sec. 20, T7N, R20W).

Whig Creek would flood State Highway 7 and the D. and R. Railroad. Highway 7 would be under water for a distance of about 1,700 ft. The D. and R. Railroad would be blocked for a distance of more than 4,000 ft.

Figure 21. - Bank erosion along the Arkansas River during the flood of April 1973 (NE¼ sec. 22, T7N, R20W).

The Russellville Pollution Control works is located on Whig Creek in the NW¼, sec. 22, T7N, R20W (Pl. 5). According to the Corp of Engineers' survey (1969, Pl. 19), the flood elevation for a "Standard Project Flood" would be 340 ft above sea level in the area of the plant. The elevation of the operating floor of the pumping station and the top of the wall of the final settling basin is 338 ft (W. Minor, 1973, personal communication). Of course, these facilities would require sand-bagging if a flood level of 340 ft were to occur.

The elevation of the tops of the trickle-filters walls is 344 ft; therefore the walls are not subject to flooding under conditions described above.

Any industrial or commercial developer planning a facility on the Arkansas or Whig Creek flood plains should consult the publication "Flood Plain Information - Arkansas River and Its Tributaries - Russellville - Dardanelle, Arkansas" published by the U. S. Army Corps of Engineers, 1969. This publication, available from the Little Rock District Engineer, is much more detailed than the discussion included in this report. As the map scale is 1 in. to 50 ft, detailed site planning can be accomplished with maps included in this report.

### Prairie Creek

Approximately 40 city blocks of Russellville are located on the flood plain of Prairie Creek. Generally, flooding is confined to areas adjoining the creek north of the Missouri Pacific railroad, but occasionally, significant flooding has occurred south of the railroad (Pl. 5). During the flood of 1957 the block bounded by the railroad and Main Street, and by South Arkansas Avenue and South Boston Avenue (Fig. 19) was partially flooded.

The U. S. Army Corps of Engineers has a flood easement which covers 600 acres of land for storage of flood water in secs. 5, 6, 31, and 32, T7N, R20W (Pl. 5). The easement includes the area that is less than 334 ft above sea level, which is projected to be the level of a 100-yr flood. The flood-storage capacity of the easement up to the elevation of 334 ft is equivalent to 5.9 in. of runoff from the Prairie Creek basin (U. S. Army Corps of Engineers, 1969, p. 31). This critical area is protected from improper development by the flood easement. However, some of the 88 acres of borrow-pit area is being used as a dumping ground for automobiles. This practice should be discontinued because it could obstruct stream flow and is unsightly. The remainder of the easement has been left in a natural state, a practice which should be continued.

The Prairie Creek sewage-pumping station is located in the NE¼ SE¼, sec. 5, T7N, R20W (Pl. 5). The floor elevation of the station is 339.2 ft above sea level. In this area the "Standard Project Flood" is predicted to reach an elevation of approximately 341 ft. Sandbagging or a flood-retaining wall therefore will be necessary to protect the station from becoming inoperative during a major flood.

The Russellville Urban Renewal Agency currently holds title to about $600,000 worth of prime commercial property north of Prairie Creek between North Arkansas and El Paso avenues (Fig. 19). The land has been cleared of older developments and structures. Very careful planning must go into the development of the area because it is located in one of the areas along Prairie Creek in which probability of flooding is highest.

### Illinois Bayou

Flood crests on the Illinois Bayou in the study area are largely controlled by the level of the Dardanelle Reservoir. The areas which would be affected by a "Standard Project Flood" lie in secs. 17, 20, 21, 28, and 29, T8N, R20W (Pl. 5).

The Russellville Waterworks is located in the SW¼ sec. 17, T8N, R20W. According to data compiled by the Corps of Engineers (1969, Pl. 28) the waterworks complex would be partially flooded during a 100-yr or greater flood (Standard Project Flood). The flood elevation in the vicinity of the waterworks is 352.1 ft. Elevations of the floors of the main buildings at the plant are about 350 ft. The spillway of the dam would be under 6.1 ft of water during such a flood.

Other structures in the vicinity of the waterworks are chiefly residential dwellings. Perhaps as many as 10 of these homes would be flooded by either an "Intermediate Regional Flood" or a "Standard Project Flood." The majority of these homes would be surrounded by water 1 or 2 ft deep.

Future development in this area should take into account the projected flood elevation of 352 ft above sea level. The building of homes below that elevation should not be allowed.

During a "Standard Project Flood" State Highway 7 will be closed by flood waters at three localities. The total length of roadway which would be flooded would be approximately 1,650 ft (see U. S. Army Corps of Engineers, 1969, Pl. 28).

## Protective Measures

The only significant flood-prevention structure located directly in the study area is the Russellville Dike (Pl. 5). This 6,000-ft-long, 40-ft-high structure protects about 50 acres of residential, agricultural, commercial, and industrial land that was formerly in the flood plain of the Illinois Bayou. The dike was completed in 1965 by the U. S. Army Corps of Engineers as part of the Dardanelle Dam project.

The dike was designed to provide 3 ft of clearance above the elevation of the "Standard Project Flood" on the Illinois Bayou. This is coincident with a flow on the Arkansas River of 650,000 cfs.

The dike protects low areas in Russellville and surrounding areas from being flooded by the Dardanelle Reservoir. However, it also blocks the natural mouth of Prairie Creek and prevents storm water from draining into the reservoir.

The dike includes a pumping station which is capable of pumping 150,000 gpm over the dike into the reservoir. These pumps are electric with no on-site emergency power capabilities. The lack of emergency power facilities could pose a serious threat to the City of Russellville during any "natural disaster" that would disrupt local electric-power service for several hours.

Any structures built in areas which are likely to be flooded should be designed and constructed in accordance with the suggestions set forth in "Introduction to Flood Proofing" by John R. Sheaffer (1967).

## Flood Plain Management

Arkansas has a progressive flood plain-management law. Act 629 passed by the 1969 General Assembly gives authority to each city, town or county in the state to enact, adopt, and enforce ordinances, building or zoning codes, or other appropriate measures regulating, restricting, or controlling the management and use of land, structures, and other developments in flood-prone areas. The Division of Soil and Water Resources in the Arkansas Department of Commerce is responsible for guiding the implementation of this law.

Local resistance to such zoning has already developed in Russellville as shown by a March 2nd, 1973 headline in the Daily

Courier-Democrat which read, "City to Pull Plug on Flood Insurance". Property owners do not favor the insurance program because of the stringent building and remodeling regulations which would be placed on property in the flood plains. It was noted by one city official that if flood plain zoning were to be implemented, the city would lose thousands of dollars in tax revenue. However, the main concern of a city government in respect to zoning should not be to make money, but rather, to provide its citizens with the kind of regulations that will protect them from unwise or unscrupulous land development schemes.

## Future Floods

> Only in rare instances has a specific stream experienced the largest flood that is likely to occur. Severe as the maximum known flood may have been on any stream, it is a commonly accepted fact that, in practically all cases, sooner or later, a larger flood will probably occur (U. S. Army Corps of Engineers, 1969, p. 45).

### Standard Project Flood

The "Standard Project Flood" is defined as follows:

> . . . the largest flood that can be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the region involved (U. S. Army Corps of Engineers, 1969, glossary of terms).

The peak discharges to be expected during such a flood in the Russellville area are shown in Table 16.

The frequency with which such discharges could be expected is rather low. Flood discharges of this magnitude would be rare, perhaps once every 100 or more yrs. However, it must be remembered that greater floods could occur, and that such a flood could occur in any given year.

## TABLE 16

## PEAK DISCHARGES DURING A STANDARD PROJECT FLOOD IN THE RUSSELLVILLE AREA

| Stream or River | Discharge (cfs) |
|---|---|
| Arkansas River | 625,000 |
| Illinois Bayou | 125,000 |
| Prairie Creek | 5,400 |
| Whig Creek | 9,800 |

Source: U. S. Army Corps of Engineers, 1969, p. 46.

A commonly held viewpoint is that because of the completion of the Arkansas River Navigation project, there exists only a remote possibility of flooding along the Arkansas. This assumption is entirely incorrect. It is true that 92.6 percent of the total drainage area of the Arkansas River above the Dardanelle Dam (142,317 sq mi) is controlled by 26 flood-control reservoirs. These reservoirs provide 10,730,500 acre ft (1.5 in. of runoff water) of storage. However, 11,390 sq mi of uncontrolled drainage basin lie upstream from the Dardanelle Dam. This uncontrolled drainage is located in western Arkansas and eastern Oklahoma, the area that receives the largest amount of rainfall in all of the Arkansas River basin upstream from the Dardanelle Dam. As described above, severe rainfall in these areas has produced major floods in Dardanelle and Russellville. Major floods can develop, therefore, without significant runoff from the controlled areas of the drainage basin. The concern that the Corps of Engineers hold regarding future flooding is expressed as follows:

> Flood damages that would result from recurrences of major known floods would be substantial even as regulated by the existing reservoirs (U. S. Army Corps of Engineers, 1969, p. 4).

### Duration of Floods

Prolonged periods of flooding are to be expected in the Russellville and Dardanelle area due to the large volumes of flood runoff in upstream areas. In May 1943, during the largest known flood, the maximum rate of rise of the Arkansas River at Dardanelle was about 1.3 ft per hr. The river rose to its crest in 5 days at an average rate of 5.75 ft per day. The above-bankfull stage lasted for 23 days. During a Standard Project Flood the river is expected to rise 34.5 ft in 6 days. The maximum rate of rise would be about 7 ft per day. The river would be expected to remain out of its banks for 10 days.

### Intermediate Regional Flood

The "Intermediate Regional Flood" is defined by the Corps of Engineers as:

> A flood having an average frequency of occurrence in order of once in 100 years although the flood may occur in any year (U. S. Army Corps of Engineers, 1969, glossary of terms).

Table 17 shows the amount of discharge to be expected during an Intermediate Regional Flood.

## TABLE 17

## PEAK DISCHARGES DURING AN INTERMEDIATE REGIONAL FLOOD IN THE RUSSELLVILLE AREA

| Stream or River | Discharge (cfs) |
|---|---|
| Arkansas River | 540,000 |
| Illinois Bayou | 88,000 |
| Prairie Creek | 3,600 |
| Whig Creek | 6,600 |

Source: U. S. Army Corps of Engineers, 1969, p. 45.

### Prairie Creek and Whig Creek Basins

Prediction of flooding in the Prairie and Whig Creek basins (Pl. 5) cannot be based on statistical analysis, because there are no records of flood stages or discharges. However, there are numerous high-water marks in downtown Russellville that can be used as bases for prediction. Historical records were also studied carefully and many persons were interviewed by the Corps of Engineers during their analysis of flooding on Prairie and Whig Creeks. The Corps of Engineers predicts that major flooding on these creeks can be expected once every 10 yr. Minor flooding may be expected every year on both Prairie and Whig Creeks.

The creeks can be expected to rise rapidly and to produce flash-floods of short duration. The maximum rates of rise to be expected are about 2 ft per hr. The larger floods are expected to have a duration of up to 18 hr, while the usual duration of flooding would be less than 12 hr.

These expected rates of rise and duration of flooding were based on conditions that existed prior to 1969. Russellville is rapidly becoming urbanized, as has been shown earlier in this report, and urbanization has pronounced effects on the hydrologic characteristics of a drainage basin.

The effects of urbanization on the hydrologic characteristics of a stream have been carefully summarized by L. J. Turk (1970). Turk points out at least five effects of urbanization on a stream's natural characteristics. These effects are produced because urbanization causes fields, forests, and open land to be replaced by impervious cover, such as streets, parking lots, buildings, sidewalks, lawns, and so on. Of course, the effects of urbanization and of increasing the impervious cover are increased runoff, decreased lag-time, increased peak discharge, increased sediment yield, and reduced recharge of ground water reservoirs.

Drastic changes in rainfall-runoff relations have been reported from many urbanizing areas. For example, a given area in Long Island, New York, before urbanization would yield about 0.25 in. of runoff following 5 in. of rainfall (Turk, 1970, p. 10). After urban development the same amount of rain produced 1.1 in. of runoff, an increase of more than 400 percent. The conclusion follows that in Russellville, a similar increase can be expected in the amount of water the drainage basins yield for a given amount of rainfall.

The more efficient drainage produced by paving, storm sewers, and other urban improvements decreases the lag-time between rainfall and runoff. Such efficient drainage is welcomed by landowners in the upstream areas, while the property owners downstream curse the "natural disaster" which has caused flash-flooding. The combined effects of more runoff and shorter lag-times result in sharply increased peak discharges in urbanized stream basins. According to Epsey (1966; as quoted by Turk, 1970) urbanization of a watershed may cause floods with peak discharges of from 100 to 300 percent greater than discharges from the undeveloped watershed. As the flood stage is increased there is also an increased frequency of overbank flow which, in turn, may cause extensive downstream flooding.

Increased sediment yields are commonly observed in areas where construction is underway. Wolman (1964; as quoted by Turk, 1970) determined that the amount of sediment eroded from an area under construction may exceed the amount eroded from farms and woodlands by as much as factors of 20,000 to 40,000. Typical sediment yields for rural areas were reported to be from 200 to 500 tn per sq mi per yr. Areas undergoing urban development may yield from 1,000 to more than 100,000 tn per sq mi per yr. Sediment-laden water overflowing the channel of Prairie Creek is likely to leave a deposit of mud in the stores and offices and on the streets of downtown Russellville.

Reduced recharge to aquifers can also be an undesirable side-effect of urbanization. In the Russellville area, however, this does not appear to be a problem in the immediate future, due to the abundance of usable surface water.

## Hazards of Great Floods

The amount of damage caused by a major flood depends upon the following factors: amount of area flooded; height of flooding; velocity of flow; rate of rise; and duration of flooding (U. S. Army Corps of Engineers, 1969, p. 47).

Hazardous conditions exist when stream velocities exceed 3 fps (ft per sec) and flood waters are deeper than 3 ft (U. S. Army Corps of Engineers, 1969, p. 53). The Arkansas River is the most hazardous stream in the area during a Standard Project Flood. Channel velocity would exceed 15 fps and overbank flow would be greater than 5 fps. Boating is considered to be very dangerous in water moving at these velocities. Prairie Creek's channel velocity would reach a hazardous 5.2 fps during a Standard Project Flood. However, the overbank flow of 1.7 fps would not be particularly dangerous.

The rapid rate of rise of Prairie Creek during an intense local storm is considered to be hazardous. During a Standard Project Flood the creek is predicted to rise at 2.1 ft per hr.

During a Standard Project Flood Prairie Creek will flood seven or eight bridges that cross it in the city of Russellville (see Table 18).

The north side of the city would be virtually isolated from the rest of the city during such a flood. This situation could cause serious problems as emergency and rescue efforts are attempted.

As mentioned earlier in this report, State Highway 7 would be flooded both north and south of Russellville. Sewage treatment facilities and the Prairie Creek sewage pumping station could become flooded and inoperative, and portions of the water treatment plant could become flooded. The city water supply could be limited to the water stored in the service tanks.

TABLE 18

PRAIRIE CREEK BRIDGES AND THEIR POSITIONS WITH RESPECT TO A STANDARD FLOOD CREST

| Bridge | Floor Clearance (ft) | Above Banks (ft) |
|---|---|---|
| Knoxville Avenue | +2½ | 3½ |
| "B" Street | -1 | 7 |
| Detroit Avenue | -3 | 7 |
| Boston Avenue | -5 | 8 |
| Arkansas Avenue | -5 | 7½ |
| North Commerce Street | -3½ | 7½ |
| Denver Street | -5 | 7½ |
| El Paso Street | -5 | 8 |

Source: U. S. Army Corps of Engineers, 1969, p. 36.

As pointed out previously, a long-term interruption of electric service (several hours) to the Russellville dike pumping station could cause much more extensive flooding than has been predicted by the Corps of Engineers.

## Recommendations for Emergency Situations Related to Flooding in Russellville

1. Monitor rate of rise and issue local warnings during the period when weather conditions could produce flash-flooding along Prairie Creek.
2. Prepare plans for sand-bagging operations at the sewage treatment plant and Prairie Creek sewage-pumping station.
3. Provide emergency-powered pumping equipment for the Russellville dike-Prairie Creek pumping station.
4. Prepare emergency plans for policy and fire protection in the northern part of the city of Russellville during a flood along Prairie Creek.
5. Plan by-pass routes for flooded roads and highways where possible.

## Recommendations for Long-Range Planning for Prairie Creek's Flood Plain

1. Insure that the Corps of Engineers' sump-storage land under flood easement does not become a dumping ground.
2. Determine the best use for the land currently held by the Russellville Urban Renewal Agency only after a careful study of the flooding potential of the area. Consideration should be given to the development of a downtown park and recreation area or possibly an elevated shopping mall with ground-level parking facilities.

## Seismicity and the Potential of Earthquakes

An evaluation of the seismic activity of the Russellville area was required by the Atomic Energy Commission prior to the construction of Arkansas Power and Light Company's Nuclear One electric generating plant, which is located only 6 mi west of Russellville (Fig. 2). Therefore, the seismic evaluation of the plant site can be applied directly to the evaluation of the seismicity of the Russellville urban area.

The seismic evaluation noted that the generally good foundation conditions and general quiescence of the area permitted the selection of a low earthquake intensity (Arkansas Power and Light Company, 1967, p. 2E-2). However, considering that the epicenter of the large New Madrid earthquakes of December 16, 1811 and February 7, 1812 is only 220 mi from the Russellville area, a maximum intensity of VII (Modified Mercalli Scale) was determined to be within reasonable probability (Arkansas Power and Light Company, 1967, p. 2E-2). According to the Modified Mercalli Earthquake Intensity Scale of 1931, an intensity of VII can be described as having the following effects:

> Everybody runs out of doors. Damage is negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars (VIII Rossi-Forel scale). (Arkansas Power and Light Company, 1967, p. 2E-9).

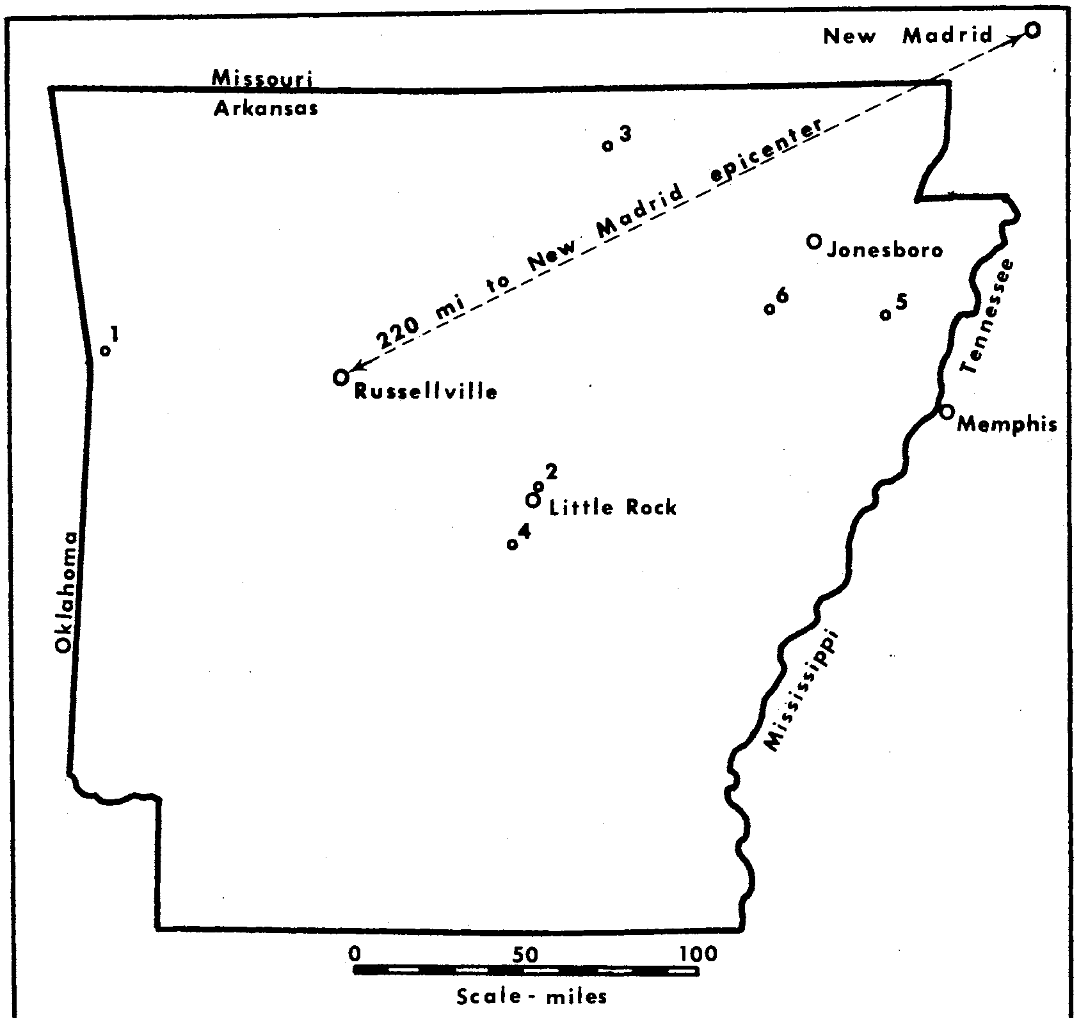
The seismic evaluation of the Nuclear One site was prepared by Bechtel Corporation for Arkansas Power and Light Company. Bechtel's evaluation was reviewed by Perry Byerly, a seismic consultant from Oakland, California, who concluded that,

> A careful study of the seismic history of the area shows that the area is not one in which earthquakes have their centers, if you wish it is not an area of active faults . . . . Considering the conditions listed in the report (from Bechtel Corporation): the firm bedrock (the McAlester shale), the distance from New Madrid, and the probable intensity of VII at St. Louis, Missouri, the conclusions in the report are quite valid. (The material above taken from Arkansas Power and Light Company, 1967, p. 2E-2.)

## Earthquake History

Locations in Arkansas where earthquakes that occurred between 1843 and 1952 were felt are shown in Fig. 22. These earthquakes probably were also felt in the Russellville area.

> ### The New Madrid Earthquakes
>
> The earthquakes which most significantly affected Arkansas and all adjoining states in the Mississippi Valley region occurred near New Madrid, Missouri in 1811 and 1812. The epicentral zone of the New Madrid earthquake was between New Madrid and Tryonza, Arkansas, and had a length of 75 miles. This earthquake consisted of a succession of shocks of varying intensities, beginning December 15, 1811, and lasting throughout the years 1812 and 1813. The nearest points at which systematic attempts were made to record the shocks from the New Madrid earthquake were at Louisville, Kentucky and Cincinnati, Ohio. At Louisville, 250 miles from the epicenter, 1764 shocks were recorded between December 16, 1811 and May 6, 1812. At Louisville the recording of shocks felt ceased at the later date. At Cincinnati, 340 miles from the epicenter, 41 periods of shocks were recorded, eight of which occurred between May 5, 1812 and December 12, 1813.
>
> The available data indicate that there were at least 1882 shocks. The maximum intensity was estimated at XII with a probable magnitude of 8 (Richter).
>
> In the heavily alluviated Mississippi Valley area fissuring, lurching, slumping, emergence of ground water, and associated effects took place on a large scale. (The material above taken from Arkansas Power and Light Company, 1967, p. 2E-2.)



EARTHQUAKES FELT (1843 - 1936)

1 - 1843 - Generally felt throughout Arkansas with three shocks reported at Van Buren but not confirmed.

2 - 1878 - Felt in Little Rock; severe along the Missouri River.

3 - 1883 - Slides in railway cut at Melbourne about 100 mi northeast of Russellville.

4 - 1918 - Epicenter 20 to 30 mi southeast of Little Rock. Felt in Memphis, Tennessee.

5 - 1923 - Epicenter at Marked Tree. Felt in Arkansas, Kentucky, Illinois, Missouri, and Tennessee.

6 - 1936 - Epicenter about 32 mi southeast of Jonesboro. Intensity IV at the epicenter, probably I at Russellville.

Figure 22. - Locations of earthquakes probably felt in the Russellville area (Arkansas Power and Light Company, 1967, Pl. 2E1).

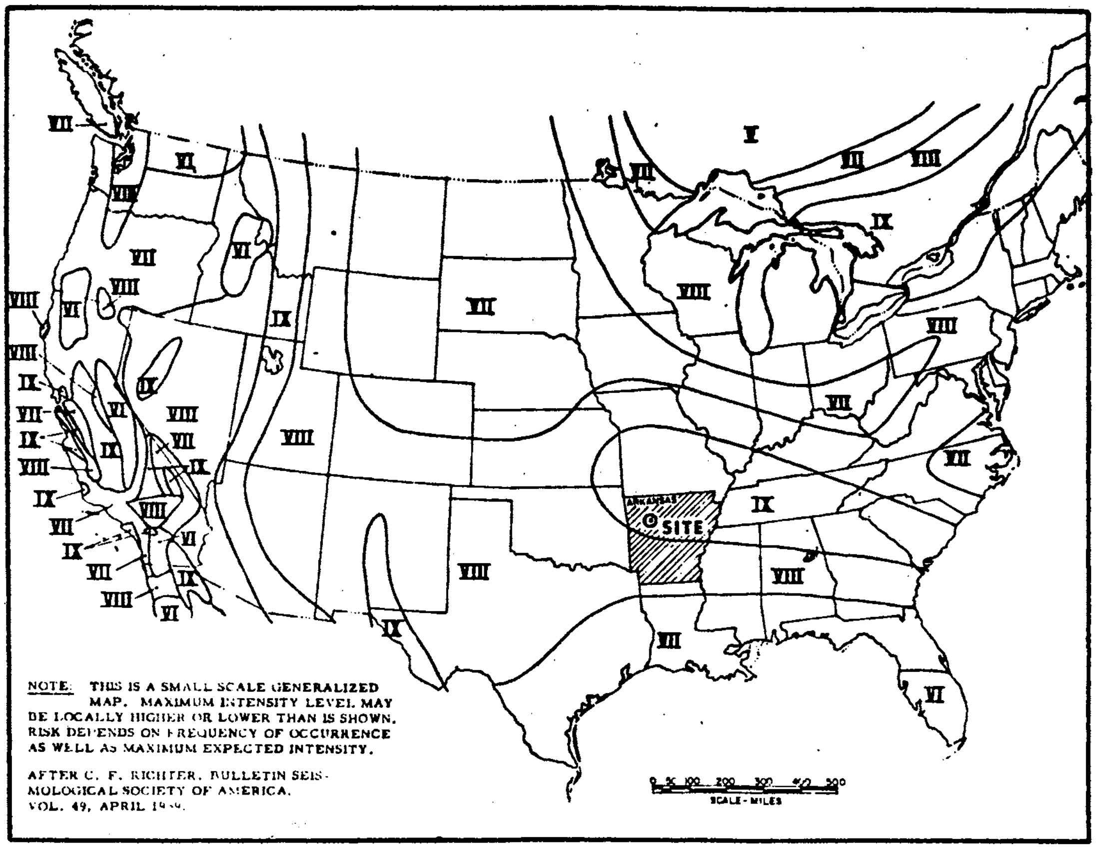
## Seismic Regionalization and Probability Maps

The Seismic Regionalization and Probability Map of the United States by C. F. Richter (Fig. 23) shows the probable maximum intensity of an earthquake in the Russellville area as IX on the Modified Mercalli scale. However, Bechtel's evaluation cited several reasons for reducing the anticipated intensity from IX to VII. They are as follows: (1) the site is near the boundary on the map between zones VIII and IX; (2) the map expresses the probable intensity of an earthquake as it would affect unconsolidated alluvium, colluvium, and residual soils; and (3) according to some seismic experts, the estimated intensity, as projected by Richter, is considered to be overestimated in areas of low seismic activity. Therefore, Bechtel's seismologists considered their estimate of a probable intensity of VII as being more realistic.

The Seismic Probability Map (Fig. 24) compiled by the U. S. Coast and Geodetic Survey is markedly different from Richter's map. It shows that the Russellville area is located in a less hazardous area than is shown on Richter's map. The Geodetic Survey's map shows Russellville in a zone of predicted "minor damage." This map shows that the "moderate/major damage" zone associated with the New Madrid epicenter is confined to the Mississippi valley of northeastern Arkansas, southeastern Missouri, western Kentucky, southern Illinois, and southwestern Indiana.

## Surficial Materials and Depth to Bedrock

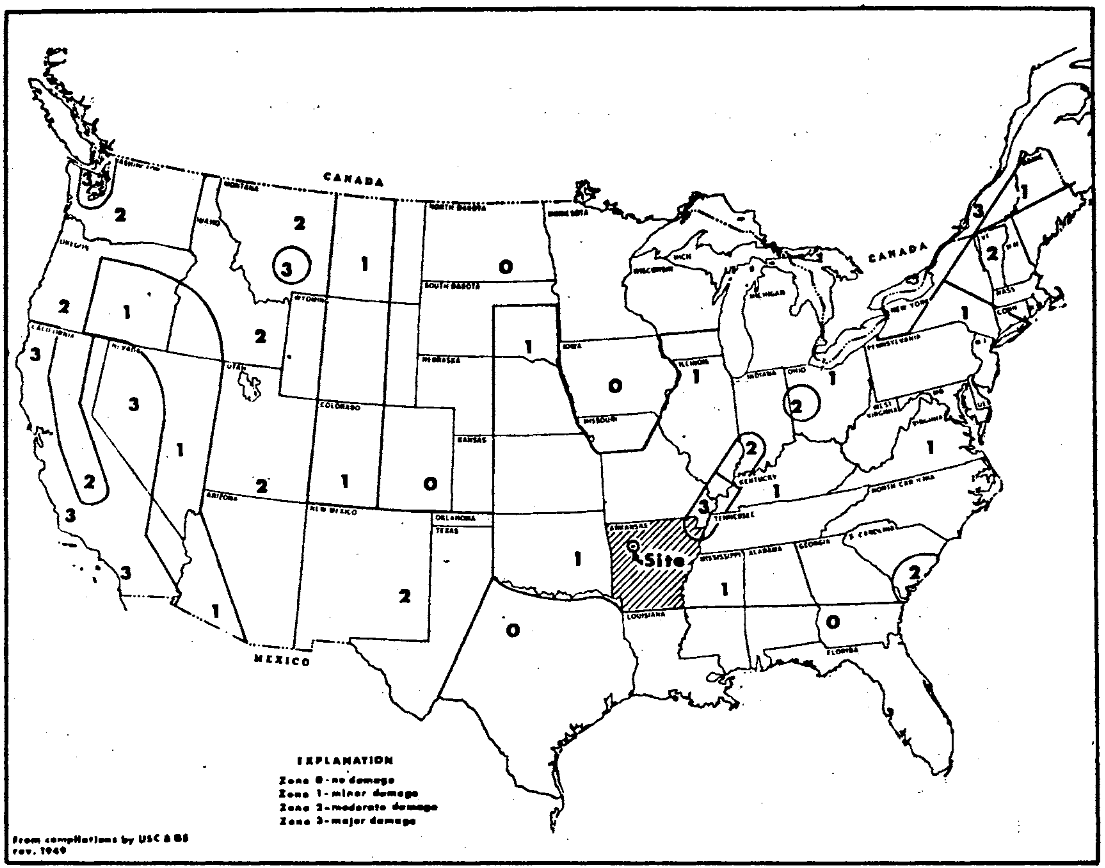
The surficial geologic materials in the Russellville area consist



NOTE: THIS IS A SMALL SCALE GENERALIZED MAP. MAXIMUM INTENSITY LEVEL MAY BE LOCALLY HIGHER OR LOWER THAN IS SHOWN. RISK DEPENDS ON FREQUENCY OF OCCURRENCE AS WELL AS MAXIMUM EXPECTED INTENSITY.

AFTER C. F. RICHTER, BULLETIN SEISMOLOGICAL SOCIETY OF AMERICA, VOL. 49, APRIL 1959.

Figure 23. - Seismic regionalization map of the United States; zones of probable maximum intensity shown by the Modified Mercalli scale (Arkansas Power and Light Company, 1967, Pl. 2E2).



From compilations by USC & GS rev. 1969

Figure 24. - Seismic probability map of the United States (Arkansas Power and Light Company, 1967, Pl. 2E3).

of alluvium, alluvial-terrace deposits (containing loess in some places), colluvium, and residual soils. The characteristics of the materials have been described previously and the construction characteristics are to be discussed in a following section of this report; therefore only the thicknesses (depths to bedrock) of the surficial materials and their "rippability" will be discussed here. The seismic velocities reported for the various materials present in the Russellville area were determined by the writer using the refraction seismic method.

## Flood Plain Alluvium

The thickest surficial materials are located along the Arkansas River in secs. 19, 20, 29, 33, and 34, T7N, R20W and secs. 2, 3, 4, 9, 10, 11, 12, and 13, T6N, R20W (Pl. 6). Many of the thicknesses reported in this area were determined by the U. S. Army Corps of Engineers by core-drilling and push-tube soil sampling prior to the construction of Dardanelle Dam. The U. S. Geological Survey drilled approximately 15 water-level observation wells in the same sections. The data all indicate that as much as 55 ft of alluvial materials overlie the bedrock.

Generally, seismic velocity of the alluvial material is less than 2,000 fps, unless it is saturated with water. This low seismic velocity indicates that excavation of the material can easily be accomplished by "common excavation" methods (Henbest and others, 1969, pp. 2-72). "Common excavation" as defined by Henbest and others (1969, pp. 2-73) does not require blasting and thus can be accomplished by track-type tractors (with a power-rating of at least 200 net hp at the flywheel) equipped with appropriate attachments.

Moderately thick deposits of alluvium (10 to 30 ft) are present near the northern edge of the modern floodplain of the Arkansas River in secs. 2, 3, 19, 20, 21, 28, 33, and 34, T7N, R20W (Pl. 6). Similar deposits are also located in close association with the previous flood plain (prior to the construction of the Russellville Dike) of the Illinois Bayou. These deposits are located in secs. 5 and 6, T7N, R20W and secs. 20, 31, and 32, T8N, R20W (Pl. 6). The thicknesses and soil types of the materials in secs. 31 and 32, T8N, R20W were determined from logs of numerous borings and from tube samples that were used in preparation for construction of the Russellville Dike (U. S. Army Corps of Engineers, 1961, Pl. 8). The alluvium was used as borrow material in the building of the dike, but soil sampling was not carried down to bedrock in the borrow-pit areas, as it was beneath the axis of the dike. However, the U. S. Geological Survey drilled three observation wells in sec. 31, T8N, R20W and one observation well in sec. 32, T8N, R20W (Pl. 6). These wells indicate that the alluvium is from 22 to 27 ft thick in these sections.

Thin (less than 10 ft) deposits of alluvium are located along Whig Creek in secs. 21, 22, and 23, T7N, R20W (Pl. 6). Similar deposits are also located in the region south and east of the Shinn basin (secs. 23, 26, 27, 28, 34, and 35, T7N, R20W and secs. 1 and 2, T6N, R20W; Pl. 6). These alluvial deposits are developed locally along stream channels. Seismic velocity of the material is similar to that of the thicker alluvial materials.

### Terrace Alluvium

Thin (less than 10 ft) to moderately thick (10 to 30 ft) alluvial-terrace soils are widely distributed in the Russellville area. The moderately thick materials are located in secs. 1, 2, 12, and 13, T6N, R20W; secs. 28 and 35, T7N, R20W; and secs. 20 and 30, T8N, R20W (Pl. 6).

Seismic velocities of these moderately thick alluvial-terrace soils range from about 1,100 fps (dry) to about 3,200 fps (moist). This range indicates that the materials can be excavated by common-excavation methods.

Thin alluvial-terrace soils are present in secs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 20, 21, 22, 26, 27, 28, and 34, T7N, R20W; secs. 20, 21, 29, 30, 31, 32, 33, 34, and 35, T8N, R20W; secs. 23 and 24, T8N, R21W; and sec. 2, T7N, R21W (Pl. 6). The average seismic velocity of the material is about 1,600 fps (dry) which indicates that excavation by the common method is highly probable.

## Shaly Colluvium and Residual Soil

Thin (less than 10 ft) clayey to silty residual soils are widely distributed in the Russellville area. They are likely to grade into colluvial soils where slopes are steeper than about 10 to 15 percent. Generally, these colluvial areas show an increased amount of shale and siltstone fragments on and near the surface and lack the normally expected soil profile. However, it was not considered feasible to map these areas separately at the scale of 1:24,000. The material is the weathered residuum of the Atoka and McAlester formations. It can be observed in secs. 23, 24, and 26, T8N, R21W; secs. 20, 28, 30, 33, and 34, T8N, R20W; secs. 5, 6, 7, 8, 9, 14, 15, 16, 17, 23, 26, 27, 28, 29, 34, and 35, T7N, R20W; and secs. 1 and 13, T6N, R20W (Pl. 6). Seismic velocity of the material is approximately 1,600 fps (dry) to 2,950 fps (moist). Excavation, as indicated by these velocities, should be relatively easy, unless large colluvial boulders are encountered. This is not likely to occur, because on the average, these residual and colluvial soils are developed on slopes of less than about 7 percent (Pl. 4).

Thick (10 to 20 ft) colluvium and residual soils occur in sec. 21, T8N, R20W; sec. 26, T8N, R21W; and secs. 15, 16, 20, 21, 22, 23, 26, 27, 28, 34, and 35, T7N, R20W (Pl. 6). Generally, these areas show low seismic velocities and thus excavation characteristics are similar to the thin materials discussed above. The probability of encountering large boulders in the colluvium is greater in this group of materials, especially where the materials are located on the outer footslopes of ridges, such as secs. 20, 21, 27, and 28, T7N, R20W and sec. 21, T8N, R20W (Pl. 6). Grades of 7 to 15 percent are common in these areas and thus soil creep is quite likely.

### Sandy Colluvium and Residual Soil

A mantle of thin (less than 10 ft) sandy colluvium and residual soil over sandstone is located in secs. 23, 24, 25, 26, 35, and 36, T8N, R21W; secs. 19, 21, 30, 31, 34, and 35, T8N, R20W; secs. 1, 2, 11, 12, and 13, T7N, R21W; and secs. 6, 7, 16, 17, 18, 20, 22, 23, 26, 27, 28, and 29, T7N, R20W (Pl. 6). The material has been weathered from the Hartshorne Sandstone and from some of the thicker sandstone beds of the Atoka Formation. Range of seismic velocity of the residuum is approximately 1,660 fps (dry) to about 3,000 fps (moist). Excavation would be fairly easily accomplished in the residual soil; however, blocks of sandstone (a few inches to 1 or 2 ft in diameter) are likely to be numerous, especially near stream channels. Some moderately large boulders of sandstone (a few feet in diameter) are found in the areas of very thin residual soil. In these areas are many outcrops of sandstone, especially in the stream channels on Norristown Mountain and Carrion Crow Mountain (Pl. 5). The largest area of exposed sandstone bedrock is Forty Acre Rock on Pleasant View Mountain (Pl. 5).

Excavation in areas where sandstone crops out or where it is overlain by only a few inches or a few feet of residual soil, will be much more difficult than where thick residual soil is present. The seismic velocity of the Hartshorne Sandstone varies from about 6,000 fps to about 13,000 fps. The velocity range can be explained as being due to variation in the amount and type of cementation in the sandstone. Velocities of seismic waves in poorly cemented ferruginous sandstones are about 6,000 fps, whereas velocities in well cemented quartzitic sandstone are more than 13,000 ft per sec. The average velocity in the Hartshorne Sandstone is approximately 6,680 fps. The degree to which pores of the sandstone are filled with water will also affect the seismic velocity, as increased water content causes higher seismic velocity.

The relationship of seismic velocity of sandstones to "rippability" has been studied by Henbest and others (1969). According to their data, the "rippability" of sandstone depends on the following factors: (1) moisture content, (2) firmness of cementation, (3) spacing of bedding planes, (4) amount of fracturing (and jointing), (5) degree of weathering, and (6) direction and degree of dip (Henbest and others, 1969, pp. 2-74 and 2-75). The U. S. Soil Conservation Service classifies sandstone into four categories of "non-rippability" as shown below in Table 19.

TABLE 19

SEISMIC VELOCITIES OF SANDSTONE INDICATING NON-RIPPABILITY

| Lithologic Characteristics and Average Ranges of Seismic Velocity (fps) | Velocities Indicating Non-Rippability (fps) |
|---|---|
| (1) Dry, poorly cemented; thick-bedded (4,000 - 5,000) | more than 5,000 |
| (2) Wet, poorly cemented; thick-bedded (5,000 - 6,500) | more than 6,500 |
| (3) Thin-bedded; jointed (5,500 - 7,000) | more than 7,000 |
| (4) Thick-bedded; weathered (5,000 - 6,000) | more than 6,000 |

Source: Modified from Henbest and others, 1969, pp. 2-75).

From the foregoing description, it seems that common excavation methods cannot be used in the Hartshorne Sandstone and that the Hartshorne should be considered to be a "non-rippable" bedrock. This means that rock excavation methods, perhaps including blasting, would have to be employed where projects require going more than a few inches below the surface.

Thick (more than 10 ft) sandy residual soil and colluvium occur in only one area in sec. 7, T7N, R20W and sec. 12, T7N, R21W on Norristown Mountain (Pl. 6). This area is located on a gentle grade of about 3 percent. Depth to bedrock in this area is approximately 13 ft and may represent only a local situation. During planning for use of this area, surveying should be done in greater detail in order to delineate the boundaries of the thick mantle.

### Mixed Colluvium

Thin (less than 10 ft) mixed sandstone and shale colluvium which contains sandstone rubble is located below Hartshorne Sandstone escarpments in secs. 6, 7, 16, and 17, T7N, R20W; sec. 31, T8N, R20W; sec. 2, T7N, R20W; secs. 23 and 24, T8N, R21W; and secs. 26 and 27, T7N, R20W (Pl. 6). These areas are on the eastward- and northward-facing escarpment of Norristown Mountain, on the southward-facing escarpment of Carrion Crow Mountain, on the northward-, westward-, and eastward-facing escarpments of Pleasant View Mountain, and on the southward-facing escarpment of the Shinn basin (Pl. 2).

At some places, colluvial material contains extremely large sandstone boulders (several tens of ft in diameter). Seismic surveying is probably meaningless where such boulders are encountered, due to the interference they cause. Therefore, seismic studies of "rippability" and depths to bedrock must be replaced by direct measurements. "Rippability" is variable due to the heterogeneous character of the colluvial material. Where large boulders are encountered blasting would be required; however the sandy and shaly matrix surrounding the boulders may be excavated by common methods. Detailed site investigation is mandatory for any project located within the area of the colluvial material. Slope instability, as mentioned previously, is to be expected in the surficial materials.

Thick (more than 10 ft) mixed sandstone and shale colluvium occurs on the footslopes of the Norristown Mountain escarpment in secs. 6 and 16, T7N, R20W and sec. 31, T8N, R20W (Pl. 6). Similarly, thick footslope colluvium is also located below Carrion Crow Mountain (sec. 2, T7N, R20W and secs. 33, 34, and 35, T8N, R20W) and Pleasant View Mountain (sec. 19, T8N, R20W and secs. 23 and 24, T8N, R21W; Pl. 6). The footslopes on the southern and eastern flanks of the Shinn basin (secs. 23, 26, 27, and 28, T7N, R20W) are also underlain by thick colluvial material (Pl. 6).

Extremely massive blocks of sandstone (50 x 40 x 30 ft) in a colluvial matrix are located at the foot of "River's Bluff" in secs. 11, 12, and 13, T7N, R21W and sec. 18, T7N, R20W (Pl. 6).

Generally, the outermost footslope colluvium can be surveyed by seismic methods because in this area near the margins, it does not contain as much sandstone rubble. Several such surveys indicate that the average seismic velocity is about 1,900 fps (dry) and approximately 3,200 fps (moist). On the basis of the seismic velocities, these materials probably could be excavated by common methods.

## Depths of Weathering

Depths of weathering in the Russellville area were determined from water-well drilling reports and core-drilling logs. The water-well drilling reports, as mentioned previously, have been filled with the "Committee on Water Well Construction" at the State Capitol in Little

Rock since 1970. However, many of the reports are useless because the rock descriptions are either not given or are not definitive enough to be of value. Fortunately, several of the drillers did make accurate descriptive logs of the materials being drilled and it is possible from their descriptions to determine to what depths weathering has penetrated the bedrock of the Russellville area. The core-drilling logs were made by the U. S. Army Corps of Engineers prior to the construction of the Dardanelle Dam. In their logs the following materials are described: (1) alluvial or residual soil types, (2) weathered rock, and (3) "top of firm rock" (U. S. Army Corps of Engineers, 1951, Pl. 29-31). The phrase "top of firm rock", as used by the U. S. Army Corps of Engineers, means the lower limit of weathering in the bedrock.

There are several factors which could cause variations in the depth of weathering. One of the most important factors would be the topographic setting. Deeper weathering is to be expected in valleys and other lowland areas because of the abundance of moisture. Because alluvium and residual soils tend to mask bedrock in these low areas, erosion is not as likely to remove weathered residuum from its position above the firm bedrock, and therefore a more complete section of the weathered material is available for sampling. However, erosion on a hillslope is likely to remove the weathered material and although the rate of weathering may be greater, the depth of weathering is not as deep. Other factors which have a significant influence on the depth of weathering are joints, fractures, rock cleavage, and bedding planes. Water may percolate more rapidly into the bedrock, and penetrate to greater depths, where such openings are present. Therefore, the spacing, depth, number, dip and strike of joints and other such discontinuities influence weathering of the bedrock. Rock composition and texture are also factors that have a major influence on the weathering of bedrock.

## Hartshorne Sandstone

The Hartshorne Sandstone on Carrion Crow Mountain (secs. 34 and 35, T8N, R20W; Pl. 2) is weathered to an average depth of about 8 ft. Depth of the material, which is logged as a "crystallized" gray sandstone ranges from 4 to 15 ft. The gray sandstone is overlain by a layer of "broken" red sandstone. The terms "crystallized" and "broken" in the language of a driller mean "unweathered" and "weathered", respectively.

On the western end of Norristown Mountain (sec. 2, T7N, R21W; and secs. 35 and 36, T8N, R21W; Pl. 2) the average depth to the top of the unweathered Hartshorne Sandstone is about 8 ft. Depths to the top of firm rock range from 4 to 16 ft.

Visual examination of several quarries in the Hartshorne Sandstone in the Russellville area show a pronounced color change from an upper zone of yellow limonitic-stained sandstone to a lower zone of medium gray sandstone, at an average depth of about 10 ft.

## McAlester Formation

Only a small amount of data is available showing depths to which the shale of the McAlester Formation weathers in the study area. The U. S. Army Corps of Engineers core-drilled at two stations where the shale was penetrated, in secs. 19 and 20, T7N, R20W (Pl. 1). In sec. 19, T7N, R20W, 14 ft of weathered shale lies on top of unweathered shale. In sec. 20, T7N, R20W only 8 ft of weathered shale was recorded.

During site examination prior to the construction of Arkansas Power and Light Company's "Nuclear One", 26 auger holes were drilled to bedrock (McAlester Formation). The site is located outside the study area, but because it is only about 6 mi from Russellville (Fig. 2), data on the McAlester Formation's weathering characteristics are applicable. At this locality, the firm shale of the McAlester is overlain by 13 to 23 ft of "stiff clay" and silty clay (weathered from the McAlester Formation) (Arkansas Power and Light Company, 1967, p. 2D-3). Also according to Arkansas Power and Light Company (1967-68, p. 2D-5) ". . . from 2 to 5 ft of weathered shale would have to be stripped from the bedrock surface to produce a satisfactory foundation."

### Atoka Formation

Data concerning the shale of the Atoka Formation were compiled from records of 23 core-drill holes in the area south of the Shinn basin (secs. 28, 29, 34, and 35, T7N, R20W) (U. S. Army Corps of Engineers, 1951, Pl. 29-31). The data show that the average depth to firm shale is 12 ft. Depths to firm shale range from 5 to 22 ft.

## Construction Properties of Geologic Materials

The most commonly utilized indices of the construction properties of soils (unconsolidated materials that overlie bedrock) are: (1) liquid limit, (2) plastic limit, (3) permeability, (4) corrosivity, (5) shrink-swell ratio, and (6) drainage. These characteristics of soils in the Russellville area are summarized on Pl. 7. The data that serve as a basis for Pl. 7 were derived from several sources, such as: (1) U. S. Soil Conservation Service, (2) Arkansas Highway Department, (3) Arkansas Power and Light Company, and (4) U. S. Army Corps of Engineers. A large amount of data is available for the Russellville area, primarily because of the construction of the Dardanelle Dam, the Russellville Dike, Interstate Highway 40, and Arkansas Power and Light Company's "Nuclear One".

The base map for Plate 7 was compiled from soil maps of the area which were prepared by the U. S. Soil Conservation Service. These maps (scale 1:20,000) were assembled into a mosaic base map and reduced photographically to the scale of 1:24,000, so that they would fit the topographic maps available for the area. During compilation the desirability became apparent of combining the 16 soil units (as classified by the Soil Conservation Service) that crop out in the Russellville area into nine units. These nine units were defined by combining soils with similar properties into one unit. For example, "Guthrie" soils were combined with "Taft" soils because the only significant differences are in thickness and color.

## Colluvial Soils

Colluvial soils are shown as units "A" and "C" on Plate 7.

### Unit "A"

Unit "A" is known as the "Allen" soil series (U. S. Soil Conservation Service, 1973a, p. 3). These soils are developed on steep slopes and footslopes and are formed on parent material of colluvium, sandstone and shale. The soil is classified as an A-4 type (AASHO classification; see Appendix). Its liquid limit is less than 30 and its plastic index ranges from non-plastic to 10. It is moderately permeable (0.6 to 2.0 in. per hr) and well drained. "Allen" soils are acidic. The pH ranges from 4.5 to 5.5, and indicates that their corrosivity on uncoated steel is low, but is moderate to high on concrete. The shrink-swell potential is considered to be low.

The properties discussed are not likely to limit construction in type "A" soils, except where moderate permeability might be undesirable. However, the slopes normally characteristic of these soils are too great to permit most types of construction. Soil creep and other forms of instability are very likely to occur in this colluvial soil unit.

### Unit "C"

Map unit "C" is classified as the "Enders" series by the U. S. Soil Conservation Service. These soils are located on the sideslopes and footslopes of steep escarpments. The regolith is a clayey residuum weathered from shales and interbedded shale and thin sandstone strata. The depth to bedrock is commonly about 6 ft on hillsides but is generally more than 10 ft on footslopes.

The "Enders" series (unit "C") is made up of well-drained, acidic soils which have a grayish-brown loamy surface layer. In severely eroded places, its texture ranges from silty clay loam to stony fine sandy loam. The subsoil is a silty clay loam over a silty clay. Below this there may be a layer of soft, weathered clay shale (U. S. Soil Conservation Service, 1970, p. 3). The soil is classified as A-4 (topsoil) to A-7 (subsoil) (AASHO classification; see Appendix). Its liquid limit ranges from 25 to 35 in the topsoil and from 65 to 80 in the subsoil. The plastic index ranges from 7 to 10 in the topsoil and from 35 to 45 in the subsoil.

Shrink-swell potential is low in the topsoil, but high in the subsoil. The permeability of the topsoil is moderate (0.6 to 2.0 in. per hr), while it is very slow (less than 0.06 in. per hr) in the subsoil. The soil is considered to be moderately to highly corrosive (pH of 4.0 to 5.5).

Unit "C" soils have several significant properties that limit their suitability for various types of construction. As a roadway or highway base, the material has limited supporting capacity because of the high shrink-swell potential of the subsoil. It is also highly susceptible to sloughing or sliding when undercut, and its position on steep slopes adds to its general instability. The very slow permeability of the subsoil makes the satisfactory operation of septic-tank filter fields highly unlikely. Generally, the soil is unsuited for construction projects (U. S. Soil Conservation Service, 1970, p. 3).

## Sandstone, Siltstone, and Shale Residual Soils

The sandstone, siltstone, and shale residual soils are mapped as two units ("B" and "D") on Pl. 7. Unit "B" is primarily a residuum from weathered sandstone bedrock (Hartshorne Sandstone) which contains only minor amounts of siltstone and shale. Unit "D" is related to the predominantly shaly composition of the Atoka Formation. However, minor amounts of sandstone and siltstone are also present at some localities.

### Unit "B"

Unit "B" soils are mapped as the "Linker" and "Mountainburg" series by the U. S. Soil Conservation Service. In the vicinity of Russellville, this soil unit generally is located on the highland areas (Pl. 7). These upland soils have a fine sandy loam surface layer and a strongly acidic sandy clay loam subsoil. Bedrock is generally from 12 to 40 in. below the surface (U. S. Soil Conservation Service, 1971b and 1971c, p. 3).

Unit "B" is an A-4 to A-6 soil type according to the AASHO classification (see Appendix), except where stony or gravelly phases occur. These are classed as A-2 type soils. The non-stony soil has a liquid limit of from 0 to 20 (topsoil) and 25 to 35 (subsoil) and a plastic index that ranges from 0 to 8 in the topsoil and from 5 to 20 in the subsoil. The shrink-swell ratio is low. The soil is moderately permeable (0.6 to 2.0 in. per hr), well-drained, and extremely to strongly acidic (pH of 4.0 to 5.5).

The main limitations of the A-4 to the A-6 type of soil in relation to construction requirements are: (1) shallow bedrock, (2) high acidity, (3) steep slopes (in some areas), and (4) moderate permeability (considered to be a limitation in construction and maintenance of ponds, and of solid-waste landfills).

A coarser "stony and gravelly" phase of unit "B" also occurs in the Russellville area. These soils are described as a "gravelly fine sandy loam" and are assigned an AASHO classification of A-2. They are non-plastic soils with a liquid limit that is less than 20 and a plasticity index of less than 10. Their shrink-swell potential is also low. Permeability is moderately rapid (2.0 to 6.0 in. per hr) in this gravelly material. Corrosivity is moderately high for concrete structures but low for uncoated steel (U. S. Soil Service, 1971b and

1971c, p. 3). The limitations on construction projects undertaken in this type of soil are similar to those described above for the finer portion of unit "B".

### Unit "D"

Unit "D" soils are classified as the "Cane" series by the U. S. Soil Conservation Service (1968a, p. 3). These soils are described as having a sandy loam topsoil with a sandy clay loam subsoil. The topsoil is classified as an A-4 type (AASHO) while the subsoils, being more plastic, are assigned to an A-6 category. The "Cane" series is considered to be an inorganic clay soil of medium plasticity. The liquid limit ranges from 28 to 38 and the plastic index ranges from about 5 in the topsoil to about 20 in the subsoil. The shrink-swell ratio is low. Permeability is moderately rapid (2.0 to 6.3 in. per hr) in the topsoil to slow (0.06 to 0.2 in. per hr) in the subsoil. The topsoil is slightly acidic (pH of 6.1 to 6.5) while the subsoil is very strongly acidic (pH of 4.5 to 5.0) (U. S. Soil Conservation Service, 1968a, p. 3).

Generally, unit "D" can be considered to be the weathered residuum of the Atoka Formation shales and siltstones. However, some of the unit overlies the shale of the McAlester Formation.

Construction problems in this soil unit would include the following: (1) low permeability limits the effective use of septic tanks, (2) high acidity of the soil would be corrosive to both uncoated steel and concrete, and (3) its bearing strength may be too low for industrial development (U. S. Soil Conservation Service, 1968a, p. 3).

## Flood Plain Alluvial and Alluvial Terrace Soils

### Unit "E"

Soil unit "E" soils are developed on alluvial terrace deposits which probably contain loess (U. S. Soil Conservation Service, 1968b, p. 3). Most of the area within the city limits of Russellville is covered by soils of this unit (Pl. 7). Soil types included within this unit are the "Guthrie", "Leadvale", "Pickwick", and "Taft", as described by the U. S. Soil Conservation Service.

The upper zone in this soil unit is a silty loam, while the subsoil is a silty clay with a compact, brittle, silty clay loam in the lower part of the subsoil. Its classification ranges from A-4 to A-7 (AASHO). The liquid limit of unit "E" soils ranges from 20 to 55 and the plastic limit is moderately low, ranging from 0 to 20. The unit is moderately permeable (0.6 to 2.0 in. per hr), especially in the topsoil. However, the subsoils may be slowly (0.6 to 2.0 in. per hr) to very slowly permeable (less than 0.06 in. per hr). These soils are very strongly acidic (pH of 4.5 to 5.0) to strongly acidic (pH of 5.1 to 5.5) and have a low shrink-swell potential. They range from moderately well drained (silty clay subsoil) to poorly drained where fragipan is developed in the subsoil.

Construction problems to be expected in this soil unit would be related to the poor soil drainage, high soil acidity, and poor load-bearing strength of the soil in some areas.

### Unit "F"

Unit "F" includes soils that have formed on flood plain alluvium.

The largest areas lie in secs. 20, 29, 31, and 32, T8N, R20W (Pl. 7). These localities are in the flood plains of Illinois Bayou and Prairie Creek (Pl. 5). The soils included within unit "F" are classified as "Cleora" and "Barling" by the U. S. Soil Conservation Service. They are generally described as brownish sandy to silty loam with silty loam subsoils. Drainage is good to very good and permeability tends to be moderate (0.6 to 2.0 in. per hr) to moderately rapid (2.0 to 6.0 in. per hr). The soils are assigned an AASHO classification of A-2 to A-4, rarely A-6. The liquid limit ranges from non-plastic to about 30 and the plasticity index ranges from non-plastic to 15. The average plastic index is less than 10. Acidity ranges from medium acidic (pH 5.6 to 6.0) to neutral (pH 6.6 to 7.3). The shrink-swell ratio is low. Unconfined-compressive-strength tests were made on soils included in unit "F" by the U. S. Army Corps of Engineers (1961, p. 17) prior to the construction of the Russellville Dike. The results of these tests show values ranging from 0.5 to 2.8 tsf (tons per sq ft); the average is 1.5 tsf.

Construction problems that are likely to be encountered in unit "F" soils are related to flooding and high water tables. Load-bearing capacity of these soils is low when they become saturated, according to the U. S. Soil Conservation Service (1971a, p. 3).

### Unit "G"

Unit "G" soils are located on the Arkansas River terrace alluvial deposits in secs. 2, 20, 28, 29, 33, and 34, T7N, R20W and secs. 1, 2, 3, 4, 10, 11, 12, and 13, T6N, R20W (Pl. 7). This unit is mapped as the "Muskogee" and "Caspiana" series by the U. S. Soil Conservation

Service.

The topsoil is a brownish silty loam and the subsoil is a silty clay. Unit "G" soils are classified as A-4 (topsoil), A-6 (upper subsoil), and A-7 (lower subsoil) (AASHO classification). The liquid limit of the topsoil is about 20, but it may increase to 50 in the lower subsoil. Plasticity indices range from 1 to 50. The soils are moderately slowly permeable (0.2 to 0.6 in. per hr) to very slowly permeable (less than 0.06 in. per hr), but are moderately well drained. The topsoil may be strongly to mediumly acidic (pH of 5 to 6) and the subsoil may be neutral (pH of 6.6 to 7.3). In some areas, soils are moderately alkaline (pH of 7.9 to 8.4). A low shrink-swell ratio is characteristic of the topsoil. However, subsoils may have a moderate to a high shrink-swell ratio.

Construction problems likely to be encountered in unit "G" soils are related to the high shrink-swell ratio of the subsoils and the highly corrosive character of the soil. Foundations or roadbeds which penetrate the subsoil where shrink-swell ratios are high are likely to fail during the normally expected life of the structure.

### Unit "H"

Where construction problems are concerned, unit "H" is potentially the most troublesome soil unit in the Russellville area. It is located in secs. 19 and 20, T7N, R20W and secs. 1 and 12, T6N, R20W (Pl. 7). Mapped as the "Perry" series by the U. S. Soil Conservation Service, it is the only montmorillonitic soil in the Russellville area (U. S. Soil Conservation Service, 1971d, p. 3).

The "Perry" series is described as a slowly permeable (less than 0.06 in. per hr) bottomland soil that is poorly drained. The surface layer consists of gray clay, while the subsoil is a reddish brown clay. The subsoil is acidic (pH of 4.5 to 7.3) in the upper part and alkaline (pH of 6.1 to 8.4) in the lower part (U. S. Conservation Service, 1971d, p. 3). The soil is assigned an AASHO classification of A-7-6. It has a liquid limit of 50 to 75 in the upper 3 ft and of 60 to 80 below 3 ft. The plasticity index ranges from 30 to 50 and the shrink-swell ratio is very high.

The soil is unsatisfactory as a foundation base or for other construction applications because it is: (1) highly compressible, (2) subject to seasonal flooding, (3) poorly drained, (4) slowly permeable, (5) subject to great variation in volume as it dries or becomes wetted, and (6) moderately to strongly corrosive.

A detailed construction-site analysis would be essential for any construction project that would be located in an area where unit "H" soils are present. Such a site investigation should include deep soil analysis (10 to 30 ft, depending on the depth to bedrock). For heavy construction it may be necessary to remove the soil and construct footings upon bedrock; thus building costs could be quite high.

### Unit "J"

Unit "J" soils are located adjacent to the Arkansas River (Pl. 7) and are essentially sandy alluvium. They are mapped as the "Bruno" series by the U. S. Soil Conservation Service. These soils are described as ". . . being nearly level, deep, excessively drained sandy soils" (U. S. Soil Conservation Service, 1973b, p. 3). The soils are classified as A-2 to A-4 (AASHO system). The liquid limit is less than 30 and the soils are non-plastic. Rapid permeability (6.0 to 20 in. per hr) is the major characteristic of this soil unit. Both strongly acidic (pH of 5.1 to 5.5) and mildly alkaline (pH 7.4 to 7.8) phases of the soil have been recorded. Since the soils are non-plastic, the shrink-swell ratio is low.

Construction limitations that would be encountered in this soil unit would relate to: (1) flooding potential, (2) moderate corrosivity, and (3) excessive permeability (U. S. Soil Conservation Service, 1973b, p. 3).

## Bedrock

### Atoka Formation

The U. S. Army Corps of Engineers tested the shale of the Atoka Formation for compressive strength prior to the construction of the Russellville Dike (secs. 31 and 32, T8N, R20W; Pl. 7). The minimum unconfined compressive strength of the shale was found to be 2600 psi (pounds per sq in.). It was noted that the shale has a tendency to slake upon exposure to air and it was suggested that protective coatings would be necessary during excavation, or that final cutting to grade should be accomplished immediately before placement of the fill (U. S. Army Corps of Engineers, 1961, p. 15).

It has been noted earlier in this report that the Atoka Formation is disrupted by numerous joints, fractures, and bedding planes. The U. S. Army Corps of Engineers tested the ability of the Atoka Formation to accept water. Seventeen core holes were drilled into bedrock and were pressure tested (30 psi gage pressure) along the Russellville Dike alignment. Fifteen holes accepted water (U. S. Army Corps of Engineers, 1961, p. 16). The maximum water loss was 27 gpm and the average loss was 12 gpm. Grouting would be necessary to prevent such water loss, if this were to be a problem during a construction project.

## Hartshorne Sandstone

The Hartshorne Sandstone is the foundation rock of the Dardanelle Dam. Therefore, extensive tests of its physical properties were conducted by the U. S. Army Corps of Engineers. Results of these tests are shown in Table 20.

TABLE 20

PHYSICAL PROPERTIES OF THE HARTSHORNE SANDSTONE

| Sample no. | Apparent specific gravity | Unit dry wt (lbs cu ft) | Porosity % | Compressive strength (psi) | Tangential resistance, normal load (tsf) |
|---|---|---|---|---|---|
| S4 | 2.58 | 147.6 | 9 | 4,920 | 199 |
| S17 | 2.77 | 168.9 | 2 | 11,200 | 310 |
| Average of 8 samples | 2.60 | 150.9 | 7.1 | 8,755 | 211 |

Source: Modified from the U. S. Army Corps of Engineers, 1957, Fig. 3).

Sample "S4" has the lowest compressive strength of all of the samples tested by the U. S. Army Corps of Engineers. Its low specific gravity, low unit dry weight, low compressive strength, and high porosity indicate that the rock is poorly cemented. This sample probably was collected from a sandstone unit with ferruginous cement (fairly common in the Hartshorne Sandstone at some localities). Sample "S17" has the highest strength of all samples tested. Its specific gravity, high unit dry weight, high compressive strength, and low porosity indicate that the sample was collected from a well-cemented, probably quartzitic, sandstone. The range of properties shown in Table 20 are considered to be representative of the Hartshorne Sandstone in the Russellville area.

### McAlester Formation Shale

The shale of the McAlester Formation was tested by the Bechtel Corporation Geology Laboratory, San Francisco, California prior to the construction of Arkansas Power and Light Company's "Nuclear One" electric generating plant. A summary of results of these tests is shown in Table 21.

Bechtel's engineers concluded that no foundation problems should be expected in shale with the properties shown in Table 21. It was also noted that this conclusion was supported by seismic velocities measured in the shale (10,000 to 14,500 fps) which indicate that the shale is dense.

Drillers logs indicate that the weathered part of the shale is from 2 to 5 ft thick (Arkansas Power and Light Company, 1967-1968, p. 20-5). This material should be stripped in order to expose rock that would provide a satisfactory foundation. This shale, like shale of the Atoka Formation, tends to expand slightly upon removal of overburden. Therefore, excavation to grade should be done immediately before placement of concrete.

### TABLE 21

### AVERAGE VALUES OF THE PROPERTIES OF SHALE OF THE McALESTER FORMATION

| Property | Average Value |
|---|---|
| Specific gravity | 2.57 |
| Porosity | 5.8% |
| Absorption | 2.5% |
| Unconfined compression | 3,470 psi |
| Modulus of elasticity | $0.8 \times 10^6$ psi |
| Poisson's ratio | 0.18 |
| Triaxial compression | 0=40 deg; C=830 psi |

Source: Arkansas Power and Light Company, 1968, p. 20-5.

# GEOLOGY AND FUTURE LAND-USE PLANS
# IN THE RUSSELLVILLE AREA

Russellville has a Comprehensive Development Plan, (City Planning Division, University of Arkansas, 1969), as has been mentioned previously. The Plan, commonly known as the "701" Plan, has been used extensively in the preparation of A Land-Use Map for the Future Development of Russellville, Arkansas (Pl. 8). Land-use categories used in the "701" Plan were adopted for use in this report and are also shown on Plate 8.

It should be understood that the land-use plan suggested herein and shown on Plate 8 is only one possible interpretation suggested by various factors that characterize the sites. Perhaps, other land-uses would fit the sites just as well, but the constraints imposed on land-use by the physical environment must always be a prime consideration in land-use planning.

## Residential Areas

Residential areas are divided into three types: low-, medium-, and high-density. Low-density residential areas are intended to provide a rural setting where building lots can be termed "acreages". These rural settings could accommodate orchards, gardens, and limited numbers of livestock in addition to residences. Medium-density residential areas can be characterized as typical suburban development areas. They are presently zoned as "R-1" residential areas, which require that building lots are not less than 10,000 sq ft. High-density residential areas may contain single-family dwellings dwellings, as well as multi-family units. These areas are presently zoned as "R-2" and "R-3" residential property. The minimum lot size for a single-family dwelling in zone "R-2" is 7,500 sq ft and, in zone "R-3", 5,000 sq ft.

### Low-Density Residential Areas

Low-density residential areas proposed for future development (not shown in "701" plan) are located on Norristown Mountain, Pleasant View Mountain, and Carrion Crow Mountain (Pl. 8). All of these areas have similar limitations. Grades are greater than 3 percent and may exceed 30 percent in some areas. Normally, development should be limited to grades which are less than 15 percent. Thin (less than 10 ft) sandy residual soils overlie the Hartshorne Sandstone within most of the areas. Commonly, sandstone bedrock is exposed in these areas and excavation could be expensive. The thinness of the soils prohibits medium- or high-density residential development where septic tanks and filter fields would be required. The thin soil will become saturated with effluents, because of both its thinness and the retarding effect that the sandstone bedrock would have on the percolation of effluents.

Another low-density residential area could be located near the Arkansas River. This region, known as the Flagg Lake area (Pl. 8), is about 9 mi (road distance) from the center of Russellville. The area is located on the Atoka Formation highlands north of the Arkansas River. The hilly character of the land prohibits its development as an industrial site. However, the excellent view of the river and of the Ouachita Mountains to the south make it a highly desirable site for development of rural homesites.

The final proposed low-density residential area is located in the Pleasant View Valley area (Pl. 8). Building conditions in this area are very similar to those on Pleasant View Mountain discussed above. The soils are fine sandy loams which tend to be less than 10 ft thick. Generally, the grades in the area are steeper than 3 percent but less than 15 percent. Some sites may have steeper grades.

### Medium-Density Residential Areas

Medium-density residential tracts are located in the South New Hope area, the area between Interstate Highway 40 and Carrion Crow Mountain (sec. 2, T7N, R20 and secs. 33, 34, and 35, T8N, R20W), and the Shiloh Creek area (secs. 21 and 28, T8N, R20W; Pl. 8).

In the South New Hope area (Pl. 8), sandy loam soils are underlain by shales, siltstones, and sandstones of the Atoka Formation. The soils should cause no extraordinary problems for residential development, except for poor drainage in areas of low slopes. The tract necessarily would be served by municipal sewage service, because the soil is only moderately well drained, and septic systems would not work well under medium-density development. Grades in the area range from 1 to 7 percent and none of the land is likely to flood. The soils are mostly thinner than 10 ft, but range from 10 to 20 ft deep where terrace or stream alluvium are present.

Soils in the area between Interstate 40 and Carrion Crow Mountain (Pl. 8) are less than 10 ft thick, and are either silty loam or fine sandy loam. Generally, they have good construction characteristics, except that they are strongly acidic. Grades range from 1 to 3 percent and should impose no limitation on development. The area is not subject to flooding, but locally drainage may be poor due to low grades.

In the Shiloh Creek area (Pl. 8) fine sandy loam residual soils less than 10 ft thick overlie the Hartshorne Sandstone. Bedrock is exposed at many localities and some foundations might be excavated in rock. Generally, the sandy soil is well drained, but its extreme thinness would make municipal sewage service essential to the development of the area. Grades may be as much as 7 percent, but this should cause minimal problems in residential development. Probability of flooding is exceedingly low, except near State Highway 7 in the vicinity of Shiloh Creek (Pl. 5).

## High-Density Residential Areas

High-density residential areas are located near the center of Russellville (Pl. 8). The thin (less than 10 ft) soils are silty loam and fine sandy loam which are either residual soils formed from the Atoka Formation or are terrace-alluvial soils. They are well-drained and have a low shrink-swell ratio. Therefore, no problems should be encountered in the construction of multifamily dwellings. A portion of the SW¼, sec. 4, T7N, R20W is in the flood plain of Prairie Creek (Pl. 5). The probability of flooding on the order of once each decade should be considered in the design of multifamily residential structures. Flood-proofing measures designed into the buildings could be very effective in lowering the amount of damage caused by the typically short-duration floods that occur along Prairie Creek. The book

"Introduction to Flood Proofing" (Sheaffer, 1967) is recommended as a guide to some of the measures which should be considered in the design of the buildings.

## Commercial Areas

Commercial development in the Russellville area encounters flooding problems in the Central Business District (Pl. 8). Several blocks of the Central Business District lie in the flood plain of Prairie Creek, as mentioned in a previous section of this report. A major segment of the land currently being redeveloped by the Russellville Urban Renewal Agency also lies in the flood plain. Projects in these areas should be carefully planned and flood-proofing devices installed as new structures are built. Soils in these areas may be poorly drained, but other soil factors important in construction are generally satisfactory.

It is suggested by the writer, that the highway commercial development pattern (as shown in the "701" plan) should be extended north along State Highway 7 (secs. 21 and 28, T8N, R20W; Pl. 8) because it would be in better agreement with current land-use in the area.

The writer disagrees with the "701" plan concerning the use of land adjacent to the Dardanelle Reservoir in the SE¼ sec. 29, T8N, R20W (Pl. 8). The "701" plan has the area marked as "flood easement", but according to data provided by the U. S. Army Corps of Engineers, flooding during a Standard Project Flood would not reach as far eastward as is shown on the "701" plan. Therefore, the area is shown on Plate 8 as commercial development, which is in agreement with current land-use.

## Industrial Areas

The major industrial areas are located south and east of the city of Russellville (Pl. 8). To be a good industrial site an area should have the following characteristics: (1) accessibility to major transportation services, (2) availability of large tracts of land, (3) adequacy of soil, drainage, and slope properties, and (4) availability of close-by housing for large numbers of workers.

Several problems in the "701" plan have been noted in regard to the location of industrial areas. The "701" plan recommends the location of an industrial area in secs. 20 and 29, T7N, R20W (Pl. 8). Portions of this land, especially along Whig Creek, are included in the area that the U. S. Army Corps of Engineers has mapped as being within the area expected to be flooded during a Standard Project Flood (Pl. 5). A portion of this area also is underlain by an alluvial soil which contains montmorillonite clay. The soil therefore has a high shrink-swell potential, which generally indicates that serious foundation problems are likely to be encountered. This soil also is poorly drained and has low permeability. In the opinion of the writer, the area marked "f" in secs. 20, 21, 29, 32, T7N, R20W should be left as agricultural land. Slope problems would be encountered in the area designated as being suited for industrial development by the "701" plan on the southwestern end of the Shinn basin (SW¼ sec. 20, T7N, R20W, and NE¼ sec. 29, T7N, R20W; Pl. 8).

Another problem has been noted in secs. 10, 14, and 15, T7N, R20W (Pl. 8). The eastern one-half of secs. 10 and 15 and the southern one-half of sec. 14 are shown in the "701" plan as being suited for low-density residential development. Several things are wrong with this proposed land-use. First, the area adjoins the Russellville Airport on two sides. This would not provide a suitable situation for future airport development, nor would it provide a very desirable residential area. Second, the area has many desirable characteristics for industrial-site development. Therefore, the area is shown on Plate 8 as an industrial tract. A portion of the southern one-half of sec. 15, T7N, R20W (Pl. 8) probably should not be developed because it is in the flood plain of Whig Creek. The writer suggests that this land should be reserved for agricultural uses.

The "701" plan proposes that land south of State Highway 7T (sec. 21, T7N, R20W) should be used for low-density residential development. This recommendation does not appear to be compatible with current land-use. The area is one of strip-mines, urban dumps, and landfills. Light industry and commercial development are already very much evident. Therefore, the writer proposes that this tract and part of the NW¼ sec. 22, T7N, R20W (Pl. 8) should be used as an extension of the industrial area discussed in the preceding paragraph.

## Undeveloped Lands

The two kinds of undeveloped lands shown on Plate 8 are agricultural lands and areas of steep slopes. Both kinds of terrain include problematic attributes that would make development hazardous, expensive, and generally unsatisfactory. Instability of steeply sloping land has been discussed in a previous section of this report. Areas designated as agricultural lands are located within the flood plain, determined by the U. S. Army Corps of Engineers to be part of the

Standard Project Flood. Periodic flooding of these areas can be beneficial to agriculture, but disastrous to other types of development. Many planning authorities also recognize that a "balanced" land-use plan should include agricultural lands and "greenbelts" for the scenic richness that they provide.

## Resource-Recovery Lands

Mineral-resource-recovery lands are located in six areas in the vicinity of Russellville (Pl. 8). Five of the areas are quarries that could produce crushed sandstone used as road-base material and concrete aggregate. These quarries can provide the area with stone adequate for future development. Another potential resource-recovery area is located in the Shinn basin (Pl. 8). The area has produced a large amount of coal. The writer estimates that about 4 million tn of coal remain to be recovered (as mentioned previously in this report). The recovery operation will require deep-mining methods that in the near future may be too expensive to be economically feasible; however this resource potential should be considered prior to commitment of the land to other uses.

## Scenic and Recreation Lands

Fortunately, Russellville is located in an area that is rich in natural beauty. Hopefully, urban development will be planned so as to preserve as much of the natural beauty of the region as possible. The following areas have been proposed as unique scenic or park areas, in addition to those shown on the "701" plan: (1) River's Bluff scenic and natural area, (2) Forty-Acre Rock scenic and natural area, and

(3) Dwight Mission park and campground (Pl. 8). The "701" plan includes Lake Dardanelle State Park, Ouita State Park, Dike View Park (not constructed), and Shiloh Park (Pl. 8), in addition to the parks located within the city limits of Russellville.

## River's Bluff Scenic and Natural Area

River's Bluff (Pl. 8) provides a magnificent view of Dardanelle Reservoir and the Ouachita Mountains to the south. Massive sandstone cliffs, deep ravines, waterfalls, and small caves make up interesting areas for hiking and nature trails. The area is rugged, and careful planning and trail layout will be necessary to minimize the danger from steep trails and vertical or overhanging cliffs.

## Forty-Acre Rock Scenic and Natural Area

The Forty-Acre Rock area (Pl. 8) combines a panoramic view of the Dardanelle Reservoir and the mountains to the south, with fascinating rock formations and beautiful vegetation. Access would necessarily be limited to trails, because of the delicate character of some of the rock formations and types of vegetation. A well designed nature trail could provide the hiker with a beautiful, educational, and interesting experience. Because Forty-Acre Rock is near an interchange on Interstate Highway 40, accessibility is no problem.

## Dwight Mission Area

The Dwight Mission area (Pl. 8) could provide good access to the north shore of the Dardanelle Reservoir. It is located between "I-40" and the reservoir; therefore, access would be no problem. The area could be developed into a campground with boat-launching facilities.

### Ouita Basin Strip-mined Area

Two strip-mined areas in the Ouita basin (Pl. 8) have been reclaimed. Shiloh Park (Pl. 8) was built on part of the reclaimed land. Two additional areas should be reclaimed. They are located in the SW¼ sec. 29, T8N, R20W and the SW¼ sec. 20, T8N, R20W (Pl. 8). These areas could provide additional lands for recreation areas as the urban population of Russellville increases.

# SUMMARY AND CONCLUSION

As Legget pointed out (1973, p. 70),

> The art of planning is no new discipline of itself but rather the skillful and effective coordination and correlation of a considerable number of individual functions, all related to the development of the urban community . . . . Geology is one of the most vital parts of the whole complex process of planning - without which the whole process is based on 'quicksand'.

As was stated at the beginning of this report, the objective of the study was to provide urban and regional planners with the kind of geologic data needed to develop land-use plans that are in harmony with the natural environment of the Russellville area.

The following is a summary and evaluation of the various maps prepared for the study.

The geologic map (Pl. 1) shows the various geologic formations that crop out in the area, and geologic structures such as folds and faults. In addition to the consolidated rock units and geologic structures, it also shows where the stream and river terraces and alluvium mask the bedrock. It outlines the basic geologic framework upon which urban development is founded and thus should be invaluable to urban planners in their analyses of the proper uses of areas.

The surficial geology map (Pl. 6) shows the positions and thicknesses of unconsolidated materials in alluvial terraces, alluvium, and colluvium and residual soil. This map should be of great value in the planning of projects requiring excavation. Excavation for foundations and basements, the laying of water, sewer, oil and gas lines, and the installation of underground electrical and communications cables could be facilitated through the use of the map. A contractor would be able to estimate the "rippability" (ease of excavation) of the material he would be required to remove. This should lead to more accurate cost estimates for construction projects.

A topographic slope map (Pl. 4) is included in the study because, in some instances, slopes are controlling factors in planning for various types of urban developments. Slopes place limitations on the kinds of buildings that can be erected, on the locations of railroads, highways, and city streets, and on areas where water and sewer lines can be located. For example, gentle slopes impose limitations on drainage whereas steep slopes are unstable. In addition, building costs soar in relationship to the steepness of the slope. Planners and builders should be made aware of the steepness of slopes and generally of the limitations that these slopes impose on the safe and economical use of the land. In this study, areas of potential landsliding have been determined by the study of aerial photographs and by on-site investigations. Field investigations led to identification of some areas of modern activity. These observations were extrapolated to delineate areas where the potential for landsliding or soil creeping seems to be great. Although these tracts are not necessarily to be condemned, they would require unusually careful geologic and engineering studies prior to development.

The correct decisions concerning the proper use of land can be made only after the consideration of all the possibilities for multiple land-use. An area that is rich in coal or building stone, stone suitable for crushing, or sand and gravel must be identified before the land is committed to other uses. If land is to have raw materials extracted from it, then plans must be made for its reclamation after completion of the mineral-extraction process. Long-term planning of this type can be made possible in the Russellville area through the use of the mineral-resources map (Pl. 2), which shows the locations of deposits of several kinds of mineral resources, including ground water, and which shows estimates of the quantities available.

Ground water is recognized as a valuable natural resource, and consideration of its availability, protection, and conservation is essential in any urban-planning process. Ground water has many desirable qualities that make it a valuable natural resource. Its temperature and quality are generally relatively constant in a given area; thus it can be very well suited for industrial applications. For homesite development beyond urban water systems, it is essential. It may even serve as a city's main water supply or at least as a standby supply for use during droughts. The protection of ground water from sewage and effluents from solid-waste landfills depends upon an understanding of the positions of the water tables, aquifers, and aquitards. The mineral-resources map shows a compilation of available information concerning the depths of water-producing zones and amounts of ground water available in the various geologic formations that crop out in the study area.

The probability of flooding in an urban area is a consideration of great importance - as was demonstrated by the recent disastrous floods at Rapid City, South Dakota, and Harrisburg, Pennsylvania. Considering Russellville's many low areas, the included flooding-potential map

(Pl. 5), showing areas likely to be flooded during expected stages on the Arkansas River and its tributaries, would be an extremely important document for urban planning. Many people feel secure in the belief that since the Dardanelle (Lock and Dam 10), Ozark (Lock and Dam 12), and Ft. Smith (Lock and Dam 13) dams have been completed, there is no longer any danger of flooding in the Arkansas River Valley. This feeling of security is not well founded. These dams were not designed to be flood-control dams. They were designed primarily to create a navigation system, which must have a specific water level for its operation; thus water levels are not maintained low enough to provide flood-storage capacity. Several of the dams also have hydroelectric generating facilities, which require fixed pool elevations for power generation. Therefore, the Arkansas River Basin upstream from the Dardanelle Dam - an area larger than 11,000 sq mi - has no reservoirs with flood-storage capacity. This fact makes a flooding-potential map one of the most essential to direction of future urban development.

A map of construction properties of soils (Pl. 7) was derived from the surficial geology map, the Pope County soil map, and soil-mechanics data. The map shows the foundation characteristics of rock and soil units that are to be encountered at the surface and in the shallow subsurface. The map includes a series of brief statements that summarize the properties of the materials that are generally important to construction projects. This map would be particularly useful to planners as they determine zoning subdivisions for such areas as industrial parks, light industry, retail business districts, and residential areas. It would serve to forewarn developers of potential problems with foundations and thus would allow them to arrive at more realistic cost estimates for projects.

A future-land-use classification map (Pl. 8) is based upon all information derived and compiled from the study of the Russellville urban area and from an evaluation of other factors such as land, historic, scenic, and recreational values. The future land-use classification map brings together all of these diverse factors and thus indicates areas that are most suitable for urban, suburban, residential, industrial, institutional, agricultural, and recreational development, and for mining and quarrying.

I believe that the information contained within this report will be of value to the Russellville Planning Commission, the Russellville Chamber of Commerce and various private corporations and citizens. It will assist them in determining the multiple-land-use plan that is most compatible with the natural setting of the area.

As Francis Bacon said almost 400 yrs ago, "Nature to be commanded must be obeyed" (quoted by Legget, 1973, p. 71).

# SELECTED REFERENCES

Arkansas Department of Planning, 1973, Atlas of Arkansas: Arkansas Department of Planning, 99 p.

Arkansas Geological Commission, 1970-73, Reports of water well construction: Arkansas Geological Commission, 117 p.

Arkansas Highway Department, 1949-69, Reports of soil tests: Arkansas Highway Department, Job Nos. 8257, 8526, 8531, and 8549.

Arkansas Power and Light Co., 1967, Russellville Nuclear Unit - preliminary safety analysis report: Arkansas Power and Light Co., v. 2, sec. 2, 71 p.

____________, 1971, Arkansas Nuclear One Unit 1 - Final safety analysis report: Arkansas Power and Light Co., v. 1, sec. 2, 22 p.

____________, 1972, Arkansas Nuclear One Unit 2 - Supplement to environmental report: Arkansas Power and Light Co., sec. 1C, 35 p.

Arkansas Tax Commission, 1972, Arkansas severance tax reports - Pope and Yell Counties: Arkansas Tax Commission.

Bedinger, M. S., Emmett, L. F., and Jeffery, H. S., 1963, Ground water potential of the alluvium of the Arkansas River between Little Rock and Fort Smith, Arkansas: U. S Geological Survey Water-supply Paper 1669-L, 27 p.

Branner, J. C., 1888, Annual report of the Geological Survey of Arkansas: Geological Survey of Arkansas, v. 1, 110 p.

Carson, M. A., and Kirkby, M. J., 1972, Hillslope - form and process: Cambridge Univ. Press, 468 p.

City Planning Division, University of Arkansas, 1969, Comprehensive report, Russellville, Arkansas: City Planning Division, Univ. of Arkansas, 77 p.

____________, 1972a, Guidelines for municipal planning in Arkansas: City Planning Division, Univ. of Arkansas, 44 p.

____________, 1972b, Guidelines for county planning in Arkansas: City Planning Division, Univ. of Arkansas, 19 p.

___________, 1972c, Guidelines for joint cooperation in area planning in Arkansas: City Planning Division, Univ. of Arkansas, 17 p.

Commercial Appeal Mid-South Magazine, 1972, Goodby West Point, hello growth center: Commercial Appeal Mid-South Magazine, Memphis, Tenn., Nov. 26, 1972, p. 20-24.

Committee on Water Well Construction, 1970, Report of water well construction: Arkansas Geological Commission.

Cooperative Extension Service, 1972, Program for developing Pope County 1972-1977: Univ. of Arkansas, Division of Agriculture, 30 p.

Cordova, R. M., 1963, Reconnaissance of the ground water resources of the Arkansas Valley region, Arkansas: U. S. Geological Survey Water Supply Paper 1669-BB, 33 p.

Courier-Democrat, 1957, City flooded by Prairie Creek: Daily Courier-Democrat, Russellville, Arkansas, Aug. 13, 1957.

___________, 1973, City to pull plug on flood insurance: Daily Courier-Democrat, Russellville, Arkansas, March 2, 1973.

Croneis, Carey, 1930, Geology of the Arkansas Paleozoic area, with special reference to oil and gas possibilities: Arkansas Geological Survey Bull. 3, 477 p.

Garver and Garver, Inc., 1970, Opportunities for development of river ports on the Arkansas River waterway system - Dardanelle - Russellville, Arkansas: Garver and Garver, Inc., 52 p.

Hahn, A. D., 1954, Summary report of minerals examination: U. S. Bureau of Mines, unpublished reports, Little Rock, Arkansas.

Halberg, H. N., 1972, Use of water in Arkansas, 1970: U. S. Geological Survey Water Resources Summary No. 7, 17 p.

Haley, B. R., 1960, Coal resources of Arkansas: U. S. Geological Survey Bull. 1072-P, p. 795-831.

___________, 1964, Geologic Maps of the Russellville east and west quadrangles: Arkansas Geological Commission, and U. S. Geological Survey, open file maps, Arkansas Geological Commission, Little Rock, Arkansas.

___________, and Hendricks, T. A., 1968, Geology of the Greenwood quadrangle Arkansas-Oklahoma: U. S. Geological Survey Prof. Paper 536-A, 15 p.

Henbest, O. J., Erinakes, D. C., and Hixson, D. H., 1969, Seismic and resistivity methods of geophysical exploration: U. S. Soil Conservation Service Technical Release No. 44, p. 2-1 to 2-76.

Hendricks, T. A., and Parks, B., 1937, Geology and mineral resources of the western part of the Arkansas coal field: U. S. Geological Survey Bull. 847-E, p. 189-224.

____________, 1950, Geology of the Fort Smith district: U. S. Geological Survey Prof. Paper 221-E, p. 67-94.

Highway Research Board, 1958, Landslides and engineering practice: Highway Research Board Special Report No. 29, 232 p.

Legget, R. F., 1973, Cities and Geology: McGraw Hill, Inc., 552 p.

Merewether, E. A., 1967, Geology of Knoxville quadrangle, Johnson and Pope Counties, Arkansas: Arkansas Geological Commission Information Circular No. 20-E, 55 p.

Merewether, E. A., and Haley, B. R., 1961, Geology of Delaware quadrangle, Logan County and vicinity, Arkansas: Arkansas Geological Commission Information Circular No. 20-A, 25 p.

____________, 1969, Geology of the Coal Hill, Hartman, and Clarksville quadrangles, Johnson County and vicinity, Arkansas: U. S. Geological Survey Prof. Paper 536-C, 27 p.

Russellville Chamber of Commerce, 1973, Russellville, Arkansas: Russellville Chamber of Commerce, 69 p.

Sheaffer, J. R., 1967, Introduction to floodproofing - an outline of principles and methods: Univ. of Chicago, Center for Urban Studies, 59 p.

Sniegocki, R. T., and Bedinger, M. S., 1969, Water for Arkansas: U. S. Geological Survey, 46 p.

Stewart, G. F., 1973, A basis for prediction of denudation and erosion in central Kansas: State Geological Survey of Kansas, open-file report, 215 p.

Stroud, R. B., Arndt, R. H., Fulkerson, F. B., and Diamond, W. G., 1969, Mineral resources and industries of Arkansas: U. S. Bureau of Mines Bull. 645, p. 335-338.

Thornbury, W. D., 1969, Principles of Geomorphology: John Wiley and Sons, 577 p.

Turk, L. J., 1970, Hydrology in the urban environment: American Geological Institute - Environmental Geology, 18 p.

U. S. Army Corps of Engineers, 1951, Geologic investigations - Dardanelle Dam and Reservoir: U. S. Army Corps of Engineers, open-file report, Little Rock District Office, 87 p.

____________, 1957, Geology and Soils: U. S. Army Corps of Engineers, Dardanelle Lock and Dam Design Memo. No. 8, 24 p.

____________, 1959, Embankment Section: U. S. Army Corps of Engineers, Dardanelle Dam Design Memo. No. 11, 17 p.

____________, 1961, Protection of Russellville: U. S. Army Corps of Engineers, Dardanelle Lock and Dam Design Memo. No. 15, 20 p.

____________, 1969, Floodplain information - Arkansas River and tributaries - Russellville - Dardanelle, Arkansas: U. S. Army Corps of Engineers, 53 p.

U. S. Geological Survey, 1959, Logs of test holes and wells, Pope County, Arkansas, T7N, R20W: U. S. Geological Survey Water Resources Branch, open-file reports, Little Rock, Arkansas.

U. S. Soil Conservation Service, 1967, Established soil series - providence series: U. S. Soil Conservation Service, 4 p.

____________, 1968a, Established soil series - Cane series: U. S. Soil Conservation Service, 4 p.

____________, 1968b, Established soil series - Guthrie series: U. S. Soil Conservation Service, 4 p.

____________, 1968c, Established soil series - Muskogee series: U. S. Soil Conservation Service, 4 p.

____________, 1969, Established soil series - Leadvale series: U. S. Soil Conservation Service, 6 p.

____________, 1970, Established soil series - Enders series: U. S. Soil Conservation Service, 4 p.

____________, 1971a, Established soil series - Barling series: U. S. Soil Conservation Service, 4 p.

____________, 1971b, Established soil series - Linker series: U. S. Soil Conservation Service, 4 p.

____________, 1971c, Established soil series - Mountainburg series: U. S. Soil Conservation Service, 4 p.

____________, 1971d, Established soil series - Perry series: U. S. Soil Conservation Service, 4 p.

____________, 1971e, Guide for interpreting engineering uses of soils: U. S. Soil Conservation Service, 77 p.

____________, 1971a, Established soil series - Cleora series: U. S. Soil Conservation Service, 4 p.

___________, 1971b, Established soil series - Pickwick series: U. S. Soil Conservation Service, 4 p.

___________, 1971c, Established soil series - Taft series: U. S. Soil Conservation Service, 4 p.

___________, 1973a, Established soil series - Allen series: U. S. Soil Conservation Service, 4 p.

___________, 1973b, Established soil series - Bruno series: U. S. Soil Conservation Service, 4 p.

___________, 1973c, Established soil series - Caspiana series: U. S. Soil Conservation Service, 4 p.

Vance, D. L., 1970, Early history of Pope County: Foreman-Payne Publishers, Malvern, Arkansas, 198 p.

Way, D. S., 1973, Terrain analysis: Dowden, Hutchinson and Ross, Inc., 392 p.

West Central Arkansas Planning and Development District, 1973, Area brief - West Central Arkansas: West Central Planning and Development District, 7 p.

Winslow, Arthur, 1888, The geology of the coal regions. A preliminary report upon a portion of the coal regions of Arkansas: Arkansas Geological Survey Annual Report for 1888, v. 3, 109 p.

# APPENDIX

## AASHO CLASSIFICATION OF SOILS AND SOIL-AGGREGATE MIXTURES FOR HIGHWAY CONSTRUCTION PURPOSES

### Description of Classification Groups

Granular Materials - Containing 35 per cent or less passing the No. 200 sieve.

Group A-1. The typical material of this group is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand and a nonplastic or feebly plastic soil binder. However, this group includes also stone fragments, gravel, coarse sand, volcanic cinders, etc. without soil binder.

Subgroup A-1-a includes those materials consisting predominantly of stone fragments or gravel, either with or without a well-graded binder of fine material.

Subgroup A-1-b includes those materials consisting predominantly of coarse sand either with or without a well-graded soil binder.

Group A-3. The typical material of this group is fine beach sand or fine desert blow sand without silty or clay fines or with a very small amount of nonplastic silt. The group includes also stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel.

Group A-2. This group includes a wide variety of "granular" materials which are border-line between the materials falling in Groups A-1 and A-3 and the silt-clay materials of Groups A-4, A-5, A-6, and A-7. It includes all materials containing 35 per cent or less passing the No. 200 sieve which cannot be classified as A-1 or A-3, due to fines content or plasticity or both, in excess of the limitations for those groups.

Subgrades A-2-4 and A-2-5 include various granular materials containing 35 per cent or less passing the No. 200 sieve and with a minus No. 40 portion having the characteristics of the A-4 and A-5 groups. These groups include such materials as gravel and coarse sand with silt contents or plasticity indexes in excess of the limitations of Group A-1, and fine sand with nonplastic silt content in excess of the limitations of Group A-3.

Subgroups A-2-6 and A-2-7 include materials similar to those described under Subgroups A-2-4 and A-2-5 except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group. The approximate combined effects of plasticity indexes in excess of 10 and percentages passing the No. 200 sieve in excess of 15 is reflected by group index values of 0 to 4.

Silt-Clay Materials - Containing more than 35 per cent passing the No. 200 sieve.

Group A-4. The typical material of this group is a nonplastic or moderately plastic silty soil usually having 75 per cent or more passing the No. 200 sieve. The group includes also mixtures of fine silty soil and up to 64 per cent of sand and gravel retained on No. 200 sieve. The group index values range from 1 to 8, with increasing percentages of coarse material being reflected by decreasing group index values.

Group A-5. The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaceous character and may be highly elastic as indicated by the high liquid limit. The group index values range from 1 to 12, with increasing values indicating the combined effect of increasing liquid limits and decreasing percentages of coarse material.

Group A-6. The typical material of this group is a plastic clay soil usually having 75 per cent or more passing the No. 200 sieve. The group includes also mixtures of fine clayey soil and up to 64 per cent of sand and gravel retained on the No. 200 sieve. Materials of this group usually have high volume change between wet and dry states. The group index values range from 1 to 16, with increasing values indicating the combined effect of increasing plasticity indexes and decreasing percentages of coarse material.

Group A-7. The typical material of this group is similar to that described under Group A-6, except that it has the high liquid limits characteristic of the A-5 group and may be elastic as well as subject to high volume change. The range of group index values is 1 to 20, with increasing values indicating the combined effect of increasing liquid limits and plasticity indexes and decreasing percentages of coarse material.

Subgroup A-7-5 includes those materials with moderate plasticity indexes in relation to liquid limit and which may be highly elastic as well as subject to considerable volume change.

Subgroup A-7-6 includes those materials with high plasticity indexes in relation to liquid limit and which are subject to extremely high volume change.

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