ENVIRONMENTAL GEOLOGY OF THE AUSTIN AREA: AN AID TO URBAN PLANNING

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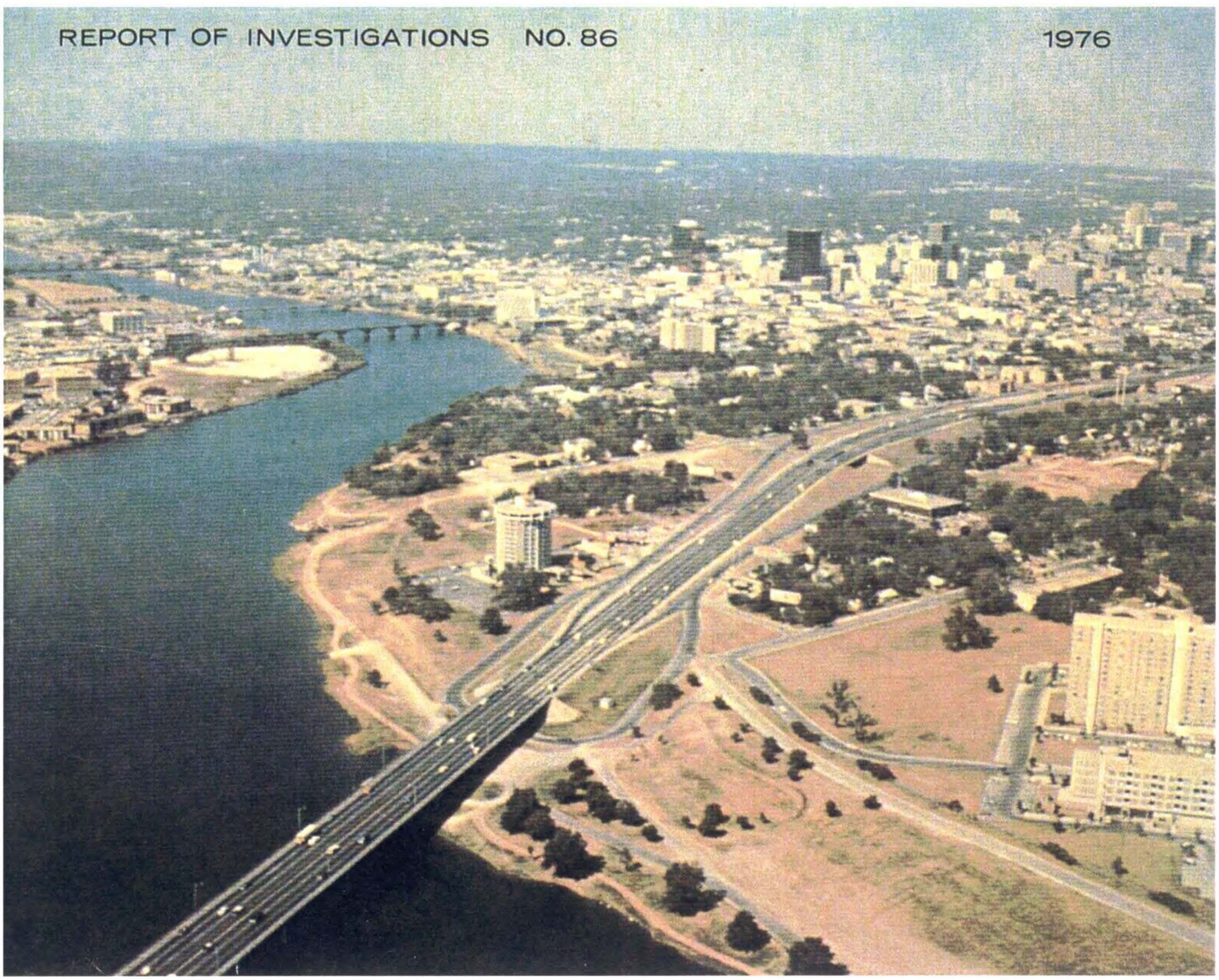

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CONTENTS

Part I: Land Resource Evaluation

Part II: Geology

FIGURES

TABLES

PLATES

ENVIRONMENTAL GEOLOGY OF THE AUSTIN AREA

An Aid to Urban Planning

L. E. GARNER[1] AND K. P. YOUNG[2]

PART I: LAND RESOURCE EVALUATION

INTRODUCTION

The conflict of urban growth with natural features and systems has prompted much interest in planning the development of metropolitan areas. People are beginning to seek a more harmonious coexistence with their environment by eliminating practices that adversely affect either natural or artificial systems and processes. One of the requisites for planning, often unavailable, is adequate data in understandable form. The aim of this publication is to supply geologic information that can be used to prevent or minimize problems that arise during urban development. A series of maps has been constructed for this purpose; the maps illustrate distribution of topographic conditions, soils, surface drainage, physical properties, rock types, land use, and vegetation.

AUSTIN

The Austin area extends from the Hill Country at the southeast margin of the Edwards Plateau across the Balcones Escarpment and onto the Blackland Prairie of Texas. Most of the city is constructed on the Blackland Prairie topographically below the Balcones Escarpment and lies entirely within the Colorado River basin at the southern end of the chain of highland lakes. In addition to being the state capitol and the county seat of Travis County, Austin has many historic attractions, recreational features, and educational institutions.

Austin is within easy reach of the Texas Coastal Zone; it is about 200 miles north of Corpus Christi and about 160 miles northwest of Houston. It is served by railways, highways, and airlines, all of which connect it to the other major metropolitan and industrial areas of Texas.

The moderate climate of the region around Austin permits outdoor activities throughout most of the year; the mean maximum temperature for July is about 95 degrees and the mean minimum temperature for January is about 41 degrees. Rainfall is about 32 inches annually and the growing season averages 270 days.

The area described in this report (fig. 1) comprises 712 square miles centered on the City of Austin. The area extends north almost to Round Rock, south to the vicinity of Buda, east to just beyond Manor, and west to about 5 miles west of Oak Hill. It includes approximately 604 square miles of Travis County, 38 square miles of Hays County, 18 square miles of Bastrop County, and 52 square miles of Williamson County.

Base maps were compiled from 7.5- and 15-minute U. S. Geological Survey topographic maps and a 1970 edition of a map of the City of Austin. Basic geologic mapping was completed on aerial photographs at a scale of 1:20,000. Supplementary maps were prepared by combining data from the basic geologic map with soils, engineering, topographic, and vegetation data. Final maps were constructed at scales of 1:62,500 (approximately 1 inch equals 1 mile) and 1:125,000 (approximately 1 inch equals 2 miles).

GROWTH

Approximately half of Austin's areal growth (fig. 2) has taken place in the past 20 years (fig. 3). This matches population growth which has also doubled in the last 20 years (fig. 4). In figure 4, projected rates of growth at 3 and 4 percent per annum are also shown. In the last few years, Austin has grown at an annual rate of nearly 4 percent;

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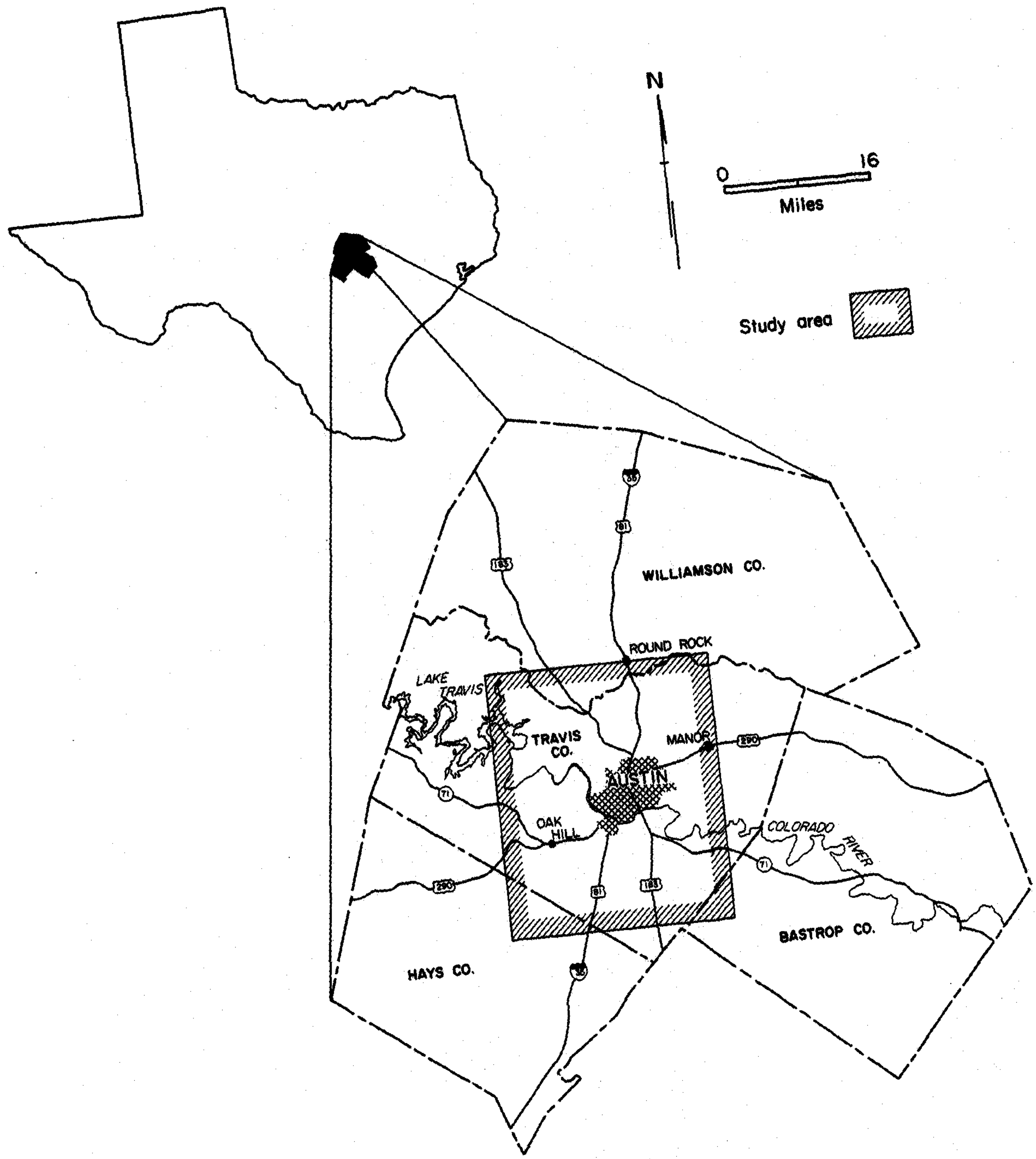

Figure 1. Index map, Travis, Williamson, Hays, and Bastrop Counties, Texas.

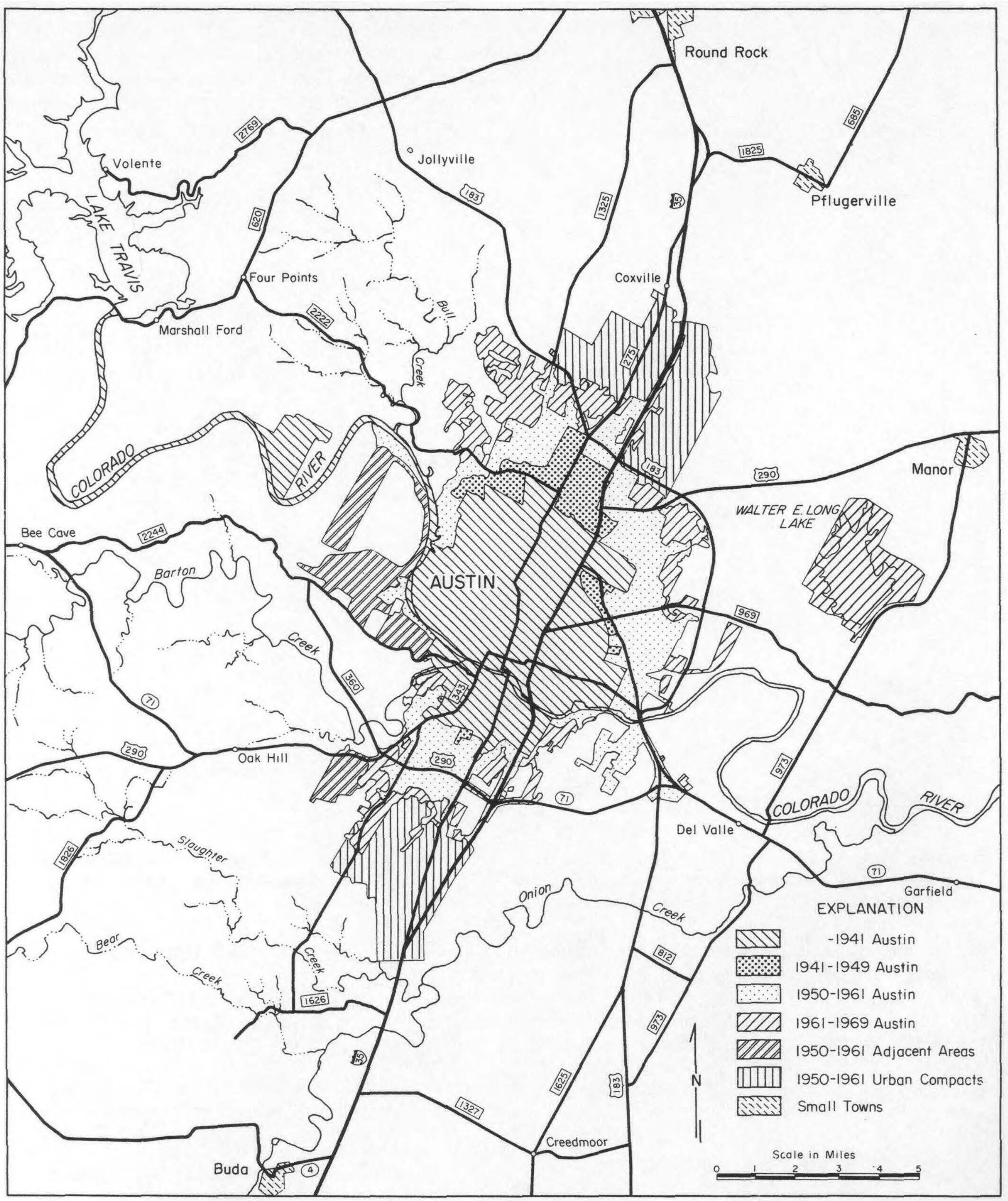

Figure 2. Areal growth of Austin from 1941 through 1969.

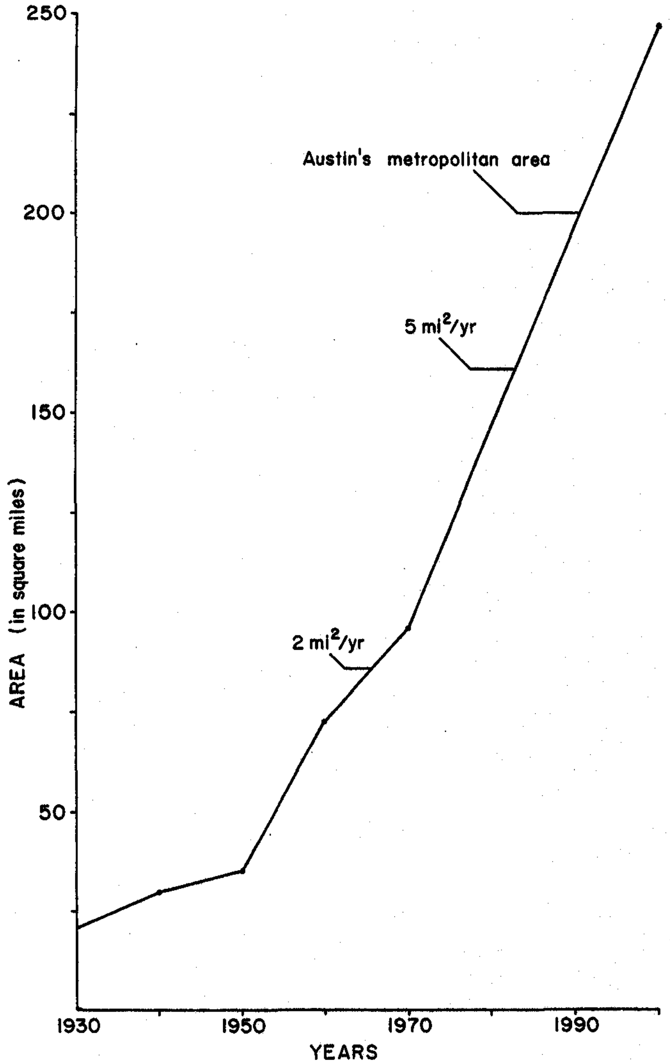

Figure 3. Rate of areal growth of Austin from 1930 through 1970, and projected growth rate from 1970 to 2000.

even if growth is slowed somewhat, its population is expected to exceed one-half million before year 2000. Interstate Highway 35 is a critical factor in the future growth of the Austin area. It forms a major transportation corridor extending from San Antonio to the Dallas-Fort Worth area and is predicted by demographers to become a giant metropolitan complex.

As Austin continues to grow, proper distribution of residential, commercial, industrial, and park areas, adequate disposal of solid and liquid wastes, and proper design of major transportation routes become more critical. Planning, based on sound land resource data, can detect or predict areas where problems are most likely to occur. Adequate adjustments based on optimum use and capability can then be made before actual development. The maps presented in this report emphasize physical features and other data that should be considered for the most effective planning.

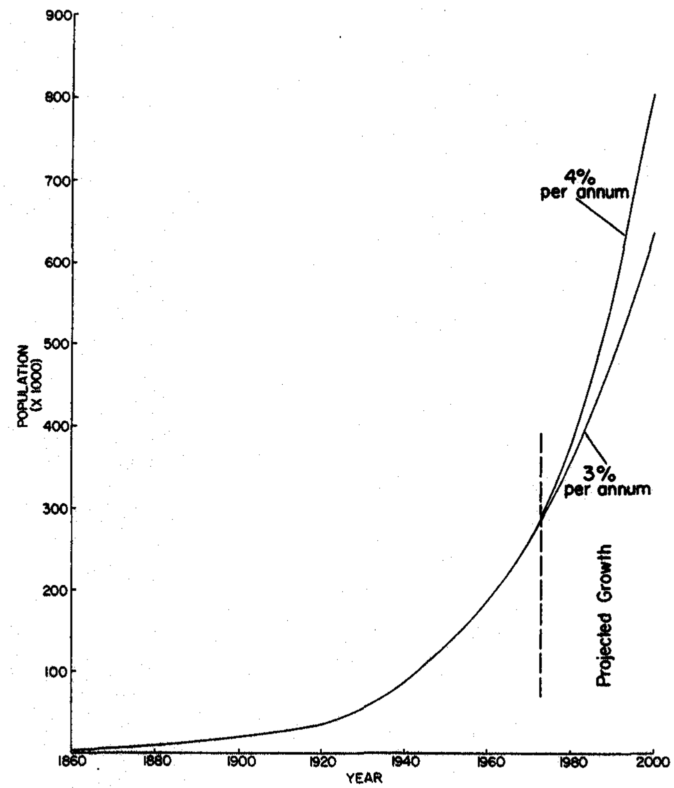

Figure 4. Population growth of Austin through 1973, and projected growths at 3 and 4 percent per annum.

ACKNOWLEDGMENTS

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Cartography was by D. F. Scranton, R. L. Dillon, D. M. Ridner, C. J. Farmer, P. D. Erickson, and S. E. Taylor; J. W. Macon supervised drafting of illustrations and cartography.

PLANNING REQUISITES

Evaluation of land use potential must be based on an inventory of the natural components of the environment. The natural components are geologic, physiographic, biologic, and hydrologic features; these include rock types, vegetation, soils, topography, stream flow, and mineral resources. The impact of development on natural features can be judged and predicted from examinations of the physical properties associated with various rock units and from the relationship of these rock units to associated features and existing land use patterns.

Land resource properties can be used to outline areas that are best suited for particular types of development, have severe limitations for other types of development, or should have development delayed. A particular advantage of this type of evaluation is recognizing problem areas prior to development rather than attempting to solve problems after development is completed.

The land resources maps (Rock Type Map of the Austin Area, Texas, plate I; Physical Properties Map, plate II; Slope Intensity Map, plate III; Soil Map, plate IV; Drainage Basins and Floodprone Areas Map, plate V; and Land Use and Natural Vegetation, Austin Area, Texas, Map, plate VI) presented in this report are designed to characterize the elements that are basic to land use planning. In the following sections, the various aspects of the natural environment are described and related to the appropriate map designations.

PHYSIOGRAPHY

The major physiographic regions of the Austin area are the Edwards Plateau, Rolling Prairie, and Blackland Prairie (fig. 5). Although the Rolling Prairie has usually been included in the Blackland Prairie, it is considered separately here because of the contrasting slope and substrate conditions. These regions are delineated primarily on the basis of topographic expression (fig. 6). Each region also contains characteristic vegetation, soil, and bedrock units, which will be discussed in subsequent sections.

The Edwards Plateau comprises approximately the northwestern one-third of the Austin area and is bounded on the east by the Balcones fault zone. This region is highly dissected by the Colorado River and its tributaries. Slopes generally range from 5 to 15 percent with slopes greater than 15 percent occurring adjacent to the Colorado River and many larger tributaries (pl. III). The Jollyville Plateau is a small, undissected portion of the Edwards Plateau, which occurs in the northwestern portion of this area.

The Rolling Prairie is developed within the Balcones fault zone, which extends in a broad northeast-trending belt across the middle of the Austin area. The major part of the City of Austin is within this zone (fig. 5). Topography of the Rolling Prairie is moderately dissected, and slopes are commonly less than 5 percent except in a few local areas (pl. III).

The Blackland Prairie is a slightly to moderately dissected area east of the Balcones fault zone. Slopes range from 2 to 5 percent with a few broad areas where slopes are less than 2 percent.

Topographic maps are used to locate and describe landscape. Each topographic contour line represents a specific elevation above sea level. The contour lines that are plotted for a local area depict the slope conditions of that area. Slope intensity is an expression of the steepness of an inclined ground surface, and values are given in percentage of slope. For example, a 0-percent slope is level, and a 2-percent slope has a vertical drop of 2 feet in a horizontal distance of 100 feet or about 106 feet per mile. The Slope Intensity Map (pl. III) was derived from topographic maps by measuring slopes in local areas and mapping similar slope conditions in the same slope intensity class. An

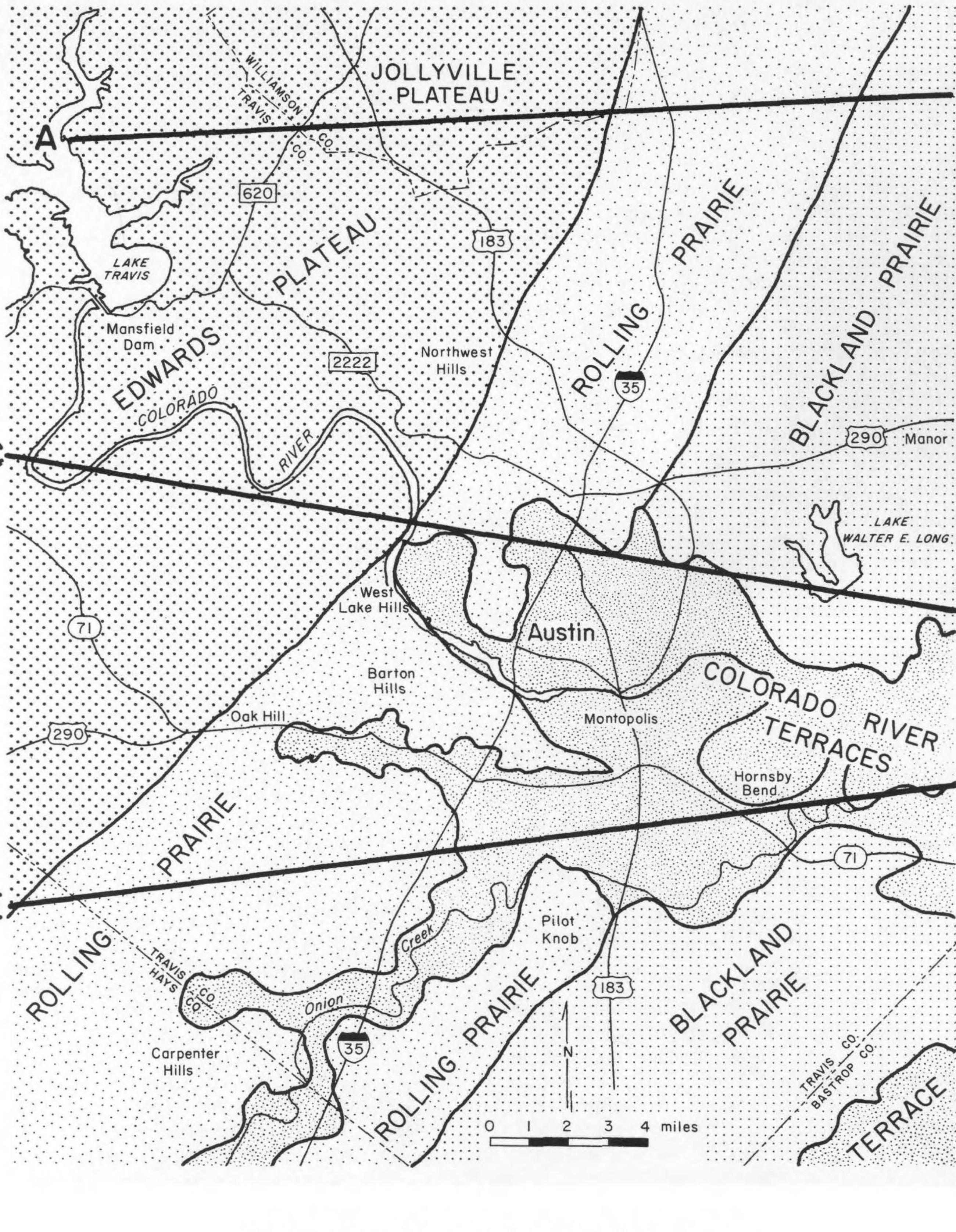


Figure 5. Physiographic subdivisions of the Austin area, Texas.

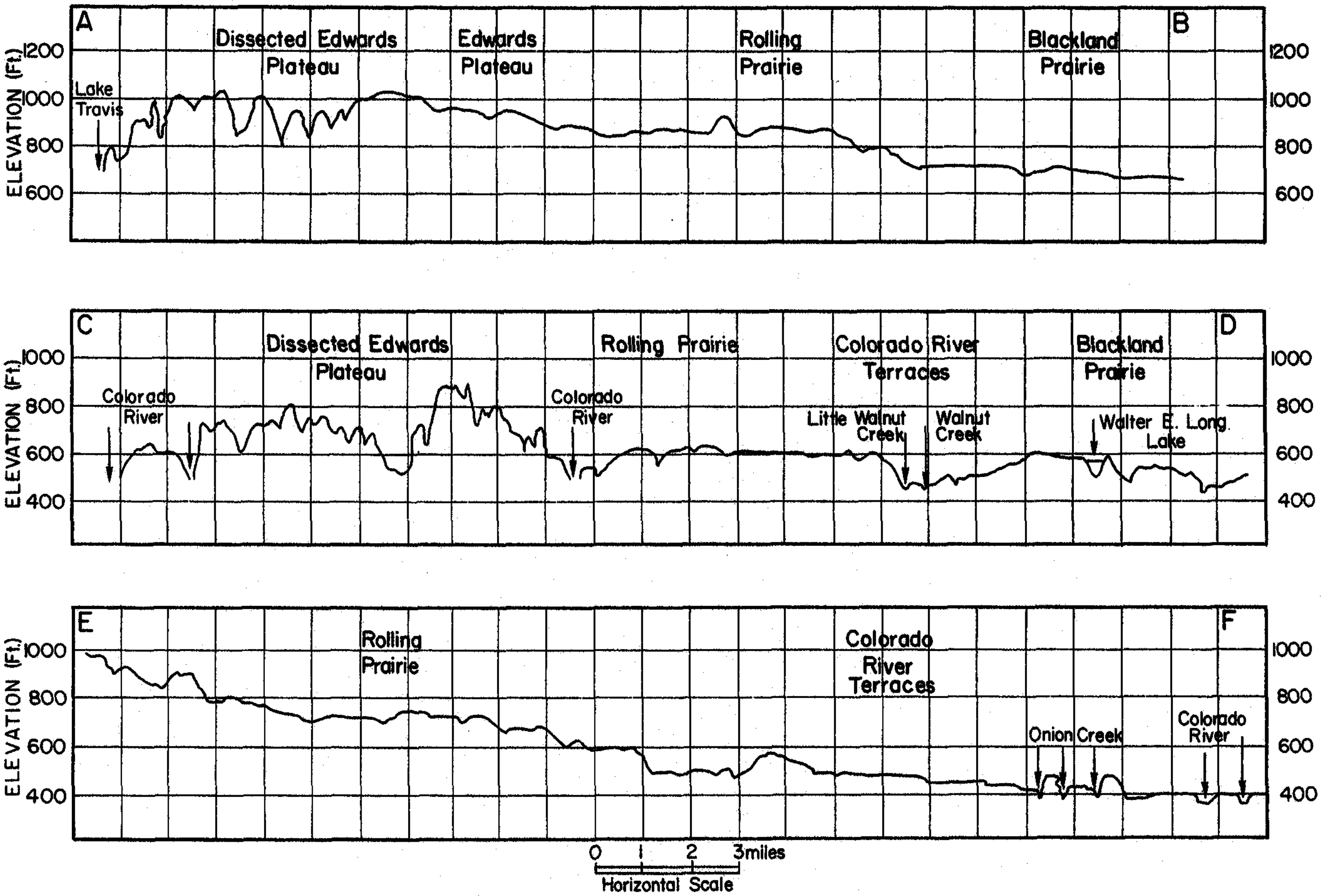


Figure 6. Profiles across Austin area from west to east comparing the topography of physiographic subdivisions in figure 5.

inventory of slope intensity units shows the following:

Slope intensity class	Percentage of Austin area
15% or greater	7
5% to 15%	22
2% to 5%	48
2% or less	23

SOILS

Soils associated with the various rock types in the Austin area (pl. IV) may be similar to the underlying rock materials. For example, clays and clay loams are developed over clay bedrock, and sandy and gravelly loams are developed over sand or gravel units. Other rock units have poorly developed or thin soils such as those over parts of the mixed limestone rock unit. Soils may also contrast with underlying rock materials such as the plastic black clay or clay loam that overlies some of the soft limestone rock unit.

Although soils in this area (table 1) are primarily related to substrate, soils northwest of the Balcones Escarpment are also strongly influenced by topography. These soils are gray-brown to tan calcareous clays and silty clays, 4 to 20 inches deep. Thick dark soils occur on relatively flat areas below steep slopes, whereas thin light soils are common on slopes and hilltops; local areas of barren rock with no soil cover are also present.

Southeast of the Balcones Escarpment there are two soil trends. One trend follows the Colorado River and its tributaries and is developed on alluvial deposits associated with the various terrace levels and floodplains (table 1; compare pls. I and IV). Soils on Colorado River terrace deposits are tan to red-brown, calcareous and noncalcareous

Table 1. Relation of soil series to physiographic regions and rock types, Austin area, Texas.

Dominant Rock Type	Dominant Physiographic Region	Soil Series*
Alluvium	Colorado River Terraces	Lincoln, Miller, Norwood, and Yahola
Alluvium	Blackland Prairie	Trinity
Alluvium	Edwards Plateau	Altoga, Frio, Lewisville, and Volente
Sand and Gravel	Colorado River Terraces	Axtell, Bergstrom, Burleson, Cheney, Dougherty, Hardeman, Heiden, Travis, and Wilson
Sand and Gravel	Rolling Prairie	Patrick and Pedernales
Clay	Blackland Prairie	Burleson, Crockett, Ferris, Houston Black, and Wilson
Soft Limestone	Rolling Prairie	Austin, Eddy, and Stephen
Hard Limestone	Rolling Prairie and Edwards Plateau	Crawford, San Saba, Speck, and Tarrant
Mixed Limestone	Edwards Plateau	Brackett, Denton, and Purves
Dolomite and Dolomitic Limestone	Edwards Plateau	Brackett, Denton, Purves, and Tarrant

*Detailed descriptions of soil series can be obtained from Soil Survey of Travis County, United States Department of Agriculture, Soil Conservation Service.

sandy loams, silty clay loams, and gravelly sands, 12 to 20 inches deep. Soils developed on tributary terrace deposits are less than 24 inches deep and include gray-brown to dark brown, calcareous, gravelly clays and silt loams. Floodplain soils are composed of dark gray to brown, calcareous silt loams, clay loams, and sandy loams, 12 to 38 inches deep.

The second soil trend occurring below the Balcones Escarpment is related to bedrock and is aligned parallel to the regional strike. Soils developed on the hard limestone near Oak Hill and southwest of Oak Hill are dark brown to reddish-brown (compare pls. I and IV) calcareous clays, clay loams, and stony clays, 4 to 20 inches deep. Bedrock is locally exposed. On the soft limestone within the Balcones fault zone, soils are dark brown to gray-brown, calcareous silty and clay loams, 7 to 60 inches deep. In the eastern part of the Austin area, soils developed over the clay formations are dark gray to olive, calcareous clays and clay loams, 12 to 36 inches deep. Gravelly clay soils are developed in areas where gravel lags overlie clay formations.

The deep, rich soils of the Blackland Prairie contrast sharply with the thin, stony, poor soils of the Edwards Plateau. The soils of the Rolling Prairie are intermediate between soils of the Blackland Prairie and soils of the Edwards Plateau in both thickness and agricultural value.

Soils of the Blackland and Rolling Prairies are thick, unstable, and tend to have low bearing strength and poor internal drainage, whereas soils of the Edwards Plateau are thin, stony, and have moderate internal drainage. Sandy alluvial soils generally have good internal drainage and low bearing strength, whereas clayey alluvial soils are unstable and have poor internal drainage.

Detailed descriptions of the soils which occur within the Austin area can be obtained from the "Soil Survey of Travis County" published by the U. S. Department of Agriculture (1974).

VEGETATION

Vegetation assemblages present in the Austin area (pl. VI) are generally associated with underlying rock types (pl. I) (Cuyler, 1930; Tharp, 1939). Assemblages are herein characterized by the dominant vegetation type that occurs within the unit. These units include the juniper-oak and oak-savannah assemblages of the Edwards Plateau hill country, the live oak-grassland assemblage of the Rolling Prairie, the grassland-mesquite assemblage of the Blackland Prairie, the elm-oak-mesquite and post oak-blackjack assemblages associated with alluvial terraces, and the bottomland assemblage located along major streams.

The juniper-oak assemblage consists primarily of juniper (mountain cedar). Spanish oak and live oak are common but are the primary woody vegetation only in areas that have been cleared of juniper for pasture improvement or in areas with sufficient moisture to allow an oak climax instead of a juniper climax. Sumac is a common small tree. This vegetation assemblage is coextensive with the mixed limestone and the dolomite and dolomitic limestone (pl. I) which compose the dissected hill country south of the Jollyville Plateau and west of the Balcones fault zone.

The oak-savannah assemblage consists of grasslands with scattered thickets of mountain live oak and scrub oak; parts of the southern area are heavily wooded with post oak and blackjack oak. Rock types associated with this vegetation assemblage are the hard limestone and dolomite and dolomitic limestone (pl. I) which crop out in the moderately dissected area west of the Balcones fault zone in the north-central part of the Austin area. The assemblage also occupies the Balcones fault zone immediately east of the main fault in the southwest part of the Austin area.

The live oak-grassland assemblage is composed of grasslands with locally abundant live oaks and junipers (mountain cedars). This assemblage is developed entirely on the soft limestones (pl. I) or chalks which are exposed in the broad northeast-southwest-trending belt across the central part of the Austin area. The assemblage may be divided into two subgroups, chalk hills and chalk prairie. Both subgroups have approximately the same types of vegetation. The chalk hills, however, are characterized by an abundance of woody vegetation, whereas the chalk prairie has broad stretches of grasslands.

The grassland-mesquite assemblage is primarily grassland prairie with scattered mesquites. This assemblage was originally developed on the clay substrates east of the Balcones fault zone (pl. I). This area is now extensively farmed and little natural vegetation remains.

An elm-oak-mesquite assemblage with a thick undergrowth of scrub vegetation occurs on remnants of high terraces overlying the clay formations in the eastern parts of the area and on limestone terraces developed along Onion Creek (pl. I).

The post oak-blackjack assemblage with a heavy scrub undergrowth occurs on the unconsolidated siliceous sand and gravel unit along the Colorado River (pl. I).

The bottomland assemblage consists of a wide variety of trees (cottonwood, sycamore, willow, pecan, ash, hackberry, and bois d'arc) and grasses. Bottomland vegetation occurs along the floodplain of the Colorado River and some of its tributaries. No vegetation occurs in areas where stream deposition is active.

DRAINAGE BASINS AND FLOODING

The Austin area lies within the drainage basin of the Colorado River and contains all or portions of the drainage basins of the major tributaries—Bull, Barton, Shoal, Waller, Boggy, Tannehill, Walnut, Onion, and Gilleland Creeks (pl. VII). Boundaries of the tributary drainage basins are shown on plate V. Reservoirs constructed on the Colorado River include Town Lake (Longhorn Dam), Lake Austin (Tom Miller Dam), and Lake Travis (Mansfield Dam) in the Austin area, with others located upstream. Town Lake and Lake Austin are low-capacity reservoirs of rather constant level; they furnish little flood control. Lake Travis and other reservoirs further upstream provide some flood control so that high water on the Colorado River is rarely a problem. However, tributary systems are often subject to flooding from local rainstorms. Austin is not protected from floodwaters resulting from rains that fall on the Colorado River drainage basin between the city and Mansfield Dam.

Drainage basins that lie totally or mostly within developed areas are more prone to flooding than those in undeveloped areas because paving and roofs of buildings prevent seepage into the ground and increase the total amount of runoff. In addition, development decreases the vegetation that normally retards runoff. These two conditions operate together to increase the total amount of water that must be drained from an area during a given time interval (Leopold, 1968). Since stream channels in urban areas evolved under natural rather than urban conditions, they are not capable of containing the increased discharge; an increased flood frequency is the result. Channel deepening and channel straightening in the upper reaches of streams also increase the rate of discharge and result in the flooding of downstream areas. Floodplain areas that are most likely to have recurrent flood problems are indicated on plate V. Shoal, Waller, Tannehill, and Boggy Creeks are the largest floodprone streams in the Austin area that lie entirely within developed areas. Other streams may produce similar hazards as a result of future development. Little can be done to prevent flooding in currently developed areas except construction of check dams and storm-water storage systems. The elimination, restriction, or special design of future construction within the flood zone, however, can reduce or eliminate property loss and damage.

PHYSICAL PROPERTIES

Physical properties used to characterize the rock types described in the following section include slope stability, shrink-swell ratio, foundation strength, excavation potential, infiltration capacity, and corrosion potential. The evaluation of physical properties is based on engineering-laboratory tests (table 2), field tests, and field observations. The ranges of data from the various engineering-laboratory tests versus depth from the ground surface are given in figures 7 through 10. Units delineated on the Physical Properties Map (pl. II) are characterized by the properties defined in this section.

Characterizations of units presented in this report should be used as a background for land use planning; they do not eliminate the need for detailed site investigations.

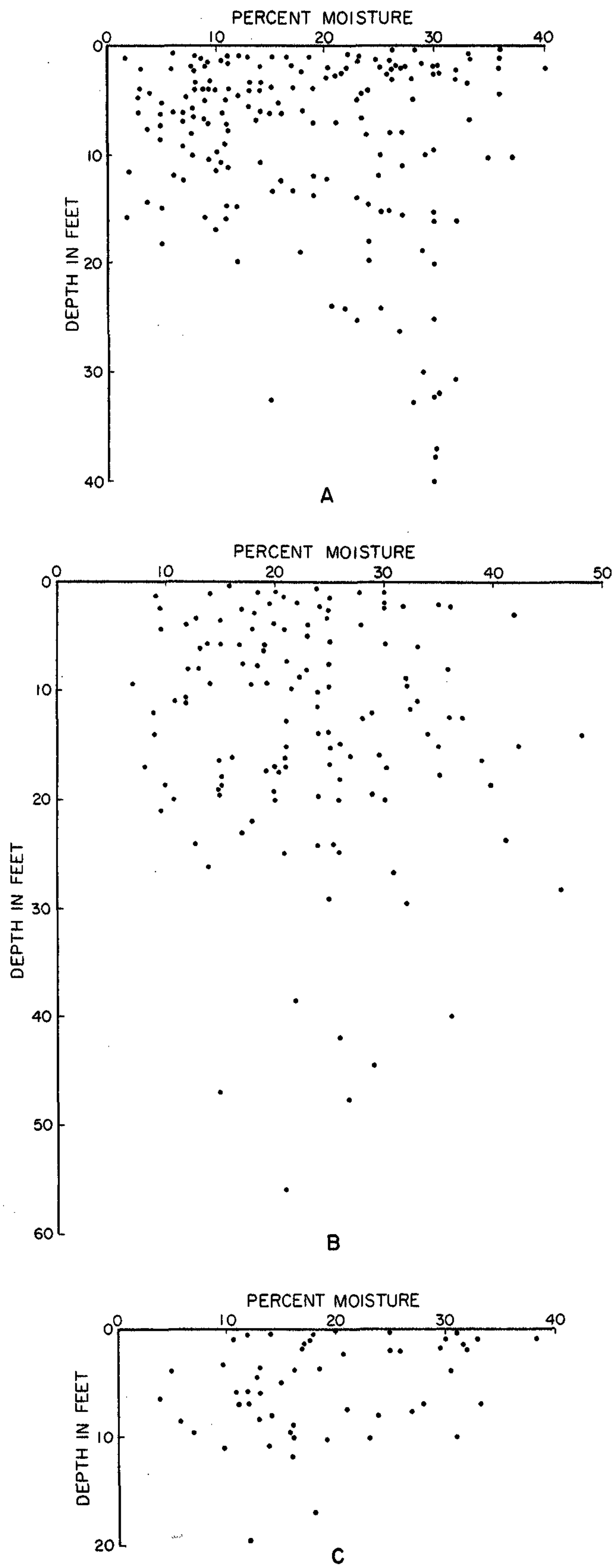
SLOPE STABILITY

Slope stability is the ability of an inclined land surface to maintain its original configuration. Landslides result from slope failure and may be rapid or slow. The most common small landslides are called slumps and are usually caused by removing the toe (fig. 11) or loading the upper

Table 2. Ranges of engineering data for rock types, Austin area.

Rock Unit	Map Symbol	Unit Weight (lb/cu.ft.)	Moisture (% by volume)	Seismic Velocity (ft/sec.)	Unconfined Compression (tons/sq.ft.)	Plasticity Index	Absorption Swell (%)	Absorption Pressure (lb/sq.ft.)
Alluvium	Ac As	81 to 123	3 to 70	1000 to 2500	0.1 to 7	4 to 60	0 to 7	2 to 6000
Sand and Gravel	Sg	81 to 123	3 to 70	1000 to 2500	0.1 to 7	4 to 40	0 to 5	2 to 4500
Clay	C	80 to 123	7 to 45	2000 to 6000	0.9 to 25	10 to 70	0.1 to 9	800 to 6600
Soft Limestone	Ls	87 to 123	10 to 30	3 to 8000	25 to 250	10 to 40	0.1 to 8	400 to 1400
Hard Limestone	Lh	x	x	6000 to 11000	60 to 420	x	x	x
Mixed Limestone (interbedded hard and soft limestone)	Lm	x	x	3000 to 11000	50 to 255	x	x	x
Dolomite and Dolomitic Limestone	D	x	x	4000 to 6000	x	x	x	x
Basalt	B	x	x	8000 to 12000	65 to 152	x	x	x
Altered Volcanic Rock	V	73 to 100	19 to 45	2000 to 5000	1 to 3	11 to 43	0 to 5	400

x data not available



edge of an existing stable slope. They may also be caused by an increase in the pore water or seepage pressure or by a decrease in cohesion that is due to gradual disintegration of the material underlying the slope. Changes in the structure of slope materials, such as fissuring of clays, also reduce slump resistance. Unconsolidated or poorly consolidated rocks are generally more prone to gravity-induced slope failure because changes in moisture content have a greater effect on the internal resistance to deformation.

In this report, rock units composed primarily of unconsolidated or moderately consolidated expansive clays are classified as having low slope stability. Expansive clays have a high shrink-swell ratio because they swell when wet and shrink when dry. Units composed of unconsolidated or moderately consolidated materials that do not have expansive properties are classed as having moderate slope stability. Consolidated materials that have a high resistance to deformation are classed as having high slope stability.

FOUNDATION STRENGTH

Foundation strength as used in this report is the ability of a material to support a structure without deforming. Estimates of the suitability of rock types for building foundations or other supports are based on the requirements of conventional designs for large and moderately large structures (for example, multistory buildings, bridges, and overpasses).

Rocks classed as having high foundation strength have high bearing capacities and require only conventional foundation design for large structures. Unconfined compression tests on these rocks commonly show support strengths greater than 50 tons per square foot. Rocks classed as having moderate foundation strength have moderate bearing capacities, can support between 10 and 50 tons per square foot, and may require special design for large structures. Units with low foundation strength have low bearing capacities, can support less than 10 tons per square foot, and usually require special design for smaller structures.

Figure 7 (left). Range of natural moisture contents for (A) Sand and gravel deposits, (B) Clay, and (C) Soft limestone in the Austin area; correlated with depth from surface.

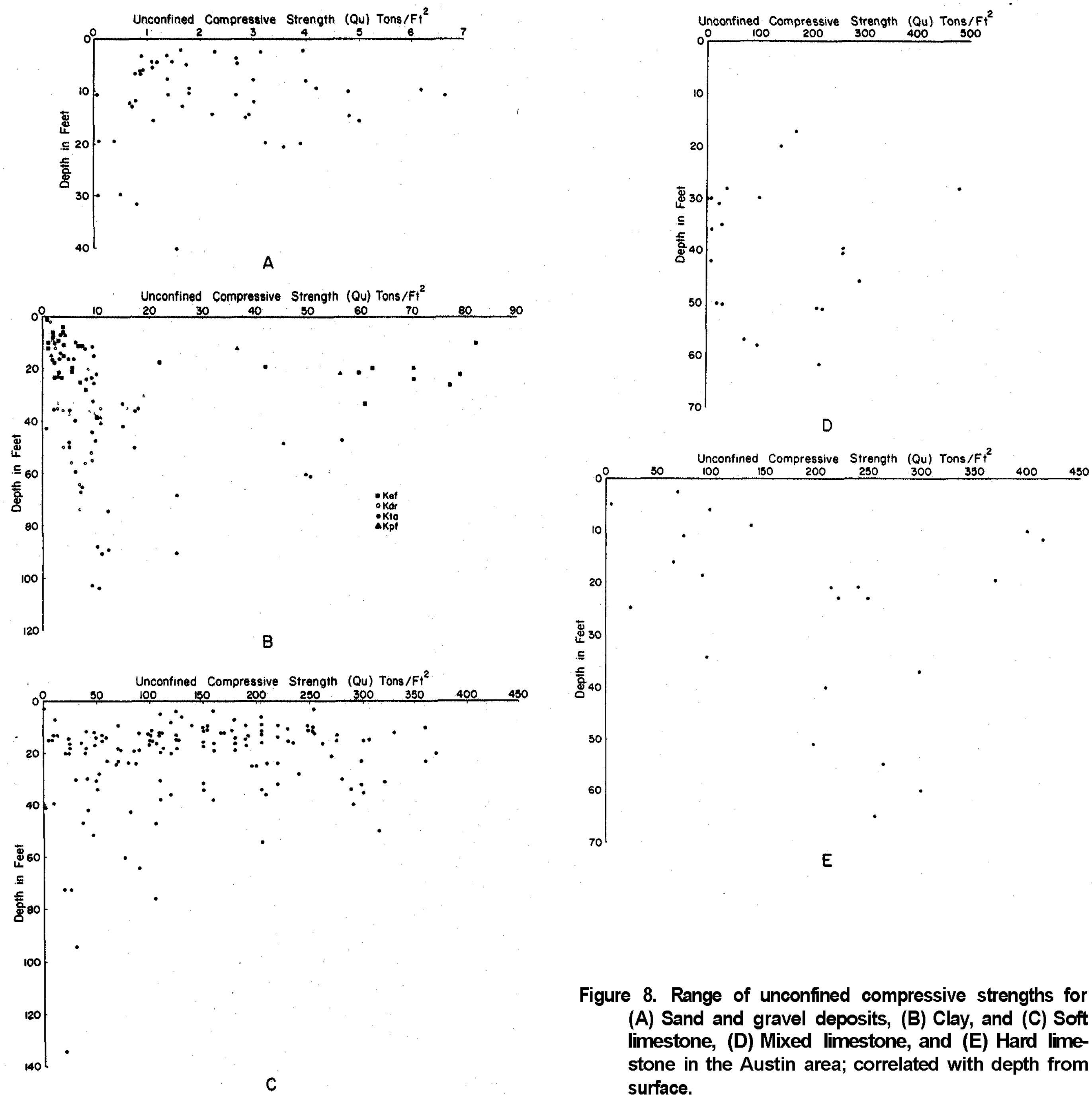


Figure 8. Range of unconfined compressive strengths for (A) Sand and gravel deposits, (B) Clay, and (C) Soft limestone, (D) Mixed limestone, and (E) Hard limestone in the Austin area; correlated with depth from surface.

Expansive properties of predominantly clay units should be considered in all types of construction. Pressures in excess of 7,000 pounds per square foot may result from the swelling of some clays. Construction design of structures in units with moderate and highly expansive clays should provide for adequate drainage to prevent the accumulation of excess water.

EXCAVATION POTENTIAL

The relative ease with which a rock may be excavated is termed excavation potential. This factor is determined primarily by the degree of consolidation or cementation of the rock material. The excavation potential of rock materials should be considered in planning buildings with basements

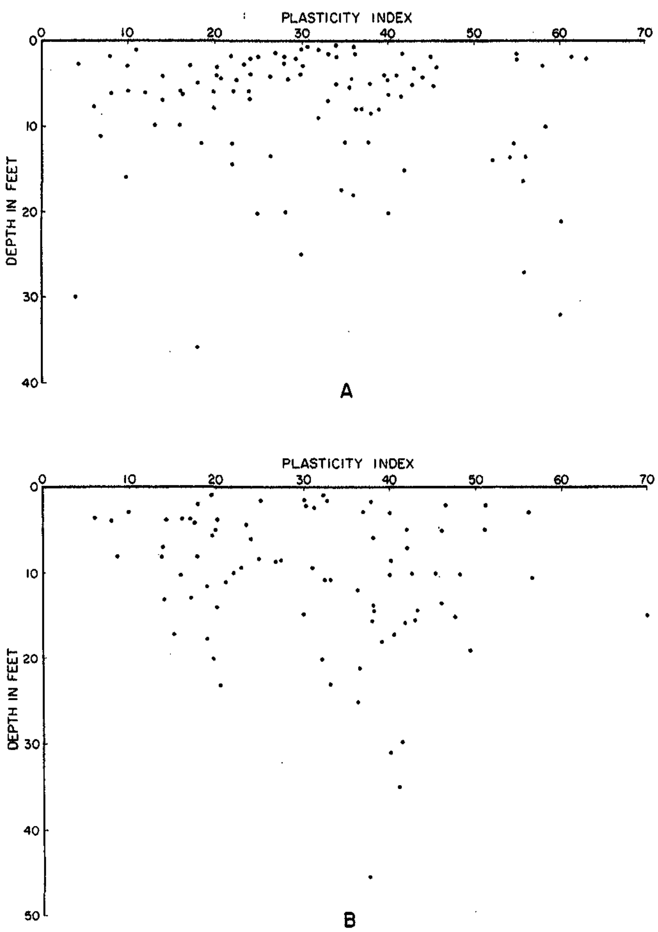


Figure 9. Range of plasticity for (A) Sand and gravel deposits and (B) Clay in the Austin area; correlated with depth from surface.

or other substructures and in designing routes of pipelines, underground utilities, sewage and water lines, or streets.

A rippability chart was developed by the Caterpillar Tractor Company; it shows the relative ease of excavation (rippable, marginal, and non-rippable) for various types of rock, based on the velocity of transmission of seismic waves. The chart was developed using a Caterpillar D-9 with mounted hydraulic No. 9 ripper and a Soil Test MD-1 Refraction Seismograph. Figure 12 is a modified form of this chart for rock types that occur in the Austin area.

INFILTRATION CAPACITY

Infiltration capacity is the ability of a material to absorb and disperse fluids. Units with high infiltration capacity are capable of providing adequate drainage of fluids at all times. Units with moderate infiltration capacity generally provide adequate drainage, except during extended wet periods, when they may become saturated. Units with low infiltration capacity do not generally absorb fluids adequately.

CORROSION POTENTIAL

Corrosion of buried metals, such as pipelines, is the result of an electrochemical reaction. Electrochemical corrosion results from a potential difference between two points that are electrically connected. This set of conditions constitutes a battery or corrosion cell in which ions are carried by electrical current from the negative pole (cathode) and deposited at the positive pole (anode). Corroded areas on pipelines are the anode of the corrosion cell. The use of different metals connected together without an insulator or a single type of metal buried in two or more kinds of rock or soil will produce a corrosion cell.

The character of the rock and soil units in which pipelines are buried determines the nature of the electrical connection between the pipe and corrosive units. Factors that determine the nature of the electrical connection and therefore the corrosivity of rock and soil units are composition, permeability, moisture content, oxygen concentration (aeration), acidity (pH), and bacterial content.

The resistivity (resistance to the flow of electric current) of a rock or soil depends on many of the same factors that are related to corrosion; thus corrosion potential of various rocks may be estimated from resistivity measurements. A modification of corrosivity groupings according to resistivity measurements (Romanoff, 1957, table 99) is used in this report. Table 3 shows the corrosion categories and their respective resistivity ranges.

ROCK TYPES

Thirty-four bedrock units (formations and members) and eight alluvial units (terraces and other alluvial deposits) have been differentiated in the Austin area (table 7). Examination of the rock types and comparison of their physical properties have resulted in the delineation of 10 basic rock types. Table 4 shows the geologic units that have been grouped into each rock type; individual formations and members are described only when included in separate rock type units.

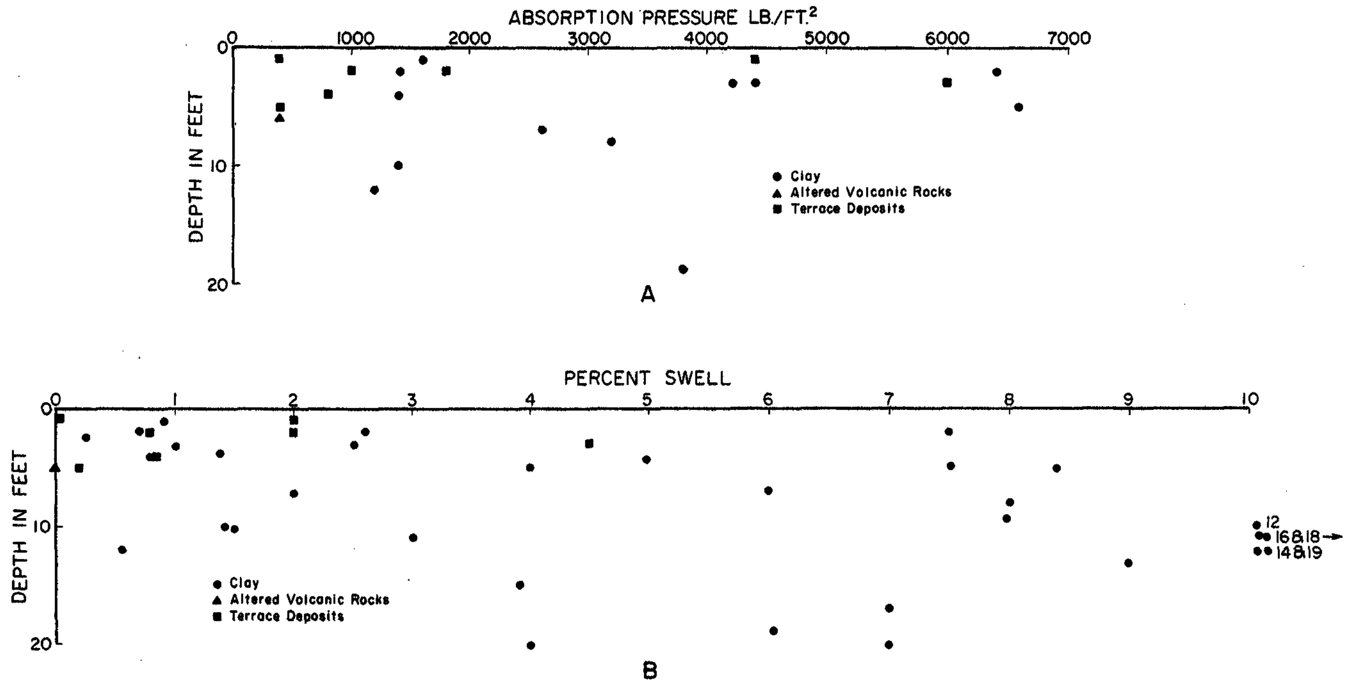


Figure 10. Range of absorption pressure and absorption swell values for clays in the Austin area, correlated with depth from soil surface.

Rock types shown on plate I include hard limestone, soft limestone, mixed limestone, dolomite and dolomitic limestone, clay, basalt, altered volcanic rock, sand and gravel, clayey alluvium, and sandy alluvium. These rock types are discussed in the following pages. Characteristic vegetation, soils, and topography are included in table 5. Evaluations of units presented in this report should be used as a background for land use planning; they do not eliminate the need for detailed site investigations.

HARD LIMESTONE

Hard limestones are generally fine to medium grained and thin to thick bedded. Beds of slightly nodular limestone and marly limestone occur within the hard limestone sequence but are too thin to be delineated at the scale of the map. Hard limestone accounts for about 10 percent of the map area. West of the Balcones fault zone, hard limestone crops out in the highly dissected hill country south of the Colorado River, along the southern margin of the Jollyville Plateau, and in the northwest part of Austin. East of the Edwards Plateau, hard limestone is exposed in a broad, moderately dissected area southwest of Oak Hill, in small fault blocks along Barton Creek, and in the western part of the City of Austin.

Exposures of the hard limestone unit can be seen in the road cuts just west of Tom Miller Dam. Here one can observe examples of the fractured and cavernous zones which occur in this unit. The thin soils developed on the hard limestones may be observed in the vicinity of Oak Hill and McNeil, where bedrock protrudes through the soil zone in many places.

Land use.—Most of the hard limestone is exposed in rural sections of the Austin area, and current construction consists primarily of single-unit residences and small commercial buildings. Although single-unit residential development is still dominant, high-density residential complexes and office developments are being planned and are presently constructed on parts of the hard limestone area.

Evaluation.—Foundation strength and slope stability of this rock unit does not limit the type of construction. However, blasting is commonly required for excavations. Corrosion of metal pipelines is generally moderate.

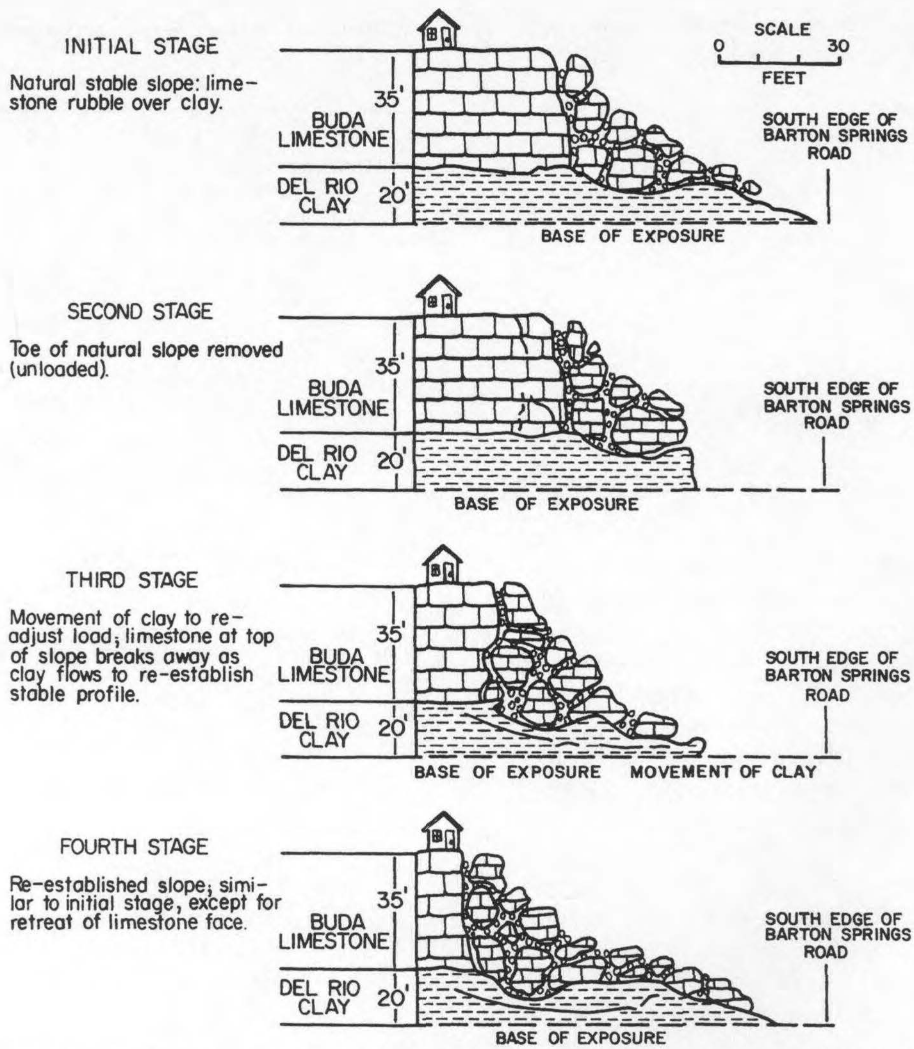


Figure 11. Behavior of the Del Rio clay underlying the Buda limestone when a natural slope is disturbed (modified from Flawn, 1970).

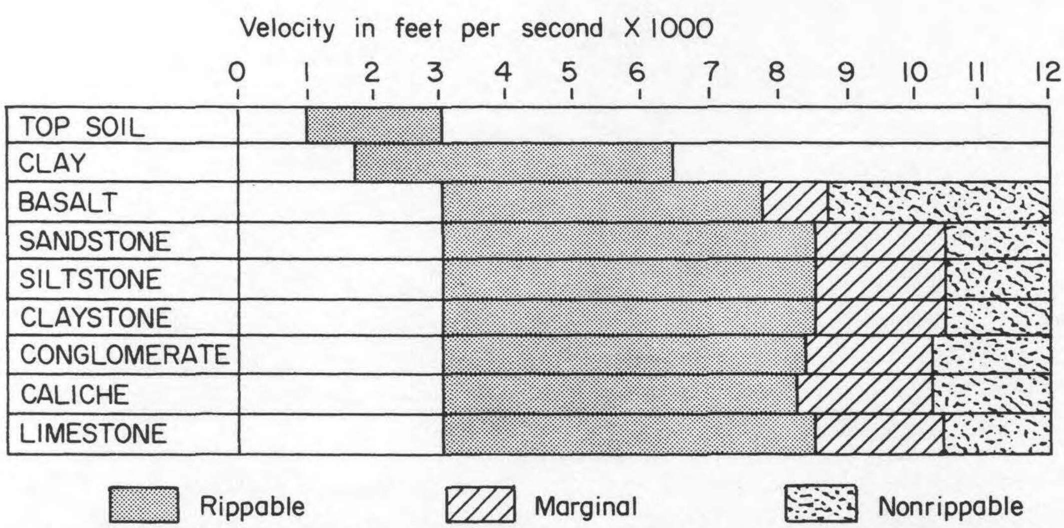


Figure 12. Relationship between seismic velocity and rippability (modified after Wylie, 1969).

Table 3. Arbitrary ranges of corrosivity with respect to resistivity (modified after Romanoff, 1957).

Corrosion Potential This Report	Corrosion Potential Romanoff	Resistivity Ohm-cm
Low	Very Low	>10,000
	Low	5000 to 9999
Moderate	Moderate	2000 to 4999
High	High	1000 to 1999
	Very High	<1000

The installation of septic-tank systems in this unit may be limited for several reasons. Thin soils that commonly occur on this rock type may be inadequate for absorption and dispersal of effluents because, in many areas, the substrate material is dense and impervious to fluids. In this case, evapotranspiration must remove all fluids from the system; during wet seasons, when evapotranspiration is low, improperly designed filter fields may overflow. In other parts of this unit where cavernous or fractured zones occur, infiltration of effluents is adequate. However, since the subsurface portion of this unit is an aquifer, unfiltered fluids may be transmitted via these cavernous and fracture zones into the ground water. Extreme care should be taken during site investigations to insure that areas where fluids may seep into ground-water systems are avoided.

SOFT LIMESTONE

Soft limestone, composing almost 14 percent of the Austin area, is composed mostly of light gray to white and tan, thin- to thick-bedded, fine-grained chalk, marl, and marly limestone. An extensive zone of chalk occurs in a broad northeast-trending belt across the central part of the area. The thickness of chalk in this zone is about 350 feet. A hard limestone bed (about 25 feet thick) occurs within the chalk sequence. West of the Balcones fault zone, beds of marl and marly limestone (15 to 30 feet thick) crop out in narrow bands on the high hills south of the Colorado River and around the southern margins of the Jollyville Plateau. A marl unit about 4 feet thick is exposed along Buttercup Creek in the northwestern part of the area. Soft limestone exposed along Onion Creek in the vicinity of Pilot Knob consists of beds of white, shelly limestone and coquina interbedded with altered volcanic rocks.

Table 4. Correlation of rock types and geologic units.

Rock Type	Map Symbol	Geologic Units*
Sandy Alluvium	As	Colorado River alluvium and tributary alluvium in limestone areas
Clayey Alluvium	Ac	Tributary alluvium in clay areas
Sand and Gravel	Sg	Colorado River, tributary, and high terrace deposits
Clay	C	Midway Group, Navarro Group, Taylor Group, Eagle Ford Formation, and Del Rio Formation
Soft Limestone	Ls	Austin Group, Walnut Formation (Keys Valley and Bee Cave members), and Comanche Peak Formation
Hard Limestone	Lh	Edwards Formation (members 2, 3, and 4 south of the Colorado River and members 1 and 2 north of the Colorado River), Buda Formation, and Walnut Formation (Bull Creek, Cedar Park, and Whitestone members)
Mixed Limestone	Lm	Georgetown Formation and Glen Rose Formation (members 1, 2, and 4)
Dolomite and Dolomitic Limestone	D	Edwards Formation (member 1 south of the Colorado River and member 3 north of the Colorado River) and Glen Rose Formation (members 3 and 5)
Basalt	B	Pilot Knob basalt
Altered Volcanic Rock	V	Pilot Knob tuff

*Descriptions of geologic units are given in Part II and table 7.

Topography varies from moderately dissected in chalk areas to highly dissected in some areas where marl and marly limestone are the primary substrates.

Exposures of chalks in the soft limestone unit can be seen along Walnut Creek near its intersection with I. H. 35. Examples of the thick soils

Table 5. Physical properties of rock types, Austin area.

Rock Unit	Map Symbol	Slope Stability	Excavation Potential	Foundation Strength	Infiltration Capacity	Rock and Mineral Resources	Corrosion Potential	Soils	Characteristic Vegetation	Topography
Sandy Alluvium	As	Moderate to Low	Low	Moderate	High	Sources of sand and gravel	Moderate	Red-brown to gray sandy loam and gravelly sand	Cottonwood, sycamore, willow, ash, pecan, bois d'arc	Broad, flat floodplain
Clayey Alluvium	Ac	Low	Low	Moderate to Low	Moderate	Sources of sand and gravel	High	Gray clay and clay loam, calcareous		
Sand and Gravel	Sg	Moderate	Low	Moderate	High	Sources of sand and gravel	Moderate to High	Red-brown and brown sandy loam and gravelly sand less than 20 inches deep	Post oak and blackjack oak, elm dominant on many tributary deposits	Broad, flat terraces, upper levels are dissected
Clay	C	Low to Moderate	Low to Moderate (local thin limestones and sandstones may require ripping)	Low	Low	Cement raw material	High	Brown, dark gray, and olive calcareous clays and clay loams, 12 to 36 inches deep	Grasses and mesquite trees	Rolling prairies
Soft Limestone	Ls	High to Moderate	Moderate to High (generally can be ripped with heavy equipment)	High	Low to Moderate	Cement raw material	Moderate to Low	Dark brown to gray-brown, calcareous silty loams, 7 to 60 inches deep	Oak, juniper	Moderately dissected
Hard Limestone	Lh	High	Very High (generally requires blasting)	High	Low to High	Crushed aggregate	Moderate	Dark brown to red-brown, calcareous clay loams and stony clays, less than 20 inches deep; locally absent	Oak, juniper	Moderately dissected
Mixed Limestone	Lm	High to Moderate	Moderate to Very High (some beds may be ripped, some will require blasting)	High	Low to Moderate	Minor source of road material	Moderate to High	Dark brown to gray-brown, calcareous silty clays; clay loams and stony clays less than 20 inches deep; locally absent	Juniper, oak	Moderately to deeply dissected, stairstep topography
Dolomite and Dolomitic Limestone	D	High to Moderate	Moderate to High	High	Moderate to High	Minor and major aquifers	Moderate to High	Red-brown and brown, calcareous clays and stony clays, less than 20 inches deep; locally absent	Oak, juniper, hackberry, persimmon	Moderately to deeply dissected, stairstep topography locally
Basalt	B	High	Very High (blasting required)	Very High	Low	Crushed aggregate Soil conditioner	Moderate	Dark brown non-calcareous clay with basalt rock fragments	Grasses	Too local for characterization
Altered Volcanic Rock	V	Moderate to Low	Moderate	Low	Low	None	High	Dark brown non-calcareous clay, 12 to 30 inches deep	Grasses and mesquite trees	Too local for characterization

which occur locally on this unit can be observed in the vicinity of Pflugerville. Just south of Walnut Creek and about three-fourths mile east of I. H. 35 is an area where a perched water table occurs in the chalk.

Land use.—Most of Austin is constructed on soft limestone. A wide variety of structures from single residences to multistory commercial buildings and industrial sites are located on this rock type. A large area of potential development northeast of Austin and within the Balcones fault zone is underlain by this rock type.

Evaluation.—Foundation strength and slope stability of this unit do not generally limit construction types. However, thick, expansive clay soils are developed on this unit in many areas. Structures placed in these areas may require special foundation design. Hard limestone beds also occur locally and may require blasting for excavations. Although the chalks in this unit are generally moderately permeable, the occurrence of perched water tables, hard impermeable limestone beds, and thick impermeable soils may limit the installation of septic-tank systems in many areas.

MIXED LIMESTONE

Mixed limestone is mostly gray to tan, thin- to thick-bedded, fine- to medium-grained, hard limestone interbedded with soft marly limestone, marl, and nodular limestone. Individual limestone beds are too thin to be mapped separately. Mixed limestone is exposed in the dissected topography west of the Balcones fault zone in the vicinity of Lake Austin and Lake Travis. It also occurs in fault blocks in the Balcones fault zone, primarily in the western part of Austin and in the areas between Barton Creek and the Colorado River.

The alternating hard limestones and marls characteristic of this unit can be observed in the terraced or stairstep topography just south of Barton Creek and east of Texas Highway 71. Barren rock outcroppings can be seen amidst areas with thin soils. A thick exposure of this unit is present in the road cut on the west side of Cat Mountain just east of Bull Creek.

Land use.—Minor amounts of mixed limestone occur within residential areas in the western part of Austin. As Austin grows westward, areas underlain by this rock type will undergo more and more development. The major part of the area where this unit occurs is presently rural; the structures are residences and small commercial buildings.

Evaluation.—Foundation strength and slope stability of this rock type do not restrict construction. Steep slopes and thin soils are characteristic of mixed limestone terranes rendering these areas unsatisfactory for high-density septic-tank installations. The thin soils, where present, have too few bacteria for proper oxidation and neutralization of effluents. Furthermore, the relatively thin, porous beds are quickly saturated allowing excess fluids to migrate along bedding planes and seep out at the surface along hillsides. The rapid movement of water through this unit is illustrated by the occurrence of springs along outcrops shortly after rains. Structures placed in areas where natural seeps occur should provide for adequate drainage.

DOLOMITE AND DOLOMITIC LIMESTONE

Dolomite and dolomitic limestone are thin to medium bedded, grayish brown to gray, and porous. They compose more than 10 percent of the area. Alternating beds of gray to tan limestone and marly limestone occur in some areas. Dolomite and dolomitic limestone are exposed primarily west of the Balcones fault zone in the highly dissected areas north and south of the Colorado River. This rock type forms part of the surface of the Jollyville Plateau and much of the broad, rolling topography north of that area. Local exposures of dolomite occur along Barton Creek and Little Bee Creek within the Balcones fault zone. One of the most extensive areas covered by this unit south of the Colorado River occurs west of Oak Hill, where exposures in road cuts of U. S. Highway 290 can be observed.

Land use.—Structures currently constructed on this rock type are single-unit residences and small commercial buildings. The major portion of this unit occurs in rural areas.

Evaluation.—The physical properties of dolomite and dolomitic limestone do not impose any limitations for construction. In many cases, however, the high permeability of some beds and the thin soils cause severe limitations for installation of high-density septic-tank systems. Conditions for septic-tank systems present in this unit are similar to those discussed in the section on mixed limestone.

CLAY

Clay units, composing about 28 percent of the Austin area, are composed primarily of dark olive to greenish-gray, tan, and bluish-gray, calcareous, thick-bedded clays. The clay-sized fraction (less than 2 microns) composes about 55 percent of the total unit. The remainder of the unit is mostly silt-sized carbonate material. Clay units contain about 50 percent clay minerals (montmorillonite, kaolinite, and illite); however, the distribution of clay mineral types is variable (see description of geologic formations in Part II). Locally some of the clay units contain thin, calcareous sandstone and marl beds that are not mapped separately.

Clay rock types are mostly extensive in the area east of the Balcones fault zone, where the total thickness ranges from 650 to 800 feet. Isolated areas of clay (35 to 70 feet thick) are exposed in fault blocks within the Balcones fault zone. North of the Colorado River, these rocks are exposed in the rolling hills east of McNeil and along Shoal Creek and Missouri-Pacific Railroad. South of the Colorado River, clays crop out within the fault zone in the area west of South Lamar Boulevard, in the vicinity of Sunset Valley, and intermittently southwestward to the Carpenter Hills area.

Slope failure of clay formations in the Austin area is a common occurrence. One can observe the effects of unstable clays in areas adjacent to Barton Creek and along Shoal Creek where natural slopes are continually moving. In the last 20 years several large blocks of hard limestone have slumped down the west bank of Shoal Creek just south of 29th Street; these slumps are gravity induced when the underlying unstable clays fail.

The greatest thickness of unstable clay in the Austin area lies east of the Balcones fault zone, where formations of the Taylor and Navarro Groups occur. Plots of some physical properties for parts of the Taylor formations (fig. 13) show that there is direct variation of cohesion, liquid limit, and plastic limit with natural moisture content and an indirect variation with calcium carbonate content. In the area between Walter E. Long Lake and Walnut Creek, many old landslides with their hummocky topography can be observed. Concave-upward joint planes filled with layers of calcite or selenite (a crystal form of gypsum) are characteristic of clay formations. These filled, concave joints are former slide surfaces and illustrate the instability of this rock type. Large slide surfaces, 20 to 100 feet long, could be seen in the fresh cuts exposed during construction of the dam for Walter E. Long Lake.

Land use.—In the area underlain by the clay rock type, structures range from single-unit residences to commercial and industrial buildings. Much of this area is rural and is used as cropland.

Evaluation.—Clay materials composing this unit generally have low slope stability and low foundation strength. Clays are generally unstable even on moderate slopes. Therefore, limitations for construction on slopes are severe, and special foundation design is required for most structures. Natural slopes should be preserved where possible. In addition to adequate foundation design, areas around foundations should be well drained to prevent moisture accumulation and swelling of the clay. The low infiltration capacity of the clay units causes severe limitations for the installation of septic-tank systems. However, the low infiltration capacity is desirable for solid-waste disposal sites because leachate is not transmitted to aquifer systems. Corrosion of unprotected metal pipelines is generally high in this unit.

ALLUVIAL MATERIALS

Alluvial deposits associated with the Colorado River and its tributaries compose about 20 percent of the area and consist of sand and gravel, clayey alluvium, and sandy alluvium rock types. These units occur in terraces that are generally flat or slightly undulating; some of the higher level terraces are dissected. Average thickness of the alluvial materials is about 30 feet, ranging from less than 10 feet to about 60 feet (fig. 14).

Sand and gravel deposits of the Colorado River are unconsolidated and locally contain lenses of sandy clay. Gravel-sized material is composed mostly of chert, limestone, and quartz with minor amounts of igneous and metamorphic rock fragments. High-level deposits of the Colorado River (50 feet or more above present river level) generally have higher proportions of gravel-sized material than lower deposits. Exposures of low-level deposits generally consist of sand, silt, and clay and contain mostly limestone gravels in the basal (unexposed) parts. Sand and gravel deposits of tributaries of the Colorado River are composed

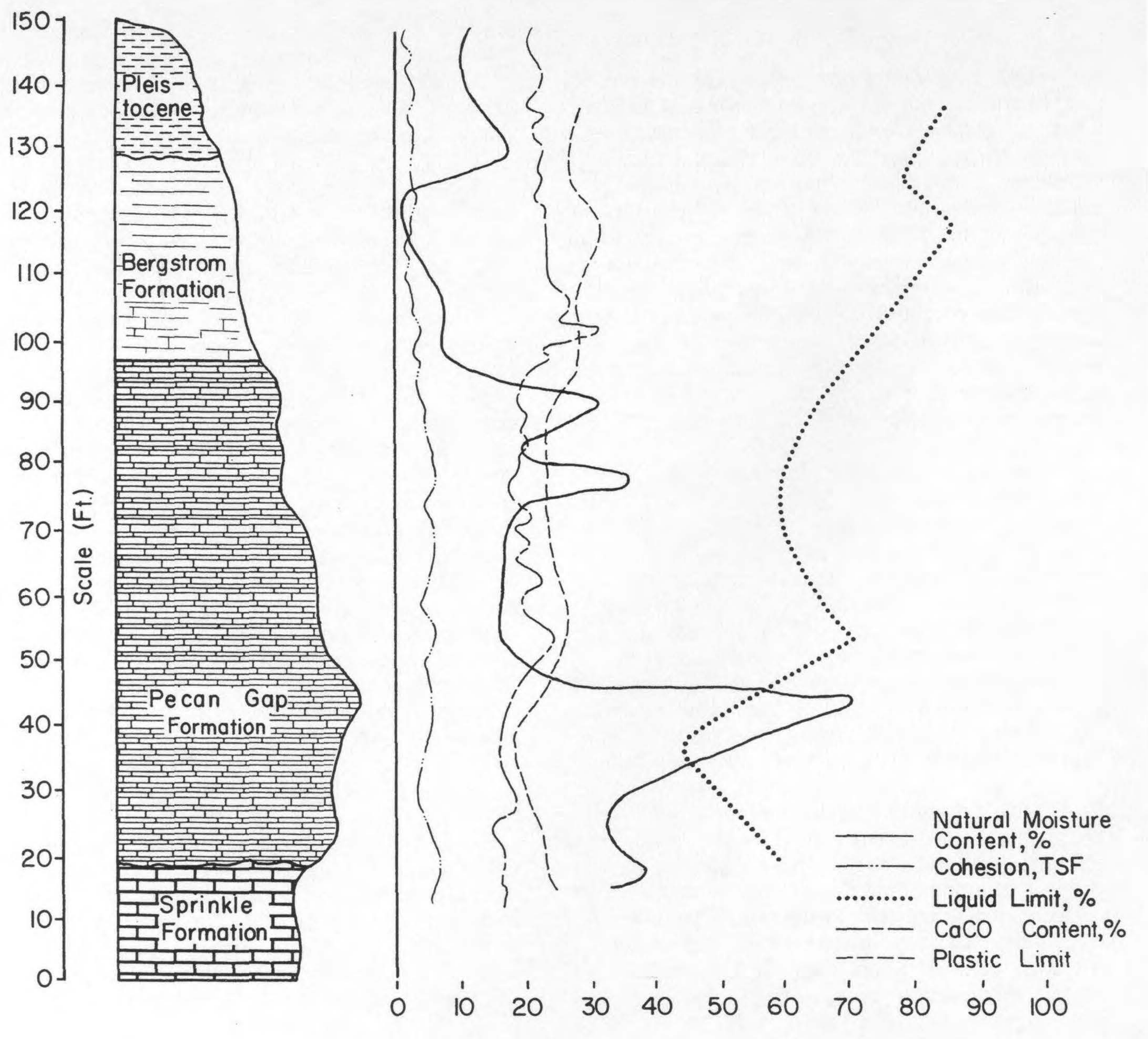


Figure 13. Physical property characteristics of the Pecan Gap and Bergstrom Formations (data compiled by National Soil Service for engineering study of Walter E. Long Lake dam, matched with slope profile and $CaCO_3$ content by K. P. Young).

primarily of limestone material with local sandy clay lenses. The most extensive tributary alluvial deposits are associated with Barton, Walnut, and Onion Creeks.

Alluvium is delineated as a separate unit to indicate areas which are dominated by normal river or stream processes. Alluvium units include modern stream channels and areas subject to flooding.

Sandy alluvium is composed primarily of sand-sized material with subordinate amounts of silt and clay. This unit occurs along the Colorado River and tributary streams which drain primarily limestone terranes.

Clayey alluvium is composed mostly of clay- and silt-sized material with subordinate amounts of sand and occurs along tributary streams which drain clay terranes.

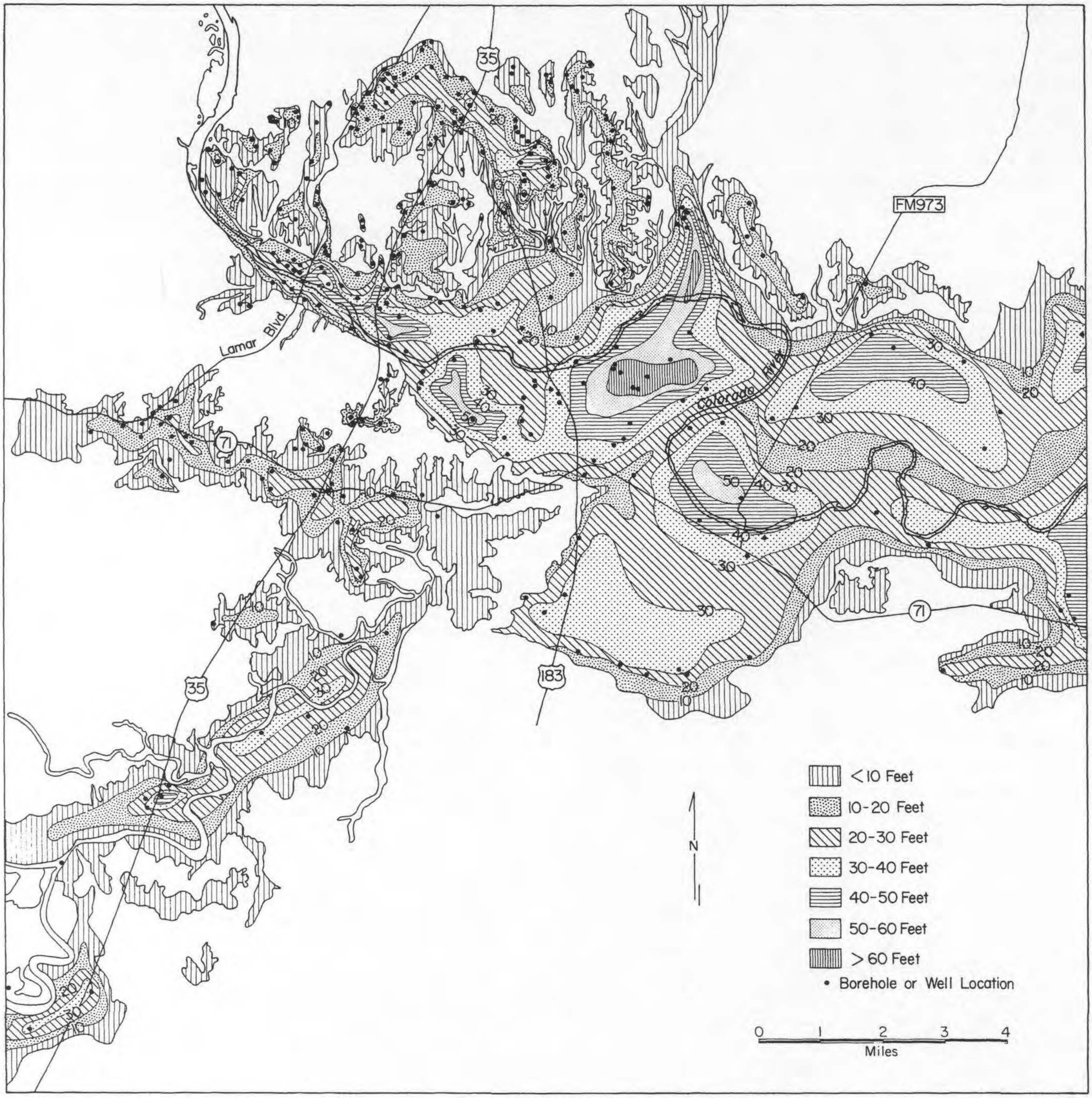


Figure 14. Isopach map of alluvial materials, Austin area, Texas.

Land use.—Construction on alluvial deposits ranges from residential to commercial and industrial. Low-level terraces adjacent to the Colorado River downstream from Austin are used extensively as cropland.

Evaluation.—Alluvial deposits generally have moderate to low slope stability because of their unconsolidated or loosely consolidated nature and the local occurrence of clay materials. These factors also contribute to severe erosion in areas of steep slopes. Because of the extremely high infiltration capacity of these units and the occurrence of a shallow water table in the lower terraces, limitations are severe for placement of septic-tank filter fields and solid-waste disposal sites. Corrosion potential is moderate to high.

BASALT

A hard, dark green to black, fine-grained olivine basalt is exposed in the hills west of the community of Pilot Knob; the hills are the remnants of an ancient volcano. This rock type composes less than 0.1 percent of the Greater Austin area.

Land use.— Only a few residences are located on the basalt because of its limited exposure and rural location.

Evaluation.—Physical properties of basalt impose no restrictions on construction except that blasting is required for excavation.

ALTERED VOLCANIC ROCKS

Altered volcanic rock in the Austin area is a greenish-brown altered basaltic tuff. Much of the original tuff material has been altered to clay. The outcrop covers about 0.3 percent of the map area. This rock type locally contains thin calcite beds and limestone fragments. Thickness of the altered tuff varies from a few inches to about 500 feet. Outcrops of altered tuff occur in the vicinity of Pilot Knob, near Huston-Tillotson College (approximately 1 mile east of I. H. 35 and half a mile north of the Colorado River), along I. H. 35 about half a mile south of the Colorado River, north of St. Edwards University (about 1½ miles south of the Colorado River and half a mile west of I. H. 35), and along Williamson Creek downstream from the Missouri-Pacific Railroad. Topography of altered volcanic rock terrane is rolling prairie.

Land use.—Residences and a few commercial buildings are constructed on this rock type. In the area around Pilot Knob, most of this unit is used as farmland.

Evaluation.—Slope stability and foundation strength are low; therefore, construction in steep-slope areas has severe limitations. Infiltration capacity is low and causes severe limitations for septic-tank filter-field installations.

ROCK AND MINERAL RESOURCES

The preservation of mineral resources within the Austin area is a necessary part of urban planning. The value of rock and mineral resources (crushed stone, dimension stone, lime, sand and gravel, and oil) produced in the Austin area in 1972 exceeded $5 million. Cement raw materials and brick clays have been produced in past years and are potential future resources. Knowledge of distribution of these mineral deposits (fig. 15) is essential to their preservation for future exploitation. Materials suitable for development as mineral resources occur only in certain areas; if these deposits are covered by urban development, potential economic benefits are lost. Proper zoning and encouragement of sequential land use can promote development and expansion without precluding the prior extraction of raw materials.

An example of loss of potential resources because of urban development occurs in the area between I. H. 35 and Walnut Creek in northeast Austin. Parts of this area are underlain by sand and gravel deposits suitable for commercial production. Development of residential and commercial areas, however, has now precluded the extraction of this resource. Comparison of figure 15 and plate VI shows the relationship of developed areas to the occurrence of potential resource materials.

LIMESTONE

Within the Austin area there are large reserves of limestone suitable for crushed stone, high-purity uses, and dimension stone.

The Edwards limestone, which is exposed extensively in the Jollyville Plateau and in the southwest part of the Austin area just east of the Mount Bonnell fault (plate VII), is a source of high-purity limestone used in producing lime, fluxstone, agricultural limestone, and crushed stone. Purity of many limestone beds in this formation exceeds 97 percent $CaCO_3$ (Rodda and others, 1966).

A particular facies of the Austin chalk, called the McKown Formation for the old McKown quarry site, is exposed along Onion Creek upstream from U. S. Highway 183; it is coarse grained and has good properties for use as road base material. Figure 16 shows the distribution of this facies both on the surface and in the subsurface. Highways and

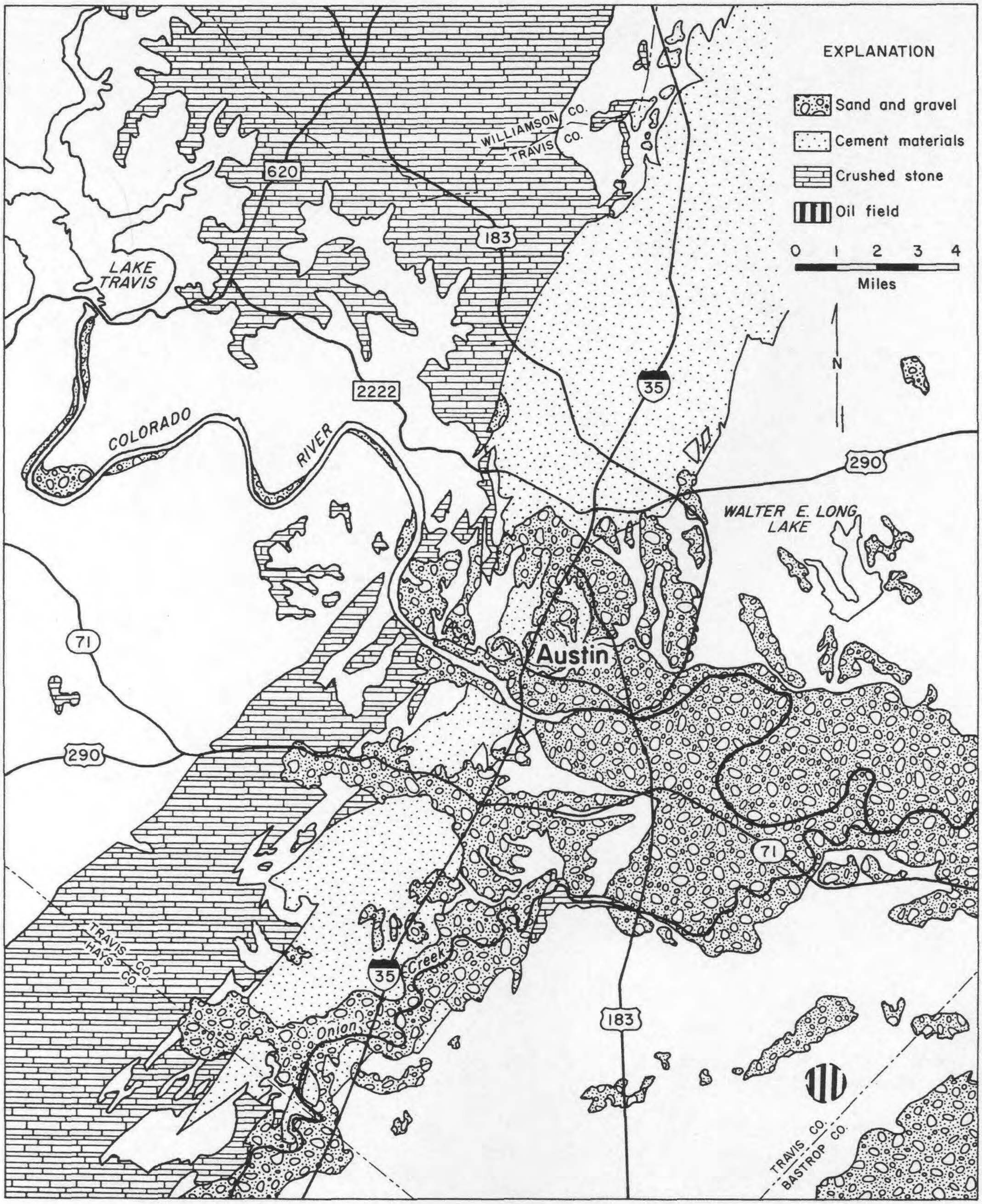


Figure 15. Distribution of mineral resources, Austin area, Texas.

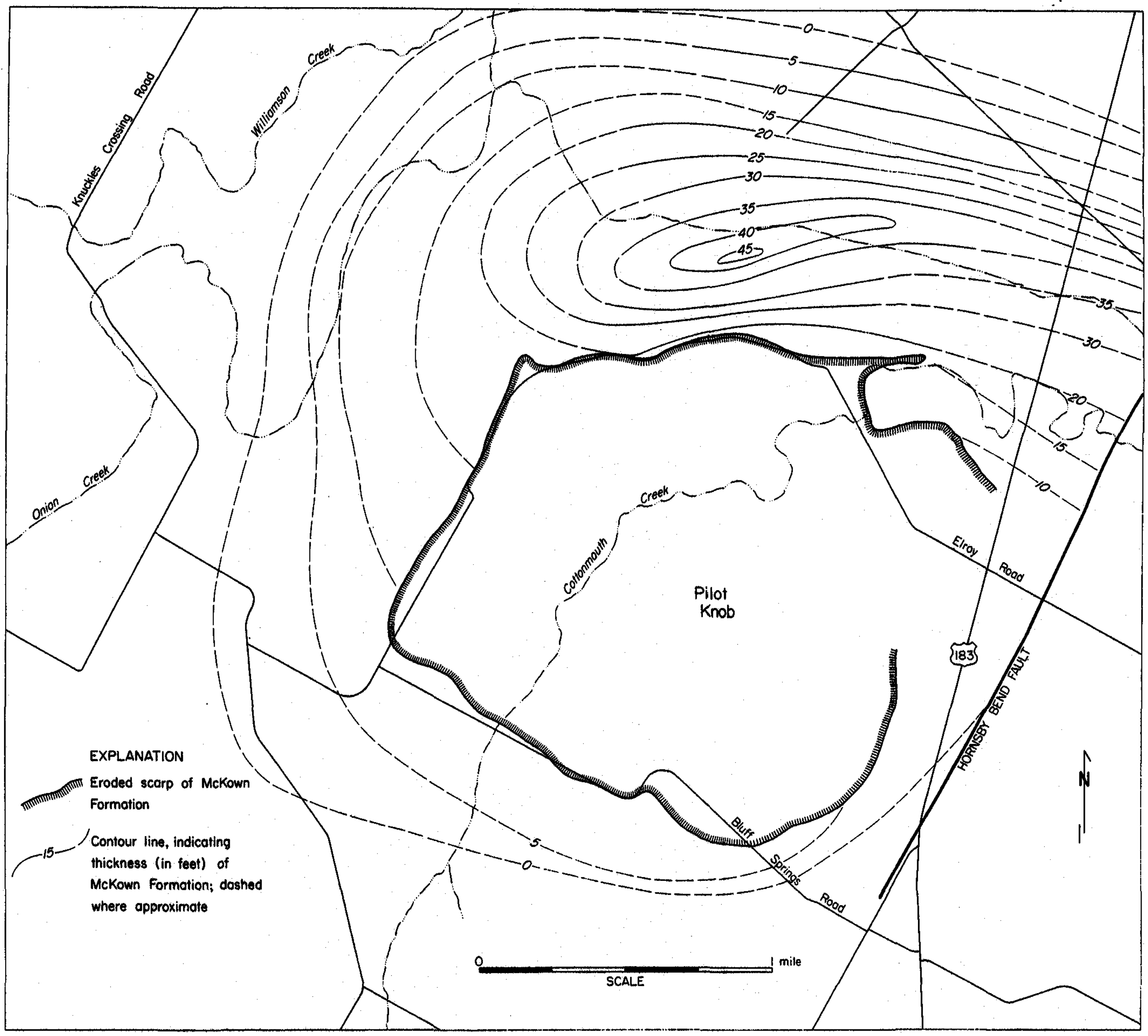


Figure 16. Isopach map showing thickness and distribution of the McKown Formation, Austin area, Texas.

development have made part of this rock unit inaccessible to extraction.

Figure 17 shows an example of sequential land use applied to a limestone resource area. An abandoned limestone quarry is now the site of a school, church, and shopping center in the northwest Austin area.

SAND AND GRAVEL

Fluvial deposits of the Colorado River and Onion Creek are currently extracted as aggregate. Many potential sources of aggregate from these deposits already have been covered and rendered unavailable by urbanization (Garner, 1975). Significant reserves of these materials still remain in

Figure 17. Photograph of an abandoned limestone quarry in northwest Austin, now occupied by a shopping center and school.

undeveloped areas. The general distribution of sand and gravel deposits is shown on plate I. The grain size distribution and composition for various samples from local deposits were described by Urbanec (1963) and Weber (1968).

Data from bore holes and refraction seismograph surveys are presented in the form of an isopach (or thickness) map (fig. 14) for the major local alluvial deposits.

GROUND WATER

Principal sources of water for rural areas, communities, industries, and small towns are the basal Cretaceous sands and the Edwards Formation (Mount and others, 1967). Low-level alluvial deposits and dolomitic limestones of the Glen Rose Formation are minor aquifers. In 1970, ground-water withdrawal for Travis County municipal and industrial use was 293,430,002 gallons.

Basal Cretaceous Trinity sands are not exposed in this area but have been penetrated by many wells (Arnow, 1957). A contour map with the elevation of the top of this aquifer is shown on figure 18. Depths to the basal Cretaceous Trinity sands west of the main Balcones fault are commonly less than 1,000 feet, whereas depths to the east are generally greater than 1,500 feet. Many communities and individuals obtain water from this aquifer.

Strata of the Edwards Formation are preserved in the subsurface east of Mount Bonnell (the main Balcones fault) and provide a source of

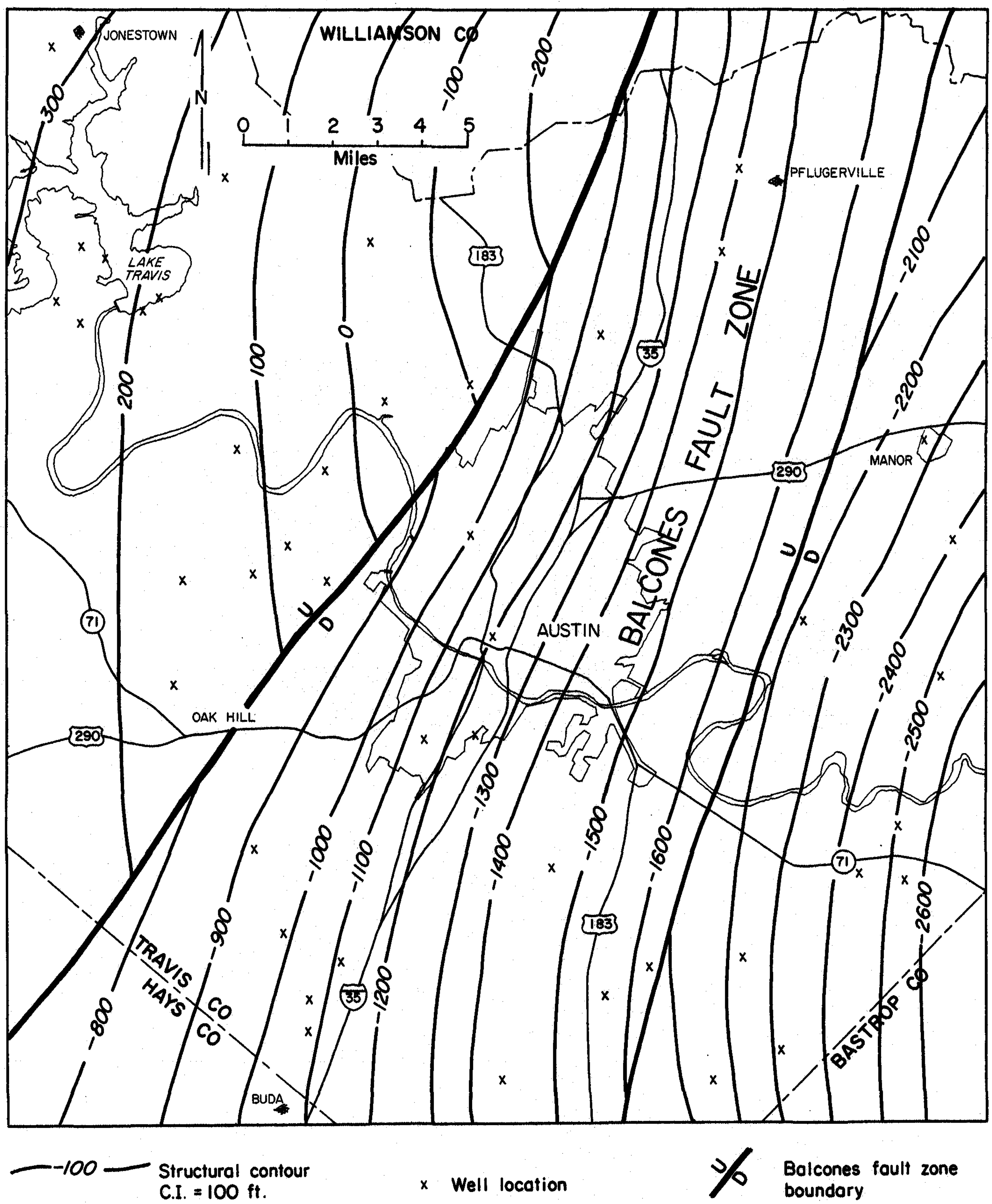


Figure 18. Structural contour map on the top of the Trinity aquifer, Austin area, Texas.

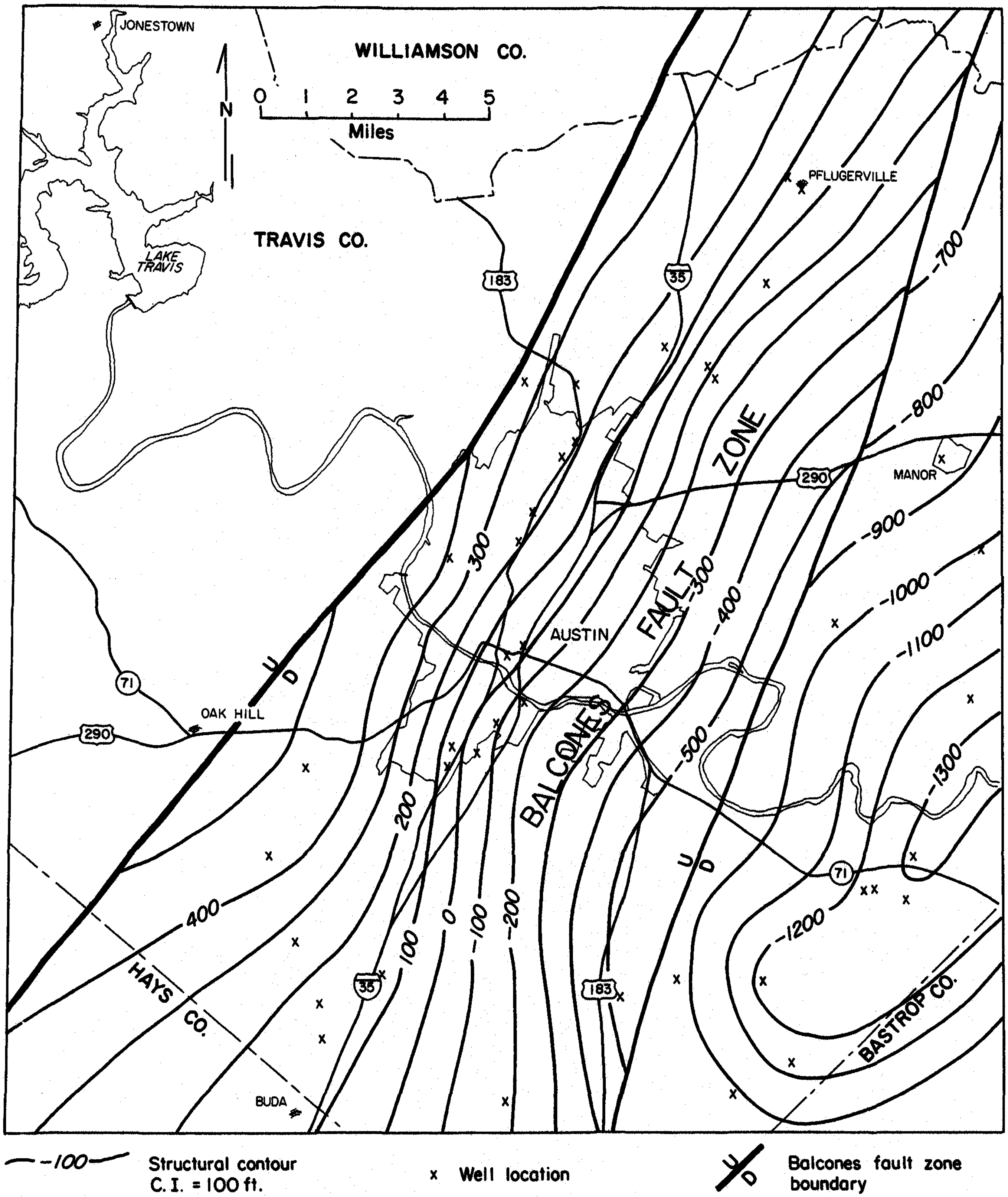


Figure 19. Structural contour map on the top of the Edwards aquifer, Austin area, Texas.

ground water at shallower depths than the basal Cretaceous sands. The Edwards aquifer is confined primarily to dolomite and dolomitic limestone that occupy the lower part of the formation. The general elevation of the Edwards aquifer is shown on figure 19. Drilling depths to the water-bearing strata in the Edwards vary from about 100 to 1,000 feet within the fault zone; east of the fault zone drilling depths are greater than 1,000 feet. Barton Springs, natural springs at the base of Deep Eddy Bluff just downstream from Tom Miller Dam, and other springs in this vicinity flow from fractures that intersect the water-bearing strata of the Edwards Formation. Many wells in the Austin area produce water from the Edwards. Water quality is generally good except in the eastern part of the area.

Minor aquifers of the Glen Rose Formation supply small quantities of water in the area west of the main Balcones fault. Water-bearing zones in this interval occur at varying depths and are laterally discontinuous. Water quality of Glen Rose aquifers is variable and may be high in sulfate.

Low-level alluvial deposits of the Colorado River are commonly saturated with water at relatively shallow depths and can provide large quantities of water. Recharge is primarily from the river. Locally, surface contaminations are easily transmitted to this shallow water table (U. S. Geological Survey, 1969). Water quality is, thus, highly variable.

PETROLEUM

One small oil field, the Elroy East field, is located within the Austin area (fig. 15). The field, discovered in 1959, comprises four wells that have a cumulative production of approximately 400,000 barrels. Oil is produced from fractured zones in coarse-grained limestones associated with the altered volcanic rocks of the igneous plugs in Late Cretaceous strata.

UTILIZATION OF LAND RESOURCE MAPS

Urban land use and planning decisions are generally based on combinations of physical factors. Therefore, it is necessary to provide data that accurately describe and delineate the distribution of environmental components related to or affected by urban land use. The physical properties of natural features and materials that should be considered for each land use category (table 6) are: (1) slope stability, (2) slope intensity, (3) flooding potential, (4) excavation potential, (5) foundation characteristics, (6) infiltration capacity, and (7) corrosion potential. Land resource maps and accompanying descriptions supply these data in a readily usable form. Each land resource map presents information about one aspect of the natural system, as follows:

Rock Type Map (pl. I) delineates rock materials that have similar characteristics;

Physical Properties Map (pl. II) describes physical properties of rock materials and shows their distribution;

Slope Intensity Map (pl. III) describes topographic conditions and delineates areas with similar topographic conditions;

Soil Map (pl. IV) characterizes soils that overlie rock materials and shows their distribution;

Drainage Basins and Floodprone Areas Map (pl. V) shows areas that contribute runoff to various streams and indicates major flood zones; and

Land Use and Natural Vegetation Map (pl. VI) illustrates the distribution of current land use and natural vegetation assemblages.

These maps can be used individually to describe the physical aspects of an area or in combination to compile special-use or suitability maps that characterize conditions for specific applications.

EXAMPLES OF LAND USE PLANNING

The complexity and number of problems associated with planning urban growth can be reduced significantly when land resource data are available. There are many physical conditions that impose limitations on development. Land use limitations within an area do not necessarily preclude all types of construction; they do, however, emphasize existing problems. Efficient planning can be accomplished through the use of land resource maps. If a choice of sites is available, the area with the least number of limiting conditions can be selected without numerous onsite investigations. For example, if the basic needs of a firm seeking a site for an industrial complex are low relief, high bearing strength in subsurface materials, and access to railroads, then the land use and natural vegetation and slope intensity maps indicate three suitable locations near railroads (fig. 20, sites A, B, and C). The rock type map and the physical properties map show that site A is

Table 6. Physical requirements for land use categories, Austin area.

	Light Construction	Heavy Construction	Parks and Recreation	Waste Disposal Solid	Waste Disposal Liquid Untreated	Street and Highway Construction	Reservoir Construction
Slope Stability	High	High	No Limit	No Limit	No Limit	High	Moderate to High
Slope Intensity	2-15%	2-5%	No Limit	2-5%	2-5%	2-15%	No Limit
Flooding Potential	Low	Low	No Limit	None	None	Low	Not Applicable
Excavation Potential	No Limit	No Limit	No Limit	Low to Moderate	No Limit	No Limit	Low to Moderate
Foundation Character-istics	Moderate to High	High	No Limit	No Limit	No Limit	Moderate to High	Moderate to High
Infiltration Capacity	Moderate	Moderate	No Limit	Low	Moderate	No Limit	Low
Corrosion Potential	Low to Moderate	Low to Moderate	No Limit	No Limit	No Limit	No Limit	No Limit

underlain by a limestone with high bearing strength, site B is underlain by sand and gravel with moderate bearing strength, and site C is underlain by plastic clay with low bearing strength. Sites B and C can be eliminated from consideration on the basis of their lower bearing strength by using the land resource maps. Detailed site evaluation is necessary for only one site rather than for all three.

Planning-cost and construction-cost savings are not the only goals of advanced planning. The expansion of a city into surrounding areas requires that planners be aware of existing conditions and potential problems that can arise during development of natural areas. For example, (1) the improper placement of solid- and liquid-waste disposal systems may result in the contamination of aquifers or surface waters, or (2) the alteration of natural vegetation and drainage systems may result in excessive erosion and flooding. Park areas can be selected in advance and located in areas less satisfactory for other types of development, such as flood zones or steep terrain areas. Acquisition of park property prior to development is less costly than purchase after development is started or completed. Waste disposal sites can be planned to harmonize with the natural environment and development. Properly managed sanitary landfills can be easily reclaimed for development after they are abandoned.

An adequate understanding of substrate materials and associated features will permit the establishment of building codes which conform to local variations. The practice of utilizing uniform construction standards can lead to inadequate designs in some areas and overcompensated designs in other areas. As indicated on the Rock Type and Physical Properties Maps, materials can vary greatly within relatively small areas. Therefore, extreme care must be taken to insure that local variations are properly considered.

Another aspect of advance planning is the location and designation of potential resource areas. Construction material resources (crushed stone and sand and gravel) are commonly obscured by urbanization because their occurrence and distribution were not considered as a part of planning. If development is allowed to preempt the exploitation of construction materials, these resources must be obtained from more remote areas; longer haul distances and higher consumer prices result (Garner, 1975).

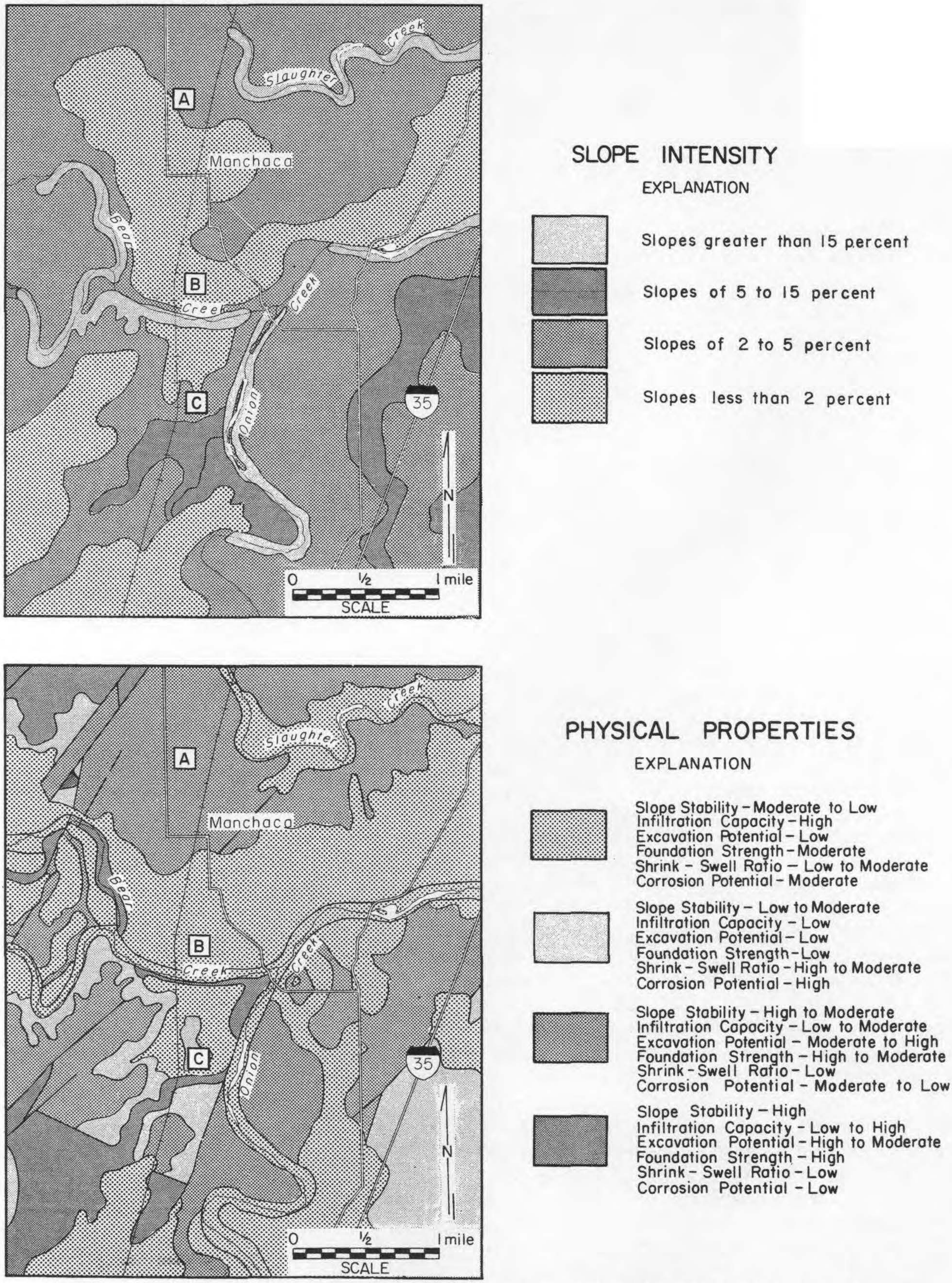


Figure 20. Example of industrial site selection from land resource maps.

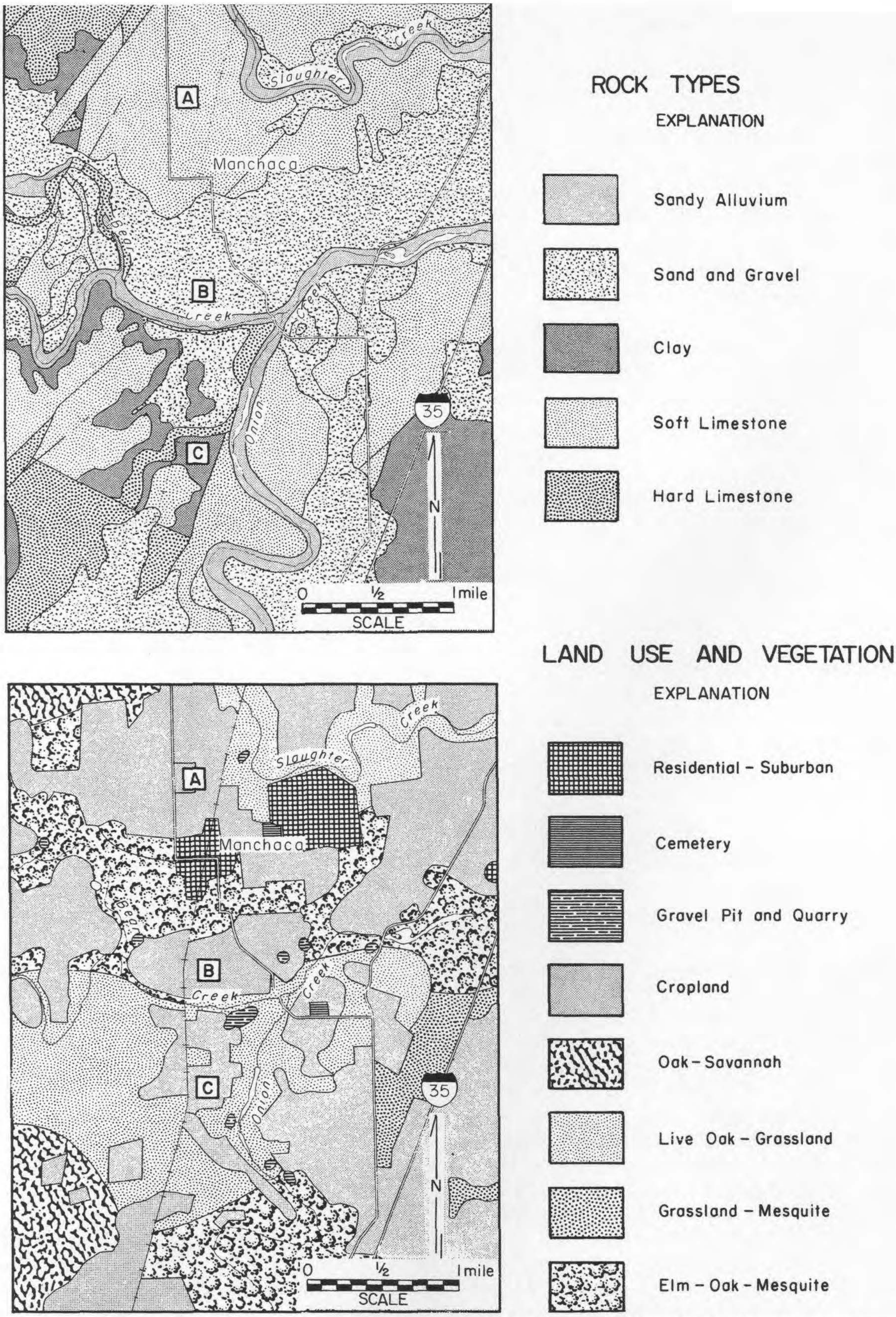


Figure 20 (continued). Example of industrial site selection from land resource maps.

All of the detrimental effects of expansion and development cannot be avoided. However, these problems can be reduced significantly when and where adequate data and planning are available.

PART II: GEOLOGY

INTRODUCTION

Rock units exposed in the Austin area include marine limestone, dolomite, and clays of Cretaceous age, sandy clays of Tertiary age, and alluvial gravel, sand, silt, and clay of Quaternary age. A dip-oriented cross section (fig. 21) illustrates the stratigraphic relationships in this area. The natural land use suitability of each unit is indicated on table 7.

Cretaceous units generally strike northeast and dip gently southeastward except in the Balcones fault zone, where magnitude and direction of dips are irregular. The total thickness of these units is about 2,500 feet. Most Cretaceous units are fossiliferous; common fossil varieties include several species of oysters, clams, and snails.

Fossils commonly found in Cretaceous rocks of the Austin area are discussed and illustrated by Adkins (1928), Hill and Vaughan (1902), Martin (1967), Whitney (1911), Wilbert (1967), and Young (1963, 1967). Regional stratigraphy is discussed by Adkins (1933), Hill (1901), and Young (1967). Feray and others (1949), Martin (1967), Moore (1961, 1964), and Rogers (1969) provide detailed accounts of stratigraphy for this area.

Tertiary strata overlie Cretaceous units in the southeast quadrant of the map area. The limited exposure of Tertiary strata includes about 60 feet of the Kincaid Formation. Gardner (1933) discusses the regional and local stratigraphy of this formation.

Alluvial deposits locally overlie Cretaceous and Tertiary bedrock units in the vicinity of the Colorado River and its tributaries. Where exposed, these units range from a few feet to about 30 feet in thickness. However, boreholes indicate that thicknesses greater than 50 feet occur in many areas (fig. 14).

STRATIGRAPHY

CRETACEOUS ROCKS

GLEN ROSE FORMATION

The alternating marl, dolomite, and limestone strata of the Glen Rose are the oldest units which are exposed within the Austin area. The total thickness of the Glen Rose Formation ranges from about 500 feet (at surface) in the northwest (Jonestown vicinity) to about 1,000 feet (in subsurface) in the southeast (Elroy vicinity). Maximum exposed thickness is about 600 feet in the vicinity of Honey Creek, west of Lake Austin and east of Farm Road 620. Five members have been recognized and defined by Rodda (1970). Member 1 occupies the interval between the basal Cretaceous sands and the *Corbula* bed and consists of nodular to thin-bedded, burrowed limestone, marly limestone, and marl. Members 2 and 4 are composed of interbedded limestone, sandy limestone, nodular limestone, and marl; each unit is about 120 feet thick. Members 3 and 5 are distinguished by their dolomite content. Member 3 consists of fine-grained porous dolomite and dolomitic limestone and is about 70 feet thick. Member 5 occupies an interval of 100 feet, consisting of thin-bedded, fine-grained porous dolomite and dolomitic limestone. The upper part of this unit is a pulverulent limestone which forms a gentle slope compared to the overlying resistant Bull Creek limestone.

WALNUT FORMATION

The Walnut Formation, defined by Moore (1961, 1964), is subdivided into five members, or lithic subdivisions. These members, in order of deposition, are Bull Creek limestone, Bee Cave marl, Cedar Park limestone, Whitestone limestone, and Keys Valley marl. The Bull Creek, Bee Cave,

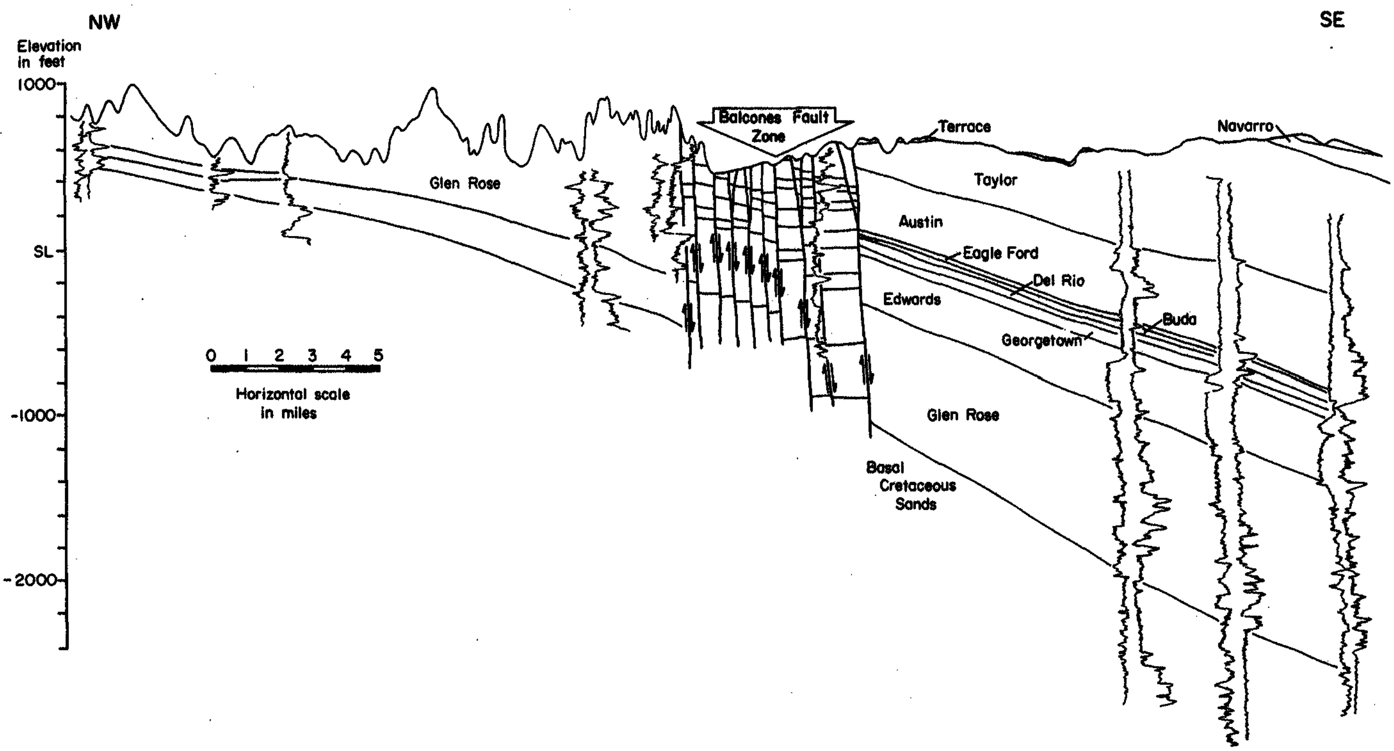


Figure 21. Dip-oriented (northwest to southeast) cross section of geologic units, Austin area, Texas.

and Cedar Park members are exposed above the Glen Rose along the dissected edges of the Jollyville Plateau and on high hills west of Lake Austin and north of Lake Travis. The Whitestone limestone is exposed only in the northern part of the map area north of Buttercup Creek and about 1½ miles west of State Highway 183. The principal area of exposure of the Keys Valley marl is in the drainage area of Buttercup Creek.

The Bull Creek, Cedar Park, and Whitestone limestones are composed of hard, fine- to medium-grained, fossiliferous limestone. Individual units are 30 to 40 feet thick. The Whitestone limestone is quarried for dimension stone near the community of Whitestone in Williamson County and is marketed under the trade names *Cordova cream* and *Cordova shell.* The Bee Cave and Keys Valley marls consist of nodular, fine-grained marl and marly limestone. Thickness of each unit is about 30 feet.

COMANCHE PEAK FORMATION

The Comanche Peak is exposed in the drainage of Buttercup Creek, where it overlies the Keys Valley marl, and in the upper reaches of Cypress Creek and Bull Creek, where it interfingers with the Edwards Formation. The Comanche Peak is composed of fine-grained, nodular limestone and marly limestone. Thickness of the Comanche Peak is about 20 feet in the northwest, but the unit thins gradually and pinches out toward the east and south. It does not occur south of the Colorado River.

EDWARDS FORMATION

The Edwards Formation crops out extensively within the Balcones fault zone, especially south of the Colorado River. A broad area of Edwards is exposed on the upthrown side of the Balcones fault zone west of McNeil. Less extensive exposures cap many of the high hills in the dissected topography west of Austin. Rodda (1970) subdivided the Edwards into four members based on their lithic character. Maximum thickness occurring in the Austin area is about 300 feet.

Member 1, at the base of the Edwards Formation, is composed of porous dolomite, dolomitic limestone, and hard limestone. Gray to black, nodular chert is common in Member 1, and a 20-foot-thick cavernous solution collapse zone

Table 7. Natural land use suitability of geologic units, Austin area, Texas.

SYSTEM	GROUP	FORMATION	MEMBER	GENERAL DESCRIPTION	LAND USE: Road Construction			Fill Material		Foundations					Waste Disposal			Water Storage			
					Earthen structures	Base material	Grade material	Topsoil	General—below topsoil	Heavy	Light	Underground installations	Buried cables and pipes	Excavatability	Septic systems	Solid waste	Unlined liquid-waste retention ponds	Earthen dams and dikes	Unlined reservoirs and ponds	Cropland	Ground-water supply
Quaternary		Alluvium		Unconsolidated gravel, sand, silt, and clay deposits of the Colorado River and tributary streams	+	0	0	+	+	0	0	0	0	+	–	–	–	0	–	–	+
		Lower Colorado River terrace deposits	Sand Beach, Riverview, First Street, and Sixth Street terraces	Yellow- to red-brown, unconsolidated gravel, sand, silt, and clay; gravel more abundant near base	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–	+	+
		Upper Colorado River terrace deposits	Capitol and Asylum terraces	Orange-brown, unconsolidated gravel, sand, silt, and clay; gravel more *common than in lower units*	+	+	+	–	+	+	+	+	+	+	–	–	–	–	–	–	+
		Tributary terrace deposits		Light gray to tan, mostly unconsolidated, calcareous gravel, sand, silt, and clay	+	+	0	0	+	+	+	0	0	+	–	–	–	–	–	+	+
		High terrace deposits		Gray to tan, unconsolidated gravel, sand, silt, and clay; topographically high, not related to modern drainage	+	0	0	0	+	+	+	+	+	+	–	–	–	–	–	+	+
Tertiary	Midway	Kincaid		Dark gray to brown-gray, sandy, micaceous, and glauconitic clays with large concretions	0	–	–	+	0	0	+	0	0	+	–	+	–	+	+	+	–
Cretaceous	Navarro	Kemp		Brown to dark gray, silty montmorillonitic clay; prominent calcareous and quartz siltstone layers; calcareous concretions occur at irregular intervals	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
		Corsicana		Dark gray to blue-gray, calcareous, montmorillonitic clay; sandy phosphatic zone near base	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
		Bergstrom		Green-gray to brown-gray, unctuous, calcareous, montmorillonitic clay; calcareous content increases toward base	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
	Taylor	Pecan Gap		Brown to dark gray, highly calcareous montmorillonitic clay and marl	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
		Sprinkle		Green-gray, calcareous, montmorillonitic clay; calcium carbonate content increases toward base	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
	Austin	Pilot Knob basalt		Black to dark green-gray, hard, fine-grained basalt	+	+	+	–	+	+	+	+	–	–	–	–	–	–	–	–	–
		Pilot Knob tuff		Green-brown to tan, nontronitic, altered tuff, lenticular	0	–	–	+	0	–	0	0	–	+	–	+	+	+	+	+	–
		McKown		Light gray to white, coarse-grained, porous, shell-fragment limestone	+	+	+	–	+	+	+	+	+	0	+	–	–	–	–	–	–
		Pflugerville		Light gray, chalky, and clayey limestone with hard limestone beds at top and base	0	0	0	+	+	0	0	0	0	+	+	0	0	0	+	–	–
		Burditt		Light gray, marly chalk containing 10 to 20 percent montmorillonitic clay	+	+	0	–	+	+	+	+	+	+	+	–	–	–	–	0	–
		Dessau		Light gray, slightly clayey chalk and soft limestone bounded by an upper hard fossiliferous limestone and a basal hard limestone	+	+	+	–	+	+	+	+	+	0	+	–	–	–	–	0	0
		Jonah		Light gray, medium- to thin-bedded, hard fossiliferous limestone	+	+	+	+	+	+	+	+	+	–	+	–	–	–	–	–	–
		Vinson		Grey to white, thin- to thick-bedded massive chalk	+	+	+	–	+	+	+	+	+	0	+	–	–	–	–	0	0
		Atco		Gray to white, thin- to thick-bedded, massive to slightly nodular, fine-grained limestone, marly limestone, and chalk	+	+	+	–	+	+	+	+	+	0	+	–	–	–	–	0	0
		Eagle Ford		Dark gray, calcareous montmorillonitic clay; mid portion consists of thin interbeds of sandy and flaggy limestone, chalk, clay, and bentonite	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
		Buda		Gray to tan, hard, fine-grained, glauconitic, shell-fragment limestone; lower part slightly nodular weathering	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
		Del Rio		Dark gray to olive-brown, pyritic, gypsiferous, calcareous clay containing abundant *Exogyra arietina*	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
		Georgetown		Gray to tan, interbedded, nodular-weathering, hard, fine-grained limestone, marly limestone, and marl, containing abundant fossil shells	+	+	+	–	+	+	+	+	+	0	–	–	–	–	–	–	–
		Edwards	4	Grey to tan, hard, dense, thick- to thin-bedded, fine-grained limestone with soft dolomitic limestone zone near middle	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			3	Gray to tan, soft, nodular-weathering marly limestone	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			2	Light gray to tan, fine- to medium-grained, hard, thin- to thick-bedded limestone; chert nodules in lower third	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			1	Gray-brown, thin- to medium-bedded, porous dolomite, dolomitic limestone, and limestone; chert common; solution collapse zone at top	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	+
		Comanche Peak		Gray to tan, fine-grained, nodular limestone, marly limestone, and marl	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	–	–
		Walnut	*Keys Valley*	*Gray to tan, soft marl and nodular limestone with abundant fossils*	–	–	–	+	–	–	0	0	–	+	–	+	+	0	+	+	–
			Whitestone	Gray to tan, hard, fine- to medium-grained, thin- to thick-bedded fossiliferous limestone	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			Cedar Park	Gray to tan, thin- to thick-bedded, fine- to medium-grained, hard limestone	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			Bee Cave	Gray to tan, soft, nodular-weathering, fine-grained limestone, marly limestone, and marl with abundant fossil shells	+	0	0	–	+	0	+	+	+	0	–	–	–	–	–	–	–
			Bull Creek	Gray to tan, hard, fine- to medium-grained, thin- to thick-bedded limestone; shell fragments common	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
		Glen Rose	5	Gray-brown, thin-bedded, fine-grained, porous dolomite; upper 10 to 20 *feet pulverulent*	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	+
			4	Gray to tan, thin- to thick-bedded, fine- to medium-grained limestone and marly limestone; many beds with fossils	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			3	Gray-brown to tan, thin interbeds of dolomite, dolomitic limestone, limestone, and marly limestone	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	+
			2	Gray to tan, thin to thick interbeds of fine- to medium-grained limestone, marly limestone, and marl; many beds with fossils	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
			1	Gray to tan, thin- to thick-bedded limestone, marly limestone, and marl; orange-brown limestone ledge at top with abundant small fossil clams (*Corbula harveyi*) underlain by a fossiliferous marly limestone; lower contact not exposed	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–

+ Satisfactory
0 Possible problems
– Unsatisfactory

containing iron-stained and brecciated limestone, dolomite, chert, calcite, and red clay occurs at the top. Total thickness of Member 1 is estimated to be 200 feet, although no total section is exposed in the Austin area. Members 2 and 4 are each about 40 feet thick and composed primarily of fine- to medium-grained hard limestone. The lower beds in Member 2 are folded and fractured as a result of the collapse in Member 1. Member 4 contains a thin solution collapse zone and associated dolomite and dolomitic limestones near the middle part. Member 3 is a soft nodular marly limestone and marl interbedded locally with flaggy limestone. This unit is 10 to 15 feet thick.

GEORGETOWN FORMATION

The Georgetown Formation is exposed in the vicinity of McNeil and in fault blocks from Mount Bonnell to the area south of Sunset Valley and just west of Buda. The Georgetown is composed of thin interbeds of gray to tan, richly fossiliferous, nodular, fine-grained limestones, marly limestone, and marl. Thickness ranges from 40 to 60 feet.

DEL RIO FORMATION

The Del Rio is a greenish-gray to olive-brown, selenitic, calcareous, pyritic, and fossiliferous clay. Kaolinite composes about 50 percent of the clay mineral fraction. Illite is generally present in unweathered samples in much larger quantities than montmorillonite. However, during the weathering process illite apparently alters to montmorillonite; weathered samples contain only small quantities of illite (T. W. Grimshaw, written communication, 1974). The Del Rio Formation is commonly poorly exposed in steep to shallow slopes below the Buda limestone.

BUDA FORMATION

The Buda Formation consists of an upper hard, resistant, fine-grained, burrowed, glauconitic, shell-fragment limestone and a lower marly, nodular, and less resistant limestone. Total thickness of the Buda in the Austin area is about 35 feet, but the unit thins northward. Freshly broken surfaces of the Buda are characteristically colored shades of tan to orange-brown that resemble discolorations caused by heating. Many early descriptions of this unit termed it the “burnt” limestone (Hill and Vaughan, 1902). Scattered outcrops of the Buda Formation occur from the area near Mount Bonnell southward to the vicinity of the town of Buda.

EAGLE FORD FORMATION

In the Austin area the Eagle Ford Formation comprises four members: from bottom to top, the Pepper shale, the Cloice shale, the Bouldin flags, and the South Bosque shale. These members are not mapped separately.

The South Bosque member is a calcareous, marly claystone which is primarily montmorillonitic clay. This member ranges from 21 to 25 feet thick in the Austin area.

The Bouldin flags member constitutes about 11 feet of interbedded montmorillonitic shale and limestone flags. The flag beds range from 4 inches to 1 foot thick, and some of them are discontinuous. Several small bentonite beds (from ½ to 3 inches thick) are present. Northward, the Bouldin flags thickens to about 15 feet.

The Cloice shale is a fissile, gray, montmorillonitic, silty formation. The shale is about 11 feet thick in the Austin area and thickens to the north.

The Pepper shale is a montmorillonitic, noncalcareous, unctuous, black claystone, which on the weathered surfaces contains much selenite and jarosite. Since the Pepper has very little material admixed with the clay, it is a structurally unstable unit. The Pepper ranges from about 1 foot thick at the Travis-Hays county line to around 5 feet thick near Round Rock.

AUSTIN GROUP

The Austin Group consists of about 350 feet of light gray chalk, limestone, marly limestone, and marl generally referred to as the Austin chalk. Formations recognized within this interval are, from base to top, Atco, Vinson, Jonah, Dessau, Burditt, Pflugerville, and McKown. These units are not mapped separately.

The Atco Formation is mostly a chalky limestone alternating with thin beds of clayey limestone and marl. Thickness is about 125 feet.

Nodular-weathering chalk and chalky limestones occur in the Vinson Formation. There is no clay and only scattered fossils in this unit. The unit is about 80 feet thick.

The Jonah Formation is composed of hard fossiliferous limestone with sparry calcite cement. The unit thins from north to south and ranges from 25 to 10 feet thick in the Austin area.

Rocks of the Dessau Formation are primarily chalk with a very low clay content. Although this unit is generally soft, a very hard *Exogyra laeviuscula* bed (3 to 6 feet thick) occurs at the top and a hard *Pycnodonte aucella* bed (12 to 30 feet thick) occurs near the middle. Near Brushy Creek this unit is about 75 feet thick, but it thins southward to about 50 feet near Pilot Knob.

The Burditt Formation consists of marly chalk. Montmorillonitic clay constitutes about 10 to 20 percent of this unit. Thickness ranges from 15 feet in the north part of the area to about 6 feet or less near Pilot Knob.

The Pflugerville Formation is a chalky and clayey limestone with a moderately hard clayey limestone at the base and a hard limestone occurring locally at the top. Thickness is about 40 feet.

The McKown Formation is a coarse-grained, shell-fragment limestone that occurs only in the vicinity of Pilot Knob. This unit is a beach rock facies, 30 to 50 feet thick, of the Pflugerville, Burditt, and possibly the upper 40 feet of the Dessau Formations. It grades laterally into pyroclastic rocks that surround the central intrusion that comprises Pilot Knob.

PILOT KNOB TUFF

The Pilot Knob tuff is a tan to green-brown, altered, nontronitic pyroclastic material. The greatest accumulation of these altered pyroclastics occurs in the low area around Pilot Knob. However, tongues of the unit interfinger with the Dessau Formation and extend upstream in Onion and Williamson Creeks. Several isolated occurrences are present in the map area.

PILOT KNOB BASALT

The Pilot Knob basalt is a very hard igneous rock that intruded rocks of the Austin Group. The basalt is dark greenish-black to black, microcrystalline basalt that weathers to a brown or rusty color. It is known to crop out only in the vicinity of Pilot Knob, where it makes up the core of Pilot Knob itself and a number of small surrounding hills.

TAYLOR GROUP

The Taylor Group consists of about 700 feet of greenish-gray to brown, calcareous, montmorillonitic clay and marly clay in the Austin area that is generally referred to as the Taylor clay. Formations recognized within this group are, from base to top, Sprinkle, Pecan Gap, and Bergstrorn (Young, 1965). These units are not mapped separately.

The Sprinkle Formation is a greenish-gray, calcareous, montmorillonitic clay. Calcium carbonate content increases toward the base. Thickness of the Sprinkle Formation is about 300 feet. This unit is best exposed along Walnut Creek.

Strata of the Pecan Gap are brown to gray, highly calcareous, montmorillonitic clay or clayey marl. The interval ranges from 50 to 75 feet thick. The Pecan Gap is poorly exposed but can be observed in outcrops just north of Manor and in the high hills south of Pilot Knob.

The Bergstrorn Formation is a greenish-gray to brownish-gray, unctuous, calcareous, montmorillonitic clay. This unit becomes more calcareous toward the base and is gradational with the underlying Pecan Gap. Thickness of the Bergstrorn ranges from 325 to 350 feet. Poorly exposed outcrops of the Bergstrorn occur around Walter E. Long Lake and southeast of Bergstrorn Air Force Base.

NAVARRO GROUP

The Corsicana and Kemp Formations are included in the Navarro Group. These units occur only in the southeast part of the map area and are not mapped separately.

The Corsicana Formation is a dark gray to blue-gray, calcareous, montmorillonitic clay. Maximum thickness is about 120 feet. This unit is poorly exposed in the Austin area except along the lower part of Onion Creek. A thin zone at the base of the Corsicana contains admixed sand and phosphatic material.

The Kemp Formation is a brown to dark gray, silty, montmorillonite clay with some calcareous intervals. Thin layers of quartz siltstone occur above the contact with the underlying Corsicana. Concretionary masses of fine calcareous siltstone occur at irregular intervals, but a zone near the mid-portion of the unit is most prominent. Maximum thickness of the Kemp Formation is about 350 feet.

TERTIARY ROCKS

MIDWAY GROUP

The Kincaid Formation is the only formation of the Midway Group exposed in the map area. The unit is composed of dark gray to brownish-gray sandy, micaceous, and glauconitic clays with glauconite lenses and ferruginous and calcareous concretions. Thickness of the Midway is about 150 feet in the Austin area; however, the section is incomplete.

QUATERNARY ROCKS

HIGH TERRACE DEPOSITS

Several terrace deposits in the Austin area occur at levels which are higher than those associated with the Colorado River and tributaries. These high deposits are commonly discordant to present drainage patterns and occur at elevations up to 680 feet above mean sea level. High gravel deposits exposed in the vicinity of Manor and in the area south of Pilot Knob between Creedmoor and Elroy are composed primarily of siliceous material.

Deposits of the St. Elmo bench, a terrace deposit of ancestral Barton Creek (Urbanec, 1963; Weber, 1968) that extends from Sunset Valley eastward to the vicinity of the U. S. Highway 183 and State Highway 70 intersection, are composed primarily of limestone, sand, and gravel with major amounts of chert. Alteration by calichification in this unit is common. Locally, the surface of the St. Elmo bench is veneered with chert granules.

High terraces associated with ancestral Onion Creek cap many of the hills between Williamson and Onion Creeks and the area between Bluff Springs and Turnersville. These deposits have been altered by calichification and now contain little of the original limestone material.

TRIBUTARY TERRACE DEPOSITS

The most extensive developments of tributary deposits occur on Barton, Onion, Williamson, and Walnut Creeks. Material in these units consists primarily of unconsolidated limestone gravel, sand, and mud and is derived from Cretaceous deposits that compose this drainage area. Average thickness of tributary terrace deposits is about 20 feet.

COLORADO RIVER TERRACE DEPOSITS

Terrace deposits of the Colorado River are composed of unconsolidated gravel, sand, silt, and clay. The gravel fraction is mostly chert and limestone with minor amounts of igneous and metamorphic rock fragments (Weber, 1968; Weeks, 1945; Urbanec, 1963).

Six terrace levels of the Colorado River are generally recognized in the Austin area. They are, from oldest to youngest, Asylum, Capitol, Sixth Street, First Street, Riverview, and Sand Beach terraces. Deposits of these terraces are generally most extensive downstream from the main Balcones fault, where the Colorado River valley broadens in the less resistant Upper Cretaceous strata.

On the geologic map (plate VII) these terrace deposits are mapped in two units. The highly dissected Asylum and Capitol terrace deposits occur at elevations above 500 feet above mean sea level and are included in the Upper Colorado River terrace deposits. The relatively undissected Sixth Street, First Street, Riverview, and Sand Beach terrace deposits are included in the Lower Colorado River terrace deposits.

Upper terrace deposits generally contain more gravel-sized material than the lower levels. Thicknesses of these terrace deposits are commonly about 30 feet. However, local thicknesses range up to 60 feet in both high and low levels (fig. 14).

ALLUVIUM

Alluvium includes deposits in modern channels of the Colorado River and tributary streams. This unit is commonly flooded and is generally composed of unconsolidated gravel, sand, silt, and clay. Alluvium in the Colorado River is composed primarily of siliceous material. In tributaries which drain clay areas such as Walnut, Gilleland, Dry, and Maha Creeks, these deposits have high clay content. Alluvium in other tributaries consists primarily of limestone, sand, and gravel. Maximum thickness of alluvium is about 20 feet.

STRUCTURAL GEOLOGY

The regional southeast dip of Cretaceous strata is altered in the Austin area as units dip gently northeastward into the Round Rock syncline. Gently dipping Cretaceous units are broken and displaced down to the southeast by the northeast-trending Balcones fault zone (fig. 21). Units on the upthrown side of the Balcones fault zone dip at about 20 feet per mile toward the northeast; near the fault zone dips are about 50 feet per mile to the east. Within the fault zone, dips vary greatly in direction and magnitude. On the downthrown side of the Balcones, the regional dip is about 100 feet per mile to the southeast (Dunaway, 1962).

Structural geology of the Austin area was discussed in detail by Dunaway (1962), Kurie (1956), and Muehlberger and Kurie (1956).

FAULTS

Most faults in the Balcones system strike about N. 40° E. and are dip-slip normal faults (Dunaway, 1962) (see pl. VII). Maximum displacement of the largest fault (Mount Bonnell fault) is about 600 feet. Dip-slip movement on smaller faults ranges from about 150 feet to less than 10 feet; most faults have displacements of less than 50 feet. Fault planes generally dip between 55° and 75°. Major faults are downthrown to the east, and about 40 percent of the small faults are downthrown to the west (Kurie, 1956). Total displacement across the fault zone is about 1,200 feet. Most of the movement in the Balcones fault zone occurred during Miocene time; no movement has been detected during modern times.

JOINTS

Joints in the Austin area control streams and contribute to the permeability of limestone strata. Two major joint sets trend N. 40° E. and N. 45° W., and two secondary sets trend N. 10° W. and N. 80° E. (Dunaway, 1962). Joints are associated with faults of the Balcones system and solution collapse zones.

FOLDS

Folds observed in the Austin area are generally associated with solution collapse zones and have small amplitudes, commonly less than 20 feet. A few small drag folds have been produced by faulting.

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