Land Resource Overview of the Capital Area Planning Council Region, Texas --

A Nontechnical Guide

by

C. M. WOODRUFF, JR.

BUREAU OF ECONOMIC GEOLOGY • THE UNIVERSITY OF TEXAS AT AUSTIN • W. L. FISHER, DIRECTOR
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1. Materials, landforms, and process characteristics of land resource units
2. Estimated physical properties of land resource units
3. Generalized capability of land resource units for sustaining selected uses and activities

MAP *(in pocket)*

Land Resources Map of the Capital Area Planning Council Region

That the . . . regions here described are natural areas is indicated by the close harmony between these regions and the major provinces of Texas as defined by the soils, the outcropping rocks and sediments, the major physiographic subdivisions and the climatic zones.

The delineation and description of all such natural regions is one of the pressing tasks of the scientist, eminently in this generation, for it forms a basis for studies of population distribution, land use, erosion control, crop adaptability, and other fundamental human problems. Through these lines of research the future of much of the life and prosperity of the state will be determined; upon them may be based economic studies in practically all fields.

W. Armstrong Price
Texas Academy Publications in Natural History,
1939

Preface

During 1973, the Capital Area Planning Council (CAPCO) initiated a contract with the Bureau of Economic Geology for obtaining maps that would aid the CAPCO staff in regional planning endeavors. This contract was completed in 1974 when two hand-colored maps with accompanying descriptive explanations were delivered to CAPCO. One of these, a *physical properties map,* depicted generalized engineering properties of rocks and sediments that underlie the CAPCO region. The other map, termed an *environmental geology map,* presented an interpretation of processes, landforms, and substrate materials. The two maps provided complementary information for determining which human activities the land can best sustain at various locations throughout the region.

The two-map format was adequate and appropriate for use by professional planners. However, the information was unduly complex for use by the general public. The CAPCO region is indeed complex, but by sacrificing some map detail and complexity, a single composite map of the region was constructed for nontechnical use. This map, termed a *Land Resources Map,* can be used to illustrate how the land differs from place to place and how these differences affect people.

This report provides a general overview of the CAPCO region as well as additional sources of information for persons interested in more detail. It is my intent that this map and report illustrate the complexities of the land without overwhelming the reader with intricate details.

Introduction

Bastrop, Blanco, Burnet, Caldwell, Fayette, Hays, Lee, Llano, Travis, and Williamson Counties make up the Capital Area Planning Council (CAPCO) region in Central Texas (fig. 1). The region covers 8,427 square miles (21,826 km^2) and includes land of great physical diversity. It contains five geographic provinces with elevations ranging from 187 to 1,904 feet (57 to 581 m) above sea level. Parts of four river systems cross the area. Six major categories of soils as well as six natural vegetation assemblages are present. The region is underlain by a complex variety of rock types and sediments representing all four eras of geologic time. Prominent geologic features include a major fault zone and a granitic upland area.

The characteristics of the land differ from place to place, and different kinds of land sustain different uses. Early settlers understood the natural constraints of the land. They recognized floodplains and built on high ground; they planted crops on fertile bottomlands instead of clearing less productive uplands. Inhabitants have always planned their homes and communities around a water supply and, with some exceptions, have avoided contamination of this water for the sake of health and hygiene. Now, however, increased population and related economic pressures have forced the land to sustain uses for which it may not be best suited. Thus, urban sprawl encroaches onto prime agricultural land, hazardous flood-prone areas, and sensitive aquifer-recharge zones. Likewise, rocky highlands and woodlands, heretofore considered unsatisfactory for intensive agricultural endeavors, have been overgrazed by livestock or have been cleared, fertilized, and planted. Additionally, rural and urban populations demand more and more water and mineral commodities and concurrently produce increasing amounts of wastes. Excavations for mining and landfills for waste disposal result from these demands, yet few people want a strip mine or a landfill as a next-door neighbor. It is clear that the land's natural capacity to support these activities is often strained.

Land is a basic and sometimes fragile resource and must be recognized as such. Proper care of this resource depends upon the user's understanding that the earth consists of diverse landforms and materials which are subject to a variety of natural processes. Given some understanding of the specific nature of earth materials, landforms, and processes, inhabitants can properly develop the land. The need for an informative overview of the varied aspects of the land in the CAPCO region has prompted this study.

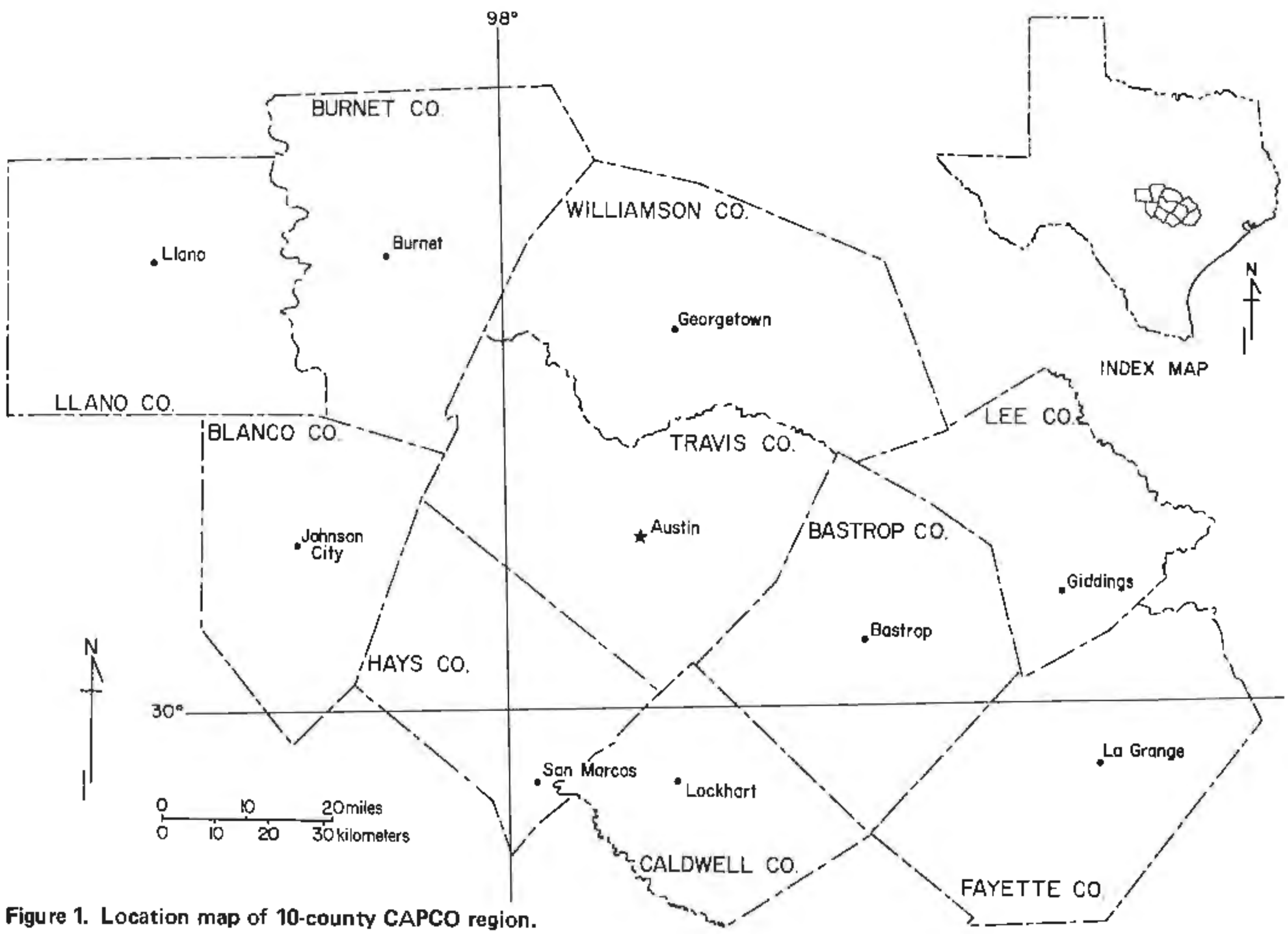

Figure 1. Location map of 10-county CAPCO region.

PROCEDURES

This report contains three major sections. The first, entitled *Regional Environmental Features,* is a region-wide analysis of the various facets of the natural setting. The second part, entitled *Land Resources Map,* discusses the enclosed map and presents the criteria by which each map unit was delineated. The third part, entitled *Natural Resource Areas,* focuses on the five *natural areas* that are delineated on the basis of the various regional environmental features. A glossary is included at the end of this report to help people understand any technical words used.

The first part of the report draws on technical data from a variety of disciplines including geology, soil science, hydrology, civil engineering, and climatology. This information is summarized and illustrated by several schematic maps, which can be used to show how various natural resources interact to affect human activities (fig. 2). These simplified maps also provide a background for understanding the more detailed, yet generalized, Land Resources Map of the Capital Area Planning Council Region (in pocket).

The focus of this report is the Land Resources Map, which is discussed in the second major section of the report. The Land Resources Map depicts the areal extent of different kinds of land that significantly affect or are affected by human endeavors; each distinct land type is termed a *land resource unit* and is represented by a different color on the map. Land resource units are mappable entities that are determined by the local characteristics of the land (processes, substrate, landforms, soils, biota, or any combination of these characteristics) and that naturally support certain levels of human activities without appreciable environmental harm or hazard to people.

The formulation of land resource units required judgments about the ability of the land to sustain various uses. These judgments are valid only when applied to the land in a natural condition; yet it is clear that human activities can upgrade the land for specific uses. Applying fertilizer to a nutrient-depleted soil is an example of an upgrading (or mitigating) activity. These mitigating measures, however, usually cost money. Thus, there is always the possibility of lessening certain adverse effects of human activities by modifying the land or by altering the design of a proposed action. Hence, this mapping of land resources units does not imply that any particular use of the land is unsatisfactory. Indeed, the scale of mapping is too small and the scope of this report too broad for an iron-clad statement that would preclude a given activity. Nevertheless, broad guidelines are provided to aid people in adapting their property to its most compatible uses with a minimum of unforeseen costs to everyone.

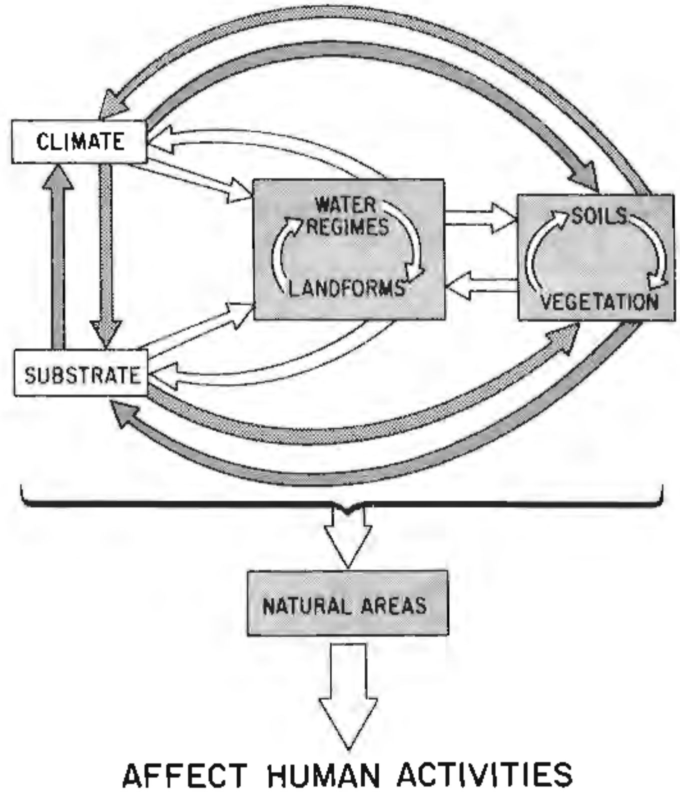

Figure 2. Interaction among various natural facets of the land and their impacts on human activities.

The last major section of this report presents an area-by-area discussion of conditions within five natural resource areas delineated in the CAPCO region. These resource areas are defined on the basis of the interactions among the various facets of the land, which are described at the outset in the schematic presentations. Unlike a repetitive county-by-county description, this area-by-area delineation affords a more succinct means for discussing the highly complex CAPCO region.

Regional Environmental Features

CLIMATE

The climate of the CAPCO region is generally subtropical, but marked intraregional climatic variations do exist. Climatic changes occur across the region because of physiography and geographic position. Simply stated, as one moves to higher altitudes or farther north, the winters become colder. As one moves farther west, the climate becomes drier.

In the northwestern part of the CAPCO region (Llano, Blanco, and Burnet Counties), seasonal temperatures vary the most (fig. 3); average annual rainfall is approximately 12 inches (30.5 cm) less (fig. 4), and relative humidity is significantly lower than temperatures, rainfall, and humidity in the southeastern counties. The length of growing seasons (fig. 4) varies by as much as 50 days across the entire CAPCO region, the longest frost-free period being in southeastern Fayette County.

The annual averages of temperature, rainfall, and humidity are sometimes misleading, however, because *climatic extremes* impose significant constraints on human activities. For instance, seasonal temperatures vary markedly from mean

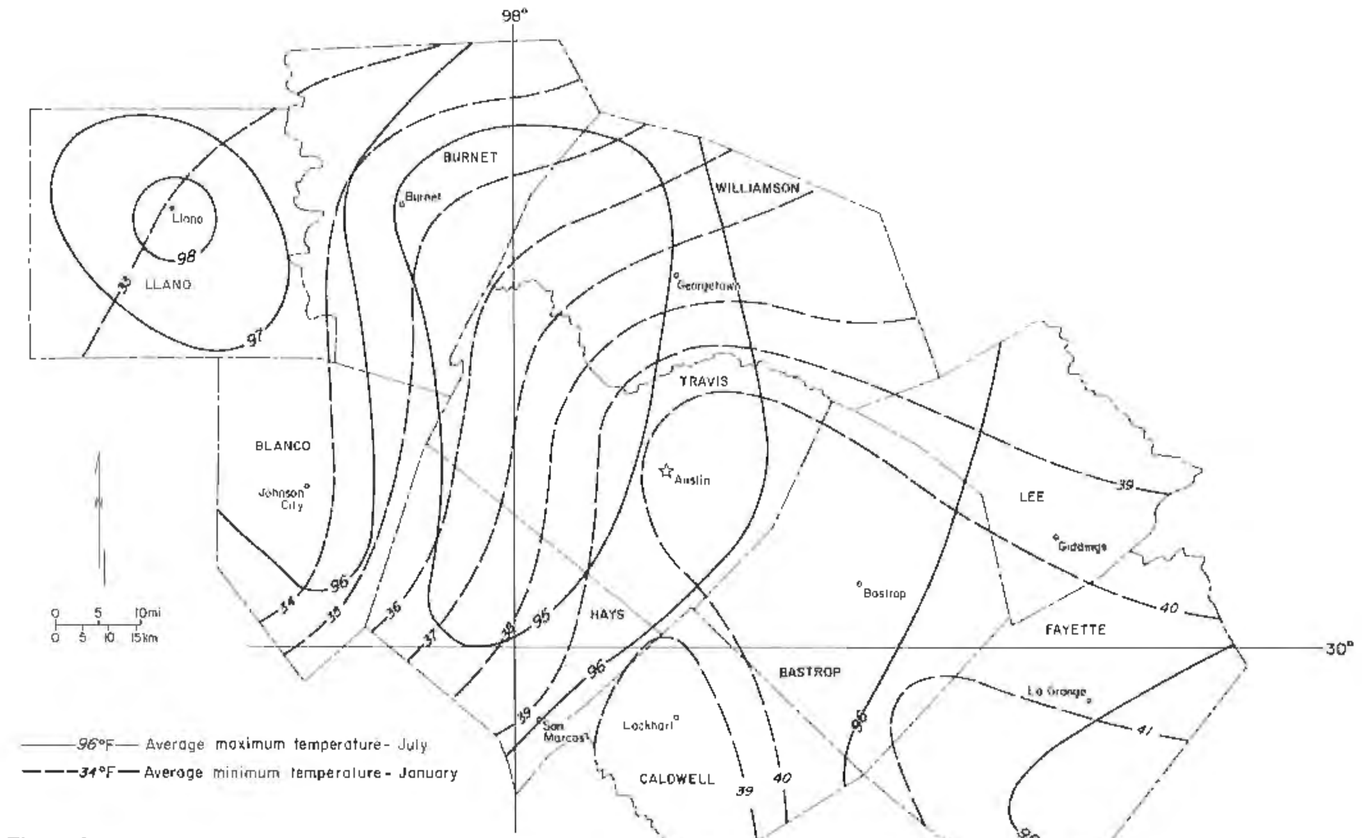

Figure 3. Simplified map of the CAPCO region showing seasonal temperature variations (data source: Texas Natural Resources Information System).

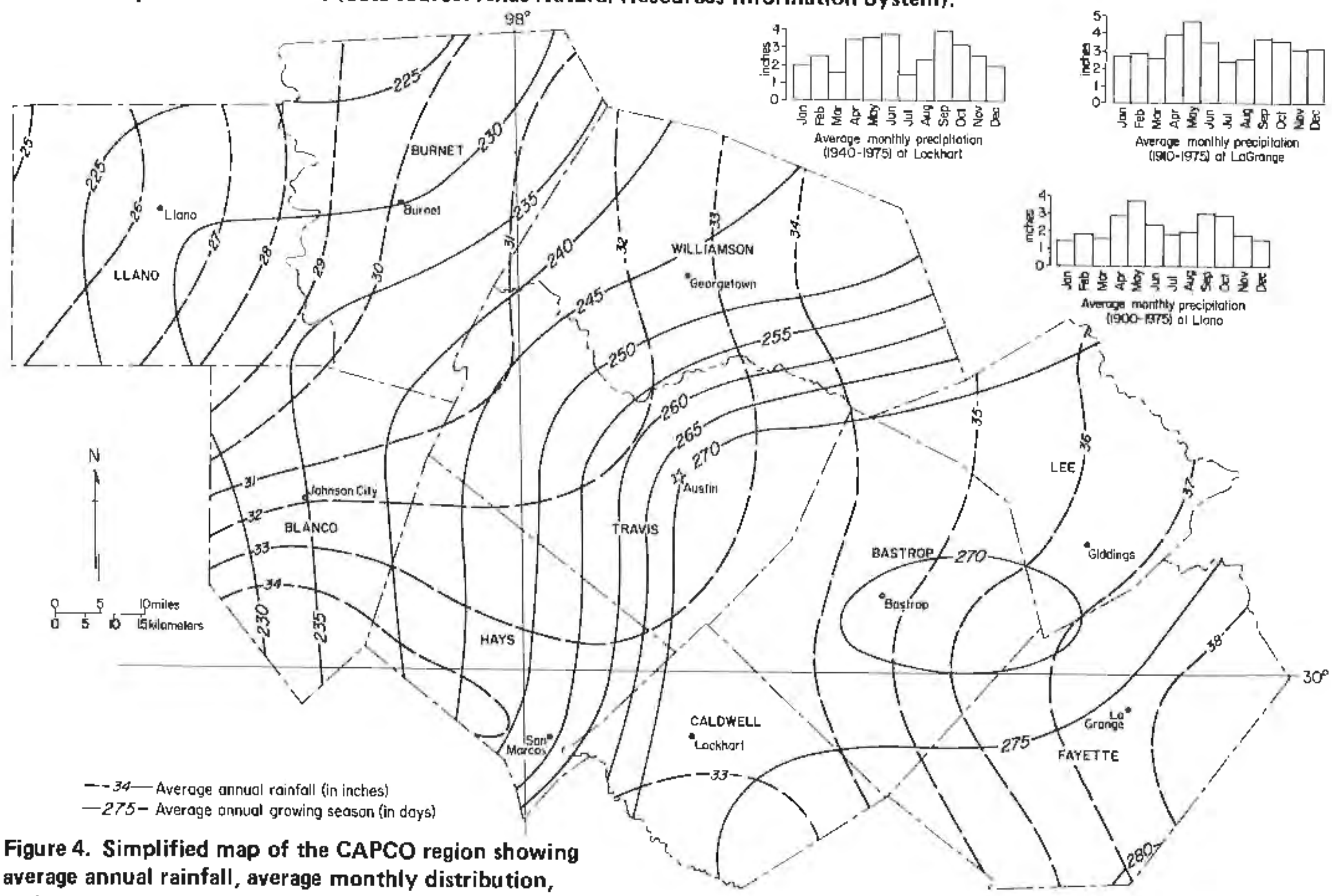

Figure 4. Simplified map of the CAPCO region showing average annual rainfall, average monthly distribution, and average annual growing season (data source: Texas Natural Resources Information System).

annual temperatures, and the figures for average annual rainfall exhibit seasonal peaks and lows (fig. 4). Moreover, beyond seasonal variations, "extraordinary climatic events" eclipse the significance of moderate average annual or seasonal values. An excellent example of such a condition is the great Thrall, Texas, flood of 1921 when over 36 inches (91 cm) of rain fell in an 18-hour period. This compares to a *mean annual rainfall* at Thrall of approximately 34 inches (86 cm). The Thrall flood was the largest single rainfall event ever recorded in the United States, and, significantly, this record locality is in the CAPCO region. In fact, the Balcones Escarpment area in Central Texas has been cited as the locus of greatest hazard from large flood-producing storms in the conterminous United States (Hoyt and Langbein, 1955).

Extraordinary climatic events notwithstanding, average values of rainfall give a rational basis for predicting erosion rates, water supply, water quality, and crop suitability. The seasonal temperature ranges and the length of growing seasons affect recreational activities as well as agricultural endeavors.

GEOLOGIC SETTING

The rocks and sediments exposed in the CAPCO region vary markedly from west to east (fig. 5). In the westernmost part of the region, which consists of a complex assemblage of Precambrian igneous and metamorphic rocks, bedrock is among the most ancient in Texas (table 1). Locally, Paleozoic limestone, sandstone, and shale strata are juxtaposed against the resistant masses of crystalline rock (fig. 6). Rocks are progressively younger southeastward or southward through the region; hence, the faulted and folded Paleozoic strata are overlain by Mesozoic (Cretaceous) limestones and other rock types that make up the Central Texas Hill Country.

Table 1. Geologic age and duration of the major subdivisions (eras) of geologic time (numbers indicate millions of years before present).

Name of era	Time span
Cenozoic	70 to present
Mesozoic*	225 to 70
Paleozoic	600 to 225
Precambrian	Prior to 600

*The Cretaceous Period is part of the Mesozoic Era extending from about 135 to 70 million years before present. During this time, the rocks of the Hill Country and the inner Gulf Coastal Plain were formed.

The Cretaceous rocks are displaced in the Balcones Fault Zone at the eastern edge of the Hill Country. Older, more resistant limestones occur on the Hill Country (up) side of the fault zone, and younger, less resistant chalks and clays occur

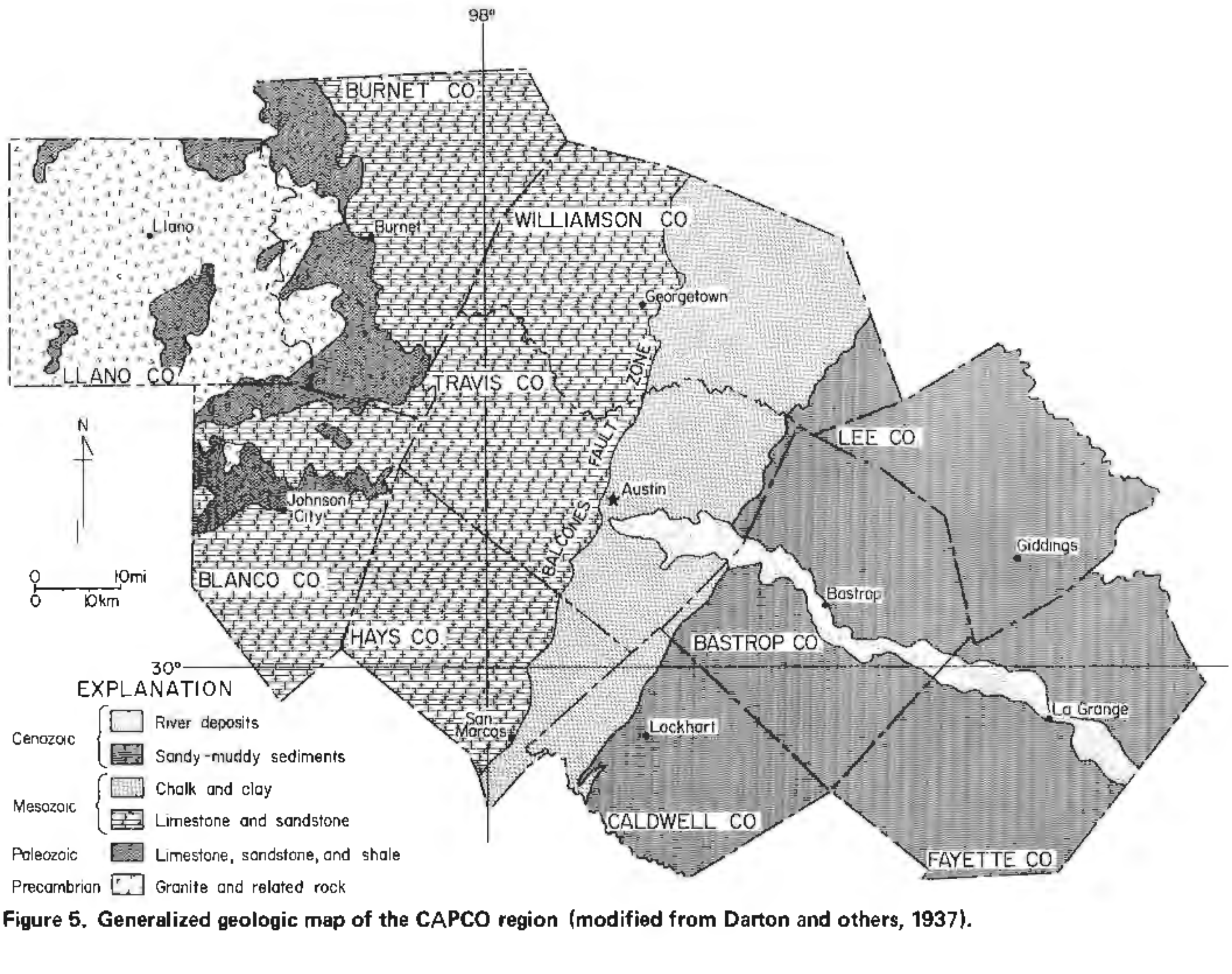

Figure 5. Generalized geologic map of the CAPCO region (modified from Darton and others, 1937).

on the Coastal Plain (down) side (fig. 6). The clays on the downthrown side of the faults are parent materials for the rich, black clay soils of the Blackland Prairie. Farther east, Cretaceous clays are overlain by younger Cenozoic strata consisting of gently tilted sand and mud deposits of the Gulf Coastal Plain. Very young (Cenozoic) river-laid deposits of sand, gravel, and mud locally overlie all other types of bedrock within the region. These relatively thin deposits are especially prominent within major river valleys such as that of the Colorado River.

The importance of subsurface variations in rock types is illustrated by the different depths at which water-bearing strata are found within the region. For example, the "Trinity Sands" aquifer lies close to the surface beneath the Hill Country, whereas, because of displacement associated with Balcones faulting, these same water-bearing strata lie several hundred feet deeper beneath the fertile Blacklands. Thus, towns and farms across the Blacklands must drill deep wells to obtain adequate water supply, whereas the ranches scattered in the Hill Country often need only relatively shallow wells to obtain abundant flows.

In summary, geologic data provide a key to understanding many phenomena that occur at the earth's surface as well as changes beneath its surface. Additionally, geologic information gives clues to the location of mineral resources (fig. 7) and ground-water supplies and provides a basis for understanding landforms, soils, and vegetative assemblages.

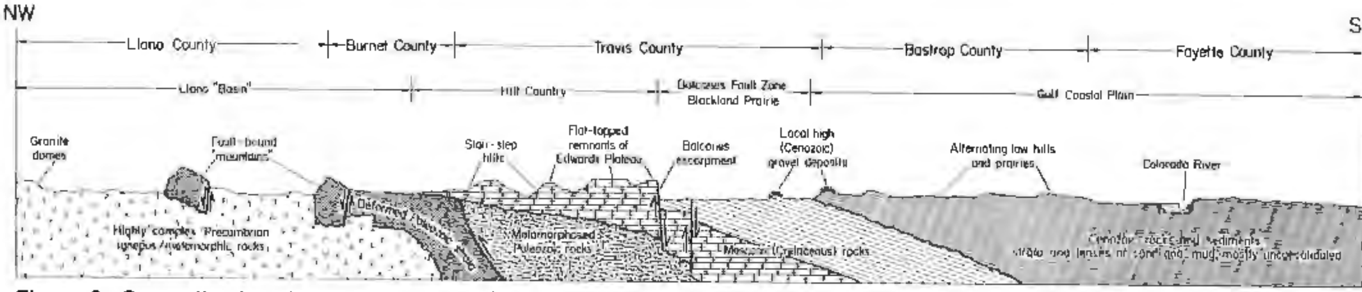

Figure 6. Generalized geologic cross section (northwest to southeast) of the CAPCO region.

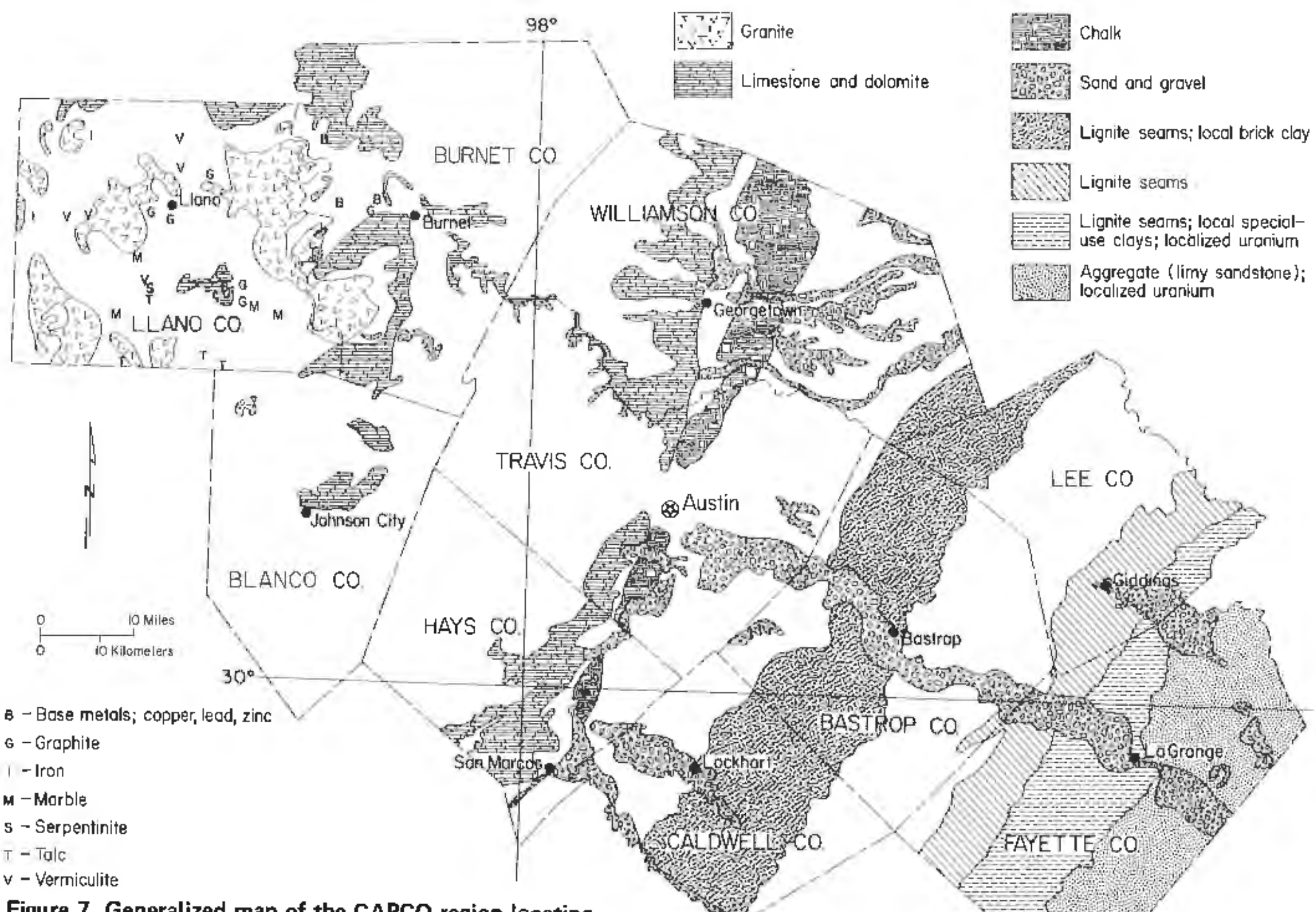

Figure 7. Generalized map of the CAPCO region locating potential near-surface economic mineral deposits (modified from Evans and others, in preparation).

PHYSIOGRAPHIC SETTING

Geology and physiography (which, broadly defined, is landscape) are closely related. The physiographic provinces of the CAPCO region are the Llano Basin, the Hill Country - Edwards Plateau, the Balcones Escarpment, the Blackland Prairie, the Gulf Coastal Plain, and the Colorado River Basin (fig. 8). The highest elevations in the CAPCO region are in its westernmost parts, and elevations become progressively lower toward the Gulf coast. The greatest relief (change in elevation within an area) is also in the western part of the region.

The Llano Basin is generally an upland (high elevation) area of low to moderate relief, but there are isolated areas of steep slopes and very high relief. Especially noteworthy are the granitic domes and "mountains" of fault-displaced Paleozoic sedimentary rocks. Streams occupy broad lowlands throughout much of the granitic terrane, but they commonly incise the strata that rim the lowlands, thereby forming steep-walled valleys.

The Hill Country - Edwards Plateau province is mostly an area of high relief and steep slopes that forms a highland area around the Llano Basin. Many of the streams in this area are entrenched in narrow valleys or "canyons"; however, there are also flat-topped remnants of the once more extensive Edwards Plateau.

The Balcones Escarpment marks a significant change in physiography along the Balcones Fault Zone. The relief is more than 300 feet (91.5 m) in the southern and central parts of the fault zone, though the escarpment is less pronounced to the north. The Balcones Escarpment marks a change, not only in geology and physiography, but also in culture. As pointed out by Flawn (1964), this line of hills marks the cultural break between the cotton economy of the Old South and the ranching and cattle economy of the Old West.

The Blackland Prairie is characterized by low, rolling hills on a predominantly limy-clay substrate, and by subdued relief and low slopes that contrast with the Hill Country on the western side of the escarpment.

The Gulf Coastal Plain consists of a series of dissected, tree-covered low hills and ridges alternating with low-relief prairies in a general coastward (southeast) direction. The low hills generally occur where sand is the bedrock type, whereas clay strata underlie prairies. High gravel terraces locally cap hills throughout the Coastal Plain.

The Colorado River Basin is a broad, extremely low relief alluvial plain. Although the river valley traverses the entire length of the CAPCO region, it first becomes sufficiently wide to be designated as a separate physiographic area southeast of the Balcones Escarpment, where easily erodible sediments occur.

In summary, landforms develop as a result of complex but understandable and predictable interactions between geologic substrate and climate. Erosion and deposition by streams are the dominant processes shaping the land in the CAPCO region. Different types of bedrock respond to these processes in different ways, resulting in a diverse array of hills and valleys and plains, which reflect local geologic and climatic conditions.

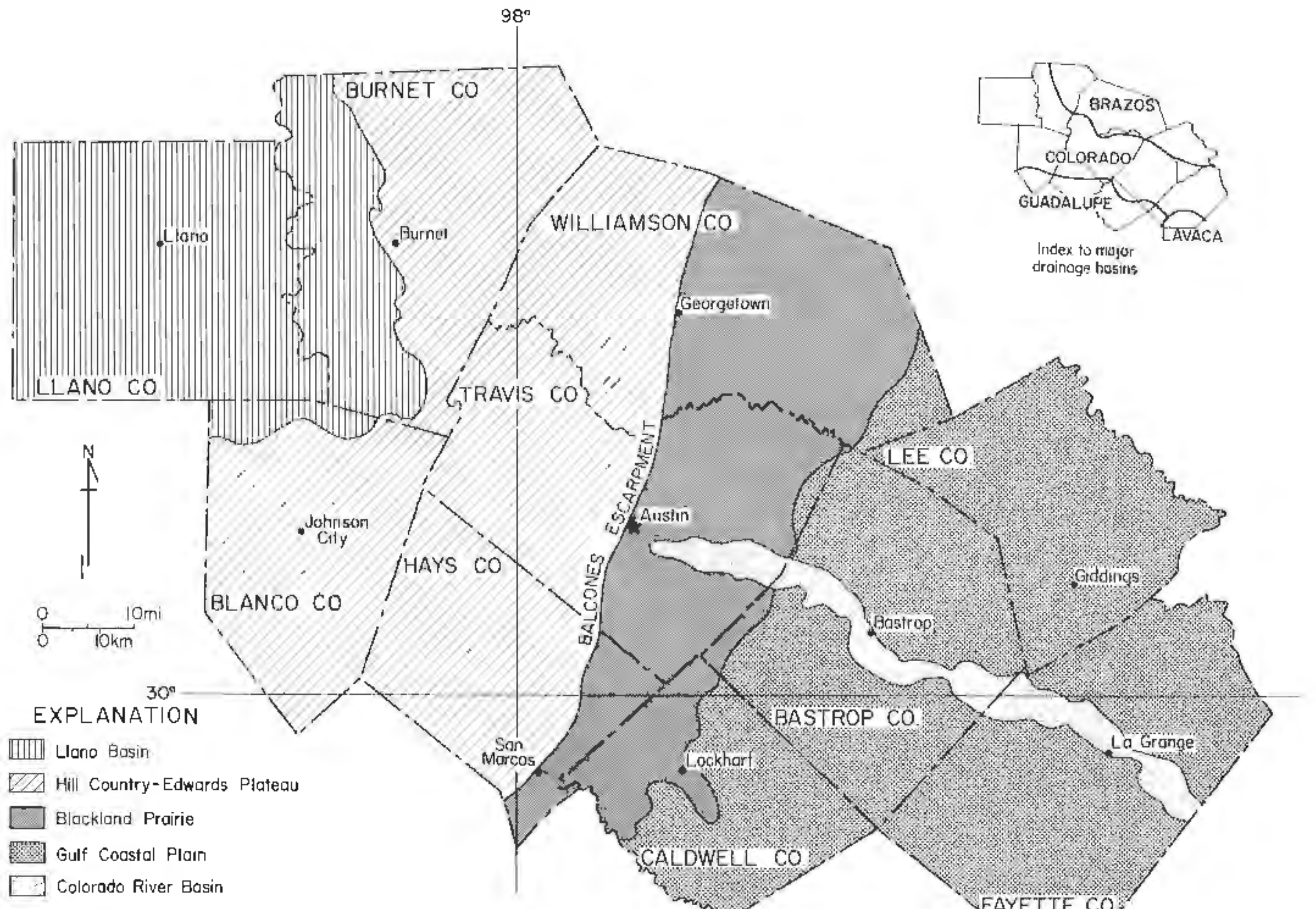

Figure 8. Generalized physiographic provinces in the CAPCO region.

WATER

Water is both a vital resource and an agent of geologic processes. In this dual role, water is important to inhabitants, because it can be a sustainer of life as well as a menace to life and property. The quantity and quality of *water—the-resource* (surface and ground water) as well as the activity of *water—the-agent-of-processes* (mainly flooding) result from complex interactions of climate, geologic setting, physiography, vegetation assemblages, soils, and land use practices.

Drinking water is obtained from surface streams and lakes as well as from underground accumulations in porous and permeable rock bodies called *aquifers.* Surface-water supplies are easily noted on a map as a network of streams and lakes. Ground-water supplies, on the other hand, are usually not evident to the untrained person, even though in most places ground water constitutes the bulk of potentially available fresh water.

Parts of four major drainage basins occur in the CAPCO region (fig. 8). Each drainage basin is a coherent unit in which water follows a predictable course determined by the network of stream channels. Thus, if Colorado River water is polluted upstream, it must become purified through natural or other means before it can be used at points downstream. Likewise, if a flood occurs in the headwaters of a stream system, the effects will eventually be felt downstream, although these effects may be moderated by natural factors or by technological restraints such as dams.

Depending on the conditions of bedrock and terrain, surface water locally feeds (recharges) underlying aquifers; elsewhere springs issue forth to sustain surface-water flow. Both conditions occur in various areas within the CAPCO region. For example, surface streams locally feed the Edwards aquifer system, while elsewhere spring discharge from the Edwards aquifer augments stream flow. Ground water, however, must usually be tapped by wells and pumped to the surface, and this is a common method used in the CAPCO region to supply homes and communities with water.

Maintenance of optimum water quality in both surface- and ground-water bodies is vital to protecting water resources. An understanding of the relations between a surface-water body and its surroundings is important in protecting water quality; the same is true of ground water, but because it is an unseen resource, the factors affecting water quality are subtle and often misunderstood. In an aquifer recharge zone, water or wastes out of sight should not be out of mind. Special care must be taken to maintain the quality of water that infiltrates water-bearing substrate.

SOILS

Soil variations depend on numerous interacting factors, including bedrock, climate, topography, vegetation, and, to some extent, time or age (fig. 9). As a result of these interacting factors, a close relation can be seen between generalized soil associations (fig. 10) and the regional geologic and physiographic settings (figs. 5 and 8).

There are five basic types of soils in the CAPCO region (fig. 10). The Llano topographic basin displays a loamy, stony topsoil of variable thickness above a clayey subsoil that overlies mostly weathered, hard bedrock. Very thin stony, clayey, and loamy soils, which overlie limestone, characterize

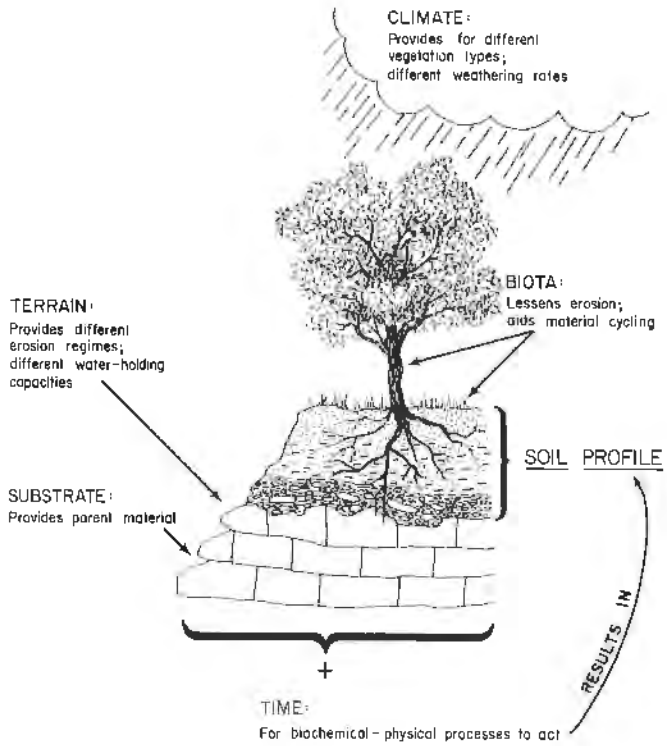

Figure 9. Natural factors that contribute to formation of a soil profile.

the Hill Country. The Blackland Prairie soils, deep, dark calcareous clays that overlie clay, marl, chalk, or gravel substrate, are the most fertile soils in the region. Most of the soils of the Gulf Coastal Plain have moderately thick, sandy, or loamy surface horizons over a clayey subsoil. These soils are similar to much of the cover in the Llano area, but they differ because they occur over the soft sediments typical of the Coastal Plain in contrast to the predominantly hard rock substrate of the Llano area. Soils in the southeastern extremity of the Coastal Plain are similar to those of the Blackland Prairie, where deep, fertile, waxy clay soils overlie limy substrate. Soils in the Colorado River bottomlands consist of thick, loamy (locally clayey) materials overlying unconsolidated river terrace and floodplain deposits.

Besides supporting plant life and providing foundation material, soils are also important for maintaining water quality. Water that percolates through soil may recharge ground-water supplies, support plant growth, or feed surface stream flow. In all instances, however, water quality is changed by various physical, chemical, and biological processes. Soil filters many undesirable ingredients out of wastewater, and this capability is basic to the design of septic-tank systems for domestic wastewater treatment. Thus, in many places, soil thickness and texture are important criteria in planning effective domestic waste-disposal systems.

VEGETATION

Natural vegetation is directly related to soil types and climate and depends indirectly on geologic setting and physiography. Therefore, natural vegetation associations (fig.11) reflect the generalized soil types (fig. 10), underlying bedrock

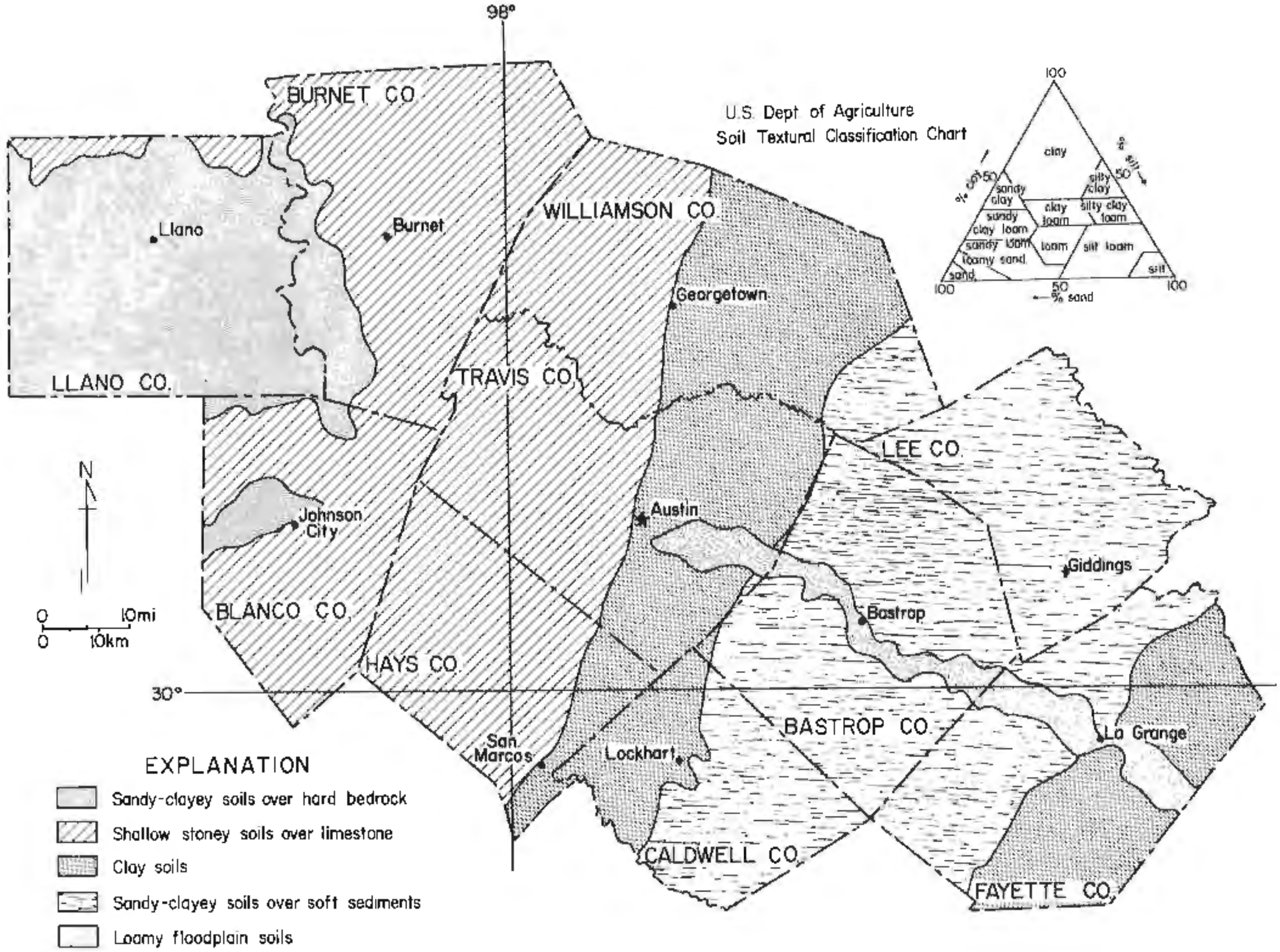

Figure 10. Generalized soil associations in the CAPCO region (modified from U. S. Geological Survey, 1970, and Godfrey and others, 1973).

(fig. 5), and physiography (fig. 8) as mapped in the CAPCO region. People generally have altered the natural vegetative setting, so that few truly "natural" vegetative stands survive; thus, the associations mapped here are termed *potential* natural vegetation associations (Küchler, 1974).

The Llano area consists mainly of a mesquite-oak grassland, or savanna. Generally, mesquite trees grow on clayey soil, whereas deciduous oaks such as post oaks and Spanish oaks grow on sandy soil. Live oak trees constitute another widespread type of vegetation in the Llano area, and dense stands of brush (white bush, varieties of acacia, and scrub juniper) cover areas with steep slopes or thin and stony soils.

The Hill Country and Edwards Plateau support mainly scrub juniper, live oak, and grasses. Although juniper and live oak trees characterize this limestone terrane, other common tree varieties are sumac, Spanish oak, elm, and Mexican persimmon.

The Blackland Prairie, as the name suggests, was originally a savanna, or grassland containing isolated mottes (groves) of live oak trees. Many of these grassland areas are now cultivated, although there are remnant live oak mottes and some encroachments of mesquite.

The Gulf Coastal Plain consists of three vegetative provinces. One province is composed of (a) an assemblage of deciduous oaks, yaupon, hackberries, elms, hickories, junipers, where sandy substrates predominate, and (b) intervening areas of prairie vegetation (mesquite trees and grasses) on muddy substrates. The second province is dominated by longleaf pines growing on the sand hills near Bastrop. These pines are probably a relict of a belt formerly continuous with the East Texas Piney Woods (Tharp, 1939). The third province in the southeasternmost fringe of the region is characterized by a live oak savanna that is similar in vegetation, soils, and bedrock to the Blackland Prairie.

Although now largely cleared and used as cropland or pasture, the Colorado River bottomland in its unaltered state supports a mixed stand of large deciduous trees. These include various types of oaks, as well as cottonwood, willow, sycamore, bald cypress, and pecan trees. This distinctive vegetative suite also characterizes other stream bottomlands throughout the region.

Natural vegetative assemblages reflect the capacity of the land to support agricultural endeavors. Generally, savanna and prairie vegetative associations (grasslands with some mesquite and local oak mottes) denote clayey soils that are superior for cultivation. The areas supporting deciduous oak, hickory, and longleaf pine trees are generally incapable of supporting intensive cultivation because soils in such areas are sandy and commonly leached of nutrients. Juniper - live oak assemblages typically occur on rocky soils that are poorly suited for cultivation.

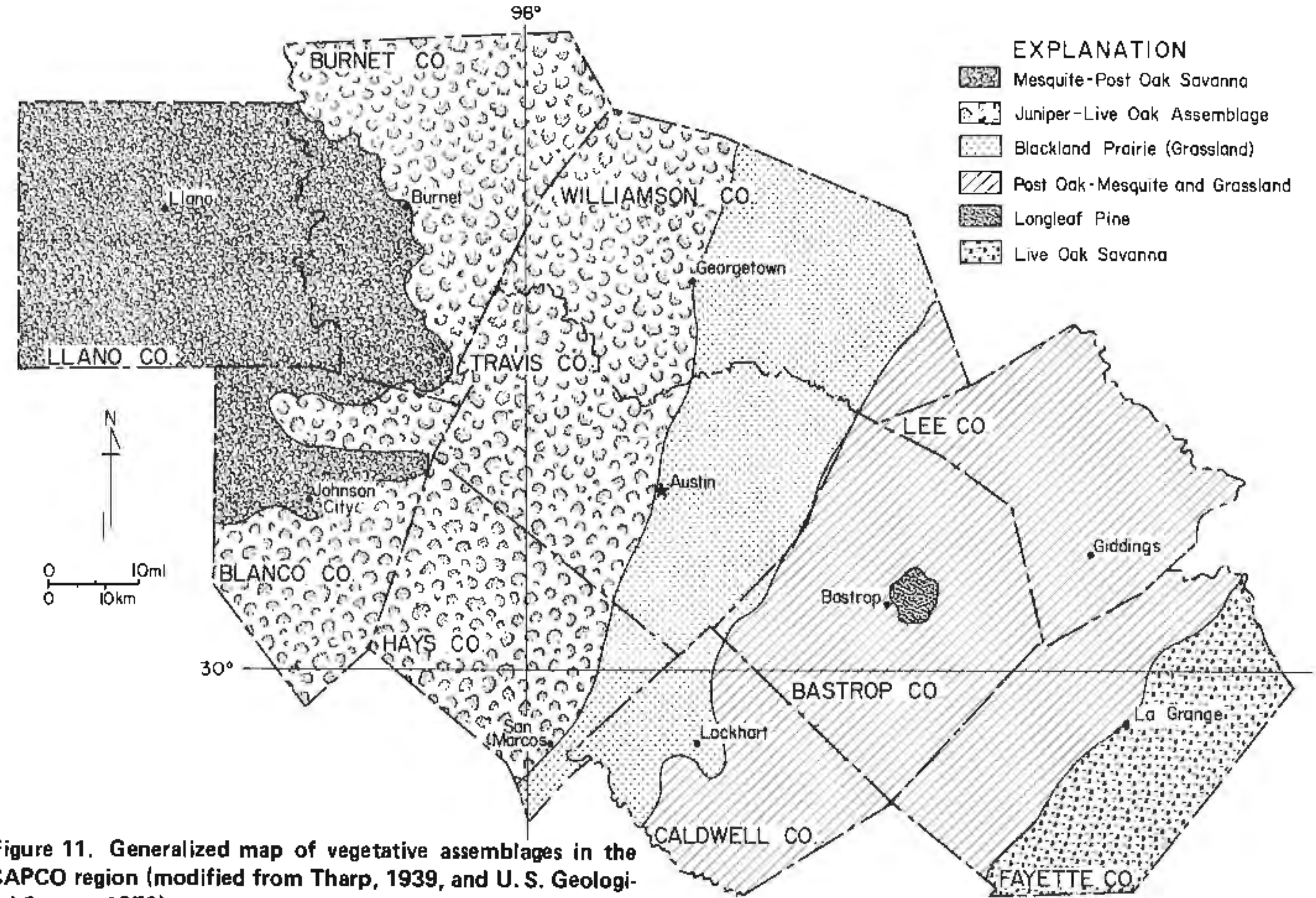

Figure 11. Generalized map of vegetative assemblages in the CAPCO region (modified from Tharp, 1939, and U. S. Geological Survey, 1970).

SUMMARY OF REGIONAL ENVIRONMENTAL FEATURES: NATURAL RESOURCE AREAS

The boundaries of the generalized units, which represent climate, geology, physiography, soils, vegetation, water, and minerals on the schematic maps, show a pronounced similarity throughout most of the CAPCO region. These close relationships among the various facets of the land are not surprising because the environmental (land) components interact. Bedrock and climate are usually the basic determinants used in defining the characteristics of the land, and these fundamental resources account for landforms, water regimes (processes), soils, and vegetative assemblages. Interactions among the various environmental facets provide a means for subdividing the CAPCO region into *natural resource areas* (fig. 12). Each natural resource area is distinctly different from adjacent ones, even though any area may contain a great variety of bedrock, landforms, or soils within its boundaries. Each area has a distinctive overall potential for sustaining human activities; thus, each has a different population density. Moreover, distinctive aesthetic and educational attributes make each area important regardless of economic value.

In short, natural resource areas are informal subdivisions of the complex CAPCO region; they are based on natural variables rather than political boundaries so that they provide a means for considering the region in terms of similar kinds of land. This, in turn, allows a better understanding of the distribution of units on the Land Resources Map of the region, even though the boundaries of the natural areas are not necessarily identical to the boundaries of individual land resource units.

The names given to the five natural resource areas in the CAPCO region are (1) the Llano area, (2) the Hill Country, (3) the Balcones/Blackland area, (4) the Coastal Plain, and (5) the Colorado River Valley. Following an introduction to and brief explanation of the Land Resources Map, each area will be discussed more fully to summarize the overall capabilities and potentials of the land.

Land Resources Map

GENERAL

The Land Resources Map of the CAPCO region contains 24 units, which are subdivided into two major groups: process units and material-landform units. This distinction is based on specific characteristics of the land that influence human uses at a particular locality. For example, on a floodplain, recurrent flooding largely eclipses the importance of either substrate or landform. On a ridge crest or mountain top, the slope and other conditions of the terrain are generally more important in delineating map units than are processes or substrate.

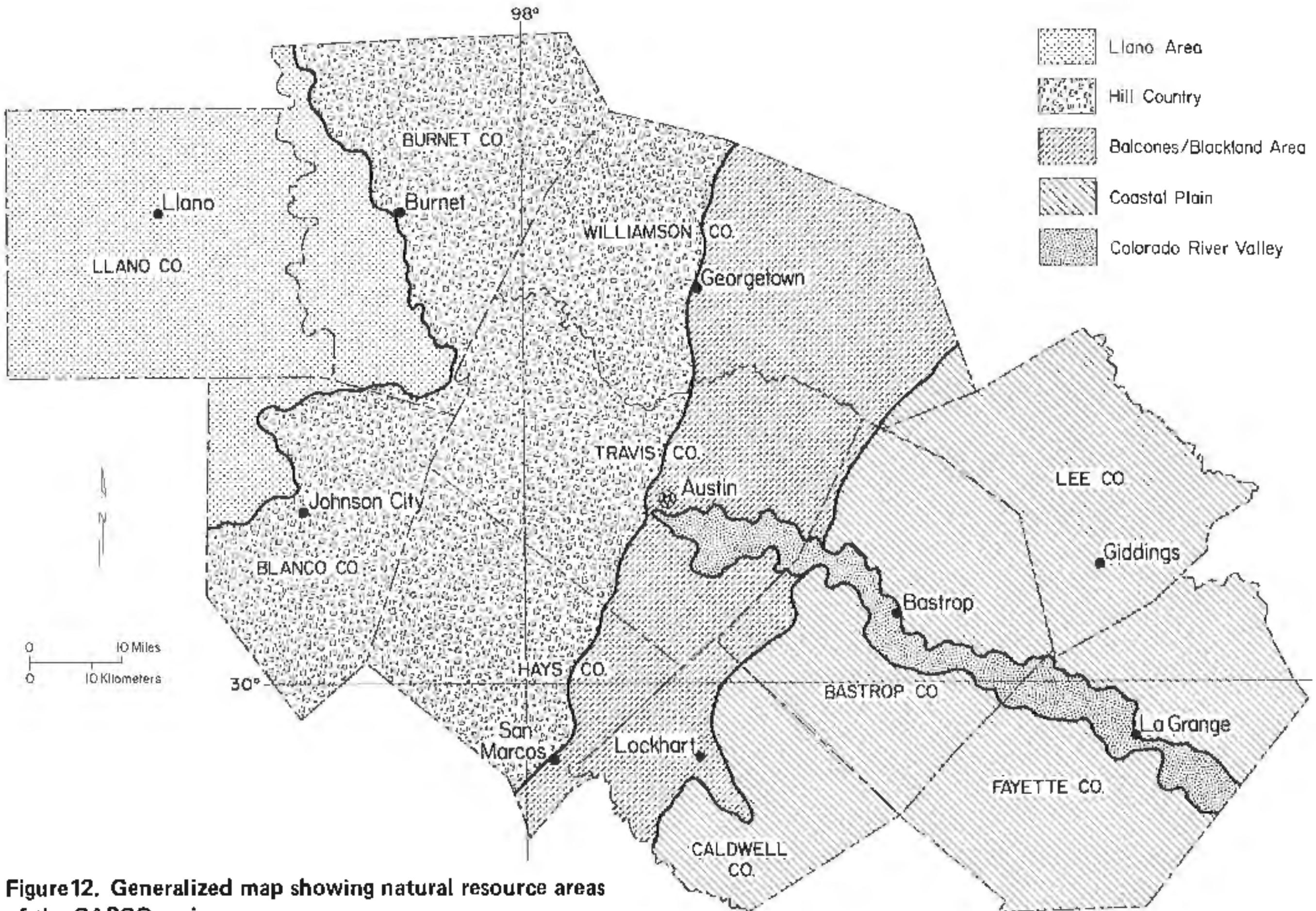

Figure 12. Generalized map showing natural resource areas of the CAPCO region.

Process units include those areas where the land is subject to ongoing or recurring natural events that slowly or dramatically modify the land and impose restrictions on specific human activities. Some processes, such as flooding and slope failure, may be hazardous to human life and property. Other less obvious processes, such as recharge of waters into an aquifer, are beneficial to mankind.

Material-landform units, too, may be subject to processes such as runoff, erosion, infiltration, and even local flooding, but the geographic extent, frequency of recurrence, or magnitude of effects of these processes are not the principal factors affecting various uses. Instead, conditions of bedrock or soils or characteristics of landforms combine to form distinctive associations mapped as material-landform units.

The CAPCO region comprises 9 process units and 15 material-landform units. Each of these divisions is further broken down into suites of units which are defined by similarities among the individual units. Thus, there is a surface-water process suite, an aquifer suite, and a slope process suite, all of which are under the broader *process* heading. Four suites compose the material-landform units: surface deposits, igneous-metamorphic rocks, limestones, and claystone-sandstones. This classification scheme was developed as an aid in using the map. Each of the suites is distinguished by a particular range of colors that facilitates recognition of similar land types. For example, among process units the surface-water process suite is depicted in shades of yellow, the aquifer suite in various tints of blue, and the slope process suite in tints of pink. The material-landform units are similarly depicted: the surface deposit suite is shown in orange and rust-colored tones; the igneous-metamorphic rocks are depicted by purples and bright red; the limestone suite is shown by various hues of green and the claystone-sandstone suite by different shades of brown and tan.

For reference and as an additional aid to map use, each process unit is designated by a simple code of combined letters and numerals, such as P1 through P9. Material-landform units are coded M1 through M15. These codes are used both in the text and on the map.

Three tabular displays provide a summary of each map unit. Plate 1 represents each map unit in terms of processes, materials, and landforms—as well as distinctive soil assemblages. Plate 2 presents each land resource unit in terms of generalized engineering properties that may affect human activities. These properties are slope stability, foundation strength, shrink-swell potential, excavation potential, corrosion potential, and permeability. Plate 3 provides simplified predictions of land capabilities. That is, the land resource units are cross-matched in a tabular matrix with selected uses and activities. These include septic tank performance, sanitary landfill operation, feedlot operation, light construction (such as single-family dwellings), heavy construction (any structure more massive than a small building), recreational activity, containment of ponds and lakes, and extraction of rock and mineral resources. Judgments on relative suitabilities for these uses are indicated by pluses, minuses, or zeros placed in each box of the matrix.

The Land Resources Map is presented at a scale of 1:250,000. This means that one increment of length (for example, 1 inch) equals 250,000 equal increments (that is, 250,000 inches) on the ground. Thus, 1 inch on the map is equivalent to approximately 4 miles on the ground.

LAND RESOURCES MAP UNITS

The mapping process included a ranking of land resource units that reflects the immediacy or severity of possible constraints. Process-dominated units are the most important indicators of immediate or long-term potential impact on human health or safety. For example, within the larger process category the surface-water process suite is assumed to have greater impact than does the aquifer suite. This is reflected on the map in parts of the Hill Country where stream bottoms constitute the main recharge areas but are mapped as Flood-Prone Areas because the recurrent flood hazard there is deemed more critical.

Process Units

SURFACE-WATER PROCESS SUITE

The surface-water suite contains two units that were mapped along streams across the entire region: Flood-Prone Areas (P1) and Valley Bottoms (P2). Both units demand special attention because they include the areas of most severe and immediate threat to human life and property in the CAPCO region. However, a variety of processes other than flooding and a diversity of materials or landforms occur within the boundaries of these units (pls. 1 and 2). Because of map scale (1 inch equals 4 miles), not all areas subject to flooding could be shown. Thus, some floodplains occur beyond the areas mapped here as flood-prone or as valley bottoms.

Despite their flood potential, areas represented by the surface-water process units are ideally suited for certain uses. Many of these areas have gentle slopes, stable substrate materials, and thick, well-drained, fertile soil that is ideal for cultivation. The river-sorted alluvium that commonly constitutes floodplains is a much needed construction material resource, so that mineral extraction is a potential use of this unit. Recreation is another human activity that may be naturally sustained by using some flood-prone areas as parks and greenbelts.

If dangers were mitigated, some areas subject to flooding could serve as residential, industrial, or commercial sites. But abatement of flood hazards by constructing dams or levees or by modifying local stream courses is always costly. Moreover, for all its cost, flood prevention is never absolute; there is always the danger of flood waters' exceeding the design of flood-prevention structures (Leopold, 1977). Indeed, much damage resulting from the flood of 1972 in New Braunfels, Texas, occurred on a so-called "safe" floodplain—an area supposedly protected by Canyon Dam. In other examples, channel-straightening procedures commonly worsen floods and increase erosion downstream, thus merely transferring the hazard to another location.

Even on the uplands away from the floodplains some human activities can cause flooding of nearby streams. For example, large areas of pavement or closely spaced buildings cause more runoff and less infiltration immediately after rainfall. This, in turn, may lead to flooding after a moderate rainfall. Similarly, upland erosion, rock or mineral extraction, or unwise construction practices may increase the amount of coarse sediment within a stream channel, choking the channel with debris and increasing the risk of flooding.

AQUIFER SUITE

The aquifer suite consists of five units: Limestone Recharge Areas (P3), Upland Sandstone Recharge Areas (P4), Mixed Rock Recharge Areas (P5), Sand and Sandstone Recharge Areas (P6), and Coastal Plain Recharge Areas (P7). These units have diverse substrate properties (pl. 2) as well as varied terrain, and they occur across the entire CAPCO region. Even though some infiltration of surface waters occurs in almost all areas, aquifer recharge units are distinguished by the large volumes of water that are received and stored by underground rock bodies. A recharge zone is an area where aquifers occur at the ground surface; most areas where aquifers are tapped by wells are underground extensions of the recharge zone. Most recharge areas do not impose engineering-structural constraints on construction (pl. 2) nor do processes of water transfer and storage usually pose immediate hazards to human life or property. Instead, problems with the aquifer suite relate mainly to issues of public health. Maintenance of ground-water resources involves managing both the amount and the quality of water stored in aquifers. Thus, careful consideration must be given to activities in either the recharge or the discharge zones of the aquifer that might diminish the quality or availability of this water resource. Overpumping will eventually cause outright consumption of the water. Similarly, unwise land use practices on the recharge zone might adversely affect water quality so as to effectively destroy the value of a ground-water resource (pl. 3).

In the CAPCO region both sandstone and limestone aquifers occur, and these two types of aquifers have markedly different properties. In most sandstone aquifers, water flows through very small, tortuous pore spaces between sand grains rather than through large open channels, whereas porosity within limestone bedrock is commonly developed erratically; grain-to-grain openings are few or poorly developed or occur only locally. However, limestones are slightly soluble in rainwater; hence, fractures, fossil casts, and other openings eventually become enlarged by dissolution. These become conduits for ground-water flow and may develop into a network of large, interconnected caverns. Although the total volume of cavernous porosity may be small compared with the total volume of rock, these relatively large openings are efficient transmitters of water. Consequently, a limestone aquifer can be recharged or deleted more rapidly than a sandstone aquifer.

The differences in properties of limestone and sandstone aquifers affect the potential uses of both kinds of terrane. Thin soils, caves, and consequent rapid recharge into limestone result in insufficient aeration and filtration that would otherwise upgrade low-quality waters. Thus, a limestone terrane is more sensitive than a sandstone aquifer to the effects of pollution.

Streams that cross limestone aquifers are typically dry or nearly dry during periods between rains, as they lose most of their water to the underlying aquifer. In fact, a large percentage of recharge into the limestone aquifers occurs along these streams even though these areas are mainly denoted as Flood-Prone Areas or Valley Bottoms on the Land Resources Map. This seeming discrepancy has been clarified by ranking the map units; Flood-Prone Areas or Valley Bottoms have a higher priority for presentation than aquifer recharge areas wherever the two processes overlap.

Certain aquifers in the CAPCO region consist of a mixture of bedrock types, and these areas may sustain a diversity of uses. For example, within the Mixed Rock Recharge Areas and the Coastal Plain Recharge Areas, there are clay strata, the properties of which are notably different from adjacent sandstone or limestone beds. Thus, because of lower permeabilities of clays compared with sands, water does not infiltrate (recharge) clayey areas within these units. Still, overall caution must be exercised to protect water quality in such mixed-rock terranes.

SLOPE PROCESS SUITE

The slope process suite contains two land resource units: Unstable Limestone and Shale Terrane (P8) and Unstable Clay Terrane (P9). These areas warrant special attention because there the ground may not support the weight of buildings, roads, bridges, or other man-made facilities (pl. 3). The limiting conditions are commonly a combination of adverse terrain conditions, such as steeply sloping ground, and material properties, such as low foundation strength, low slope stability, and high shrink-swell potential (pl. 2).

Because of geologic complexity in the Balcones Fault Zone and because of map scale, all problem areas within the Unstable Limestone and Shale Terrane cannot be precisely delineated. All shale outcrops simply cannot be shown on a map of this scale. The unstable shale strata occur both above and below limestone strata, and areal continuity of these unstable strata is not extensive because of faulting. Yet, instability of a shale unit similar to those present in the Austin vicinity resulted in the failure of the Waco Dam in 1959 (Baylor Geological Society, 1972).

Limestone beds within the Unstable Limestone and Shale Terrane form stable ground where they occur alone, but they form oversteepened bluffs where they occur above the underlying weak clayey shale; areas near these bluffs are especially subject to slope failure (fig. 13). Moreover, the tops of slopes continually adjust by slow soil creep (fig. 14) wherever shale is exposed above the otherwise stable limestone beds.

Farther east, the Unstable Clay Terrane constrains human activities in many ways. Not only does potential for slope failure exist, but erosion readily removes fertile soil, thus precluding most agricultural uses. By contributing to erosion and by lessening slope stability, water runoff and infiltration on this terrane further reduce the potentials for land use. Grazing is essentially the only activity that can be imposed on this terrane without high risk.

a

b

Figure 13. Oversteepened slope where limestone overlies weak shale (a. before failure; b. after failure).

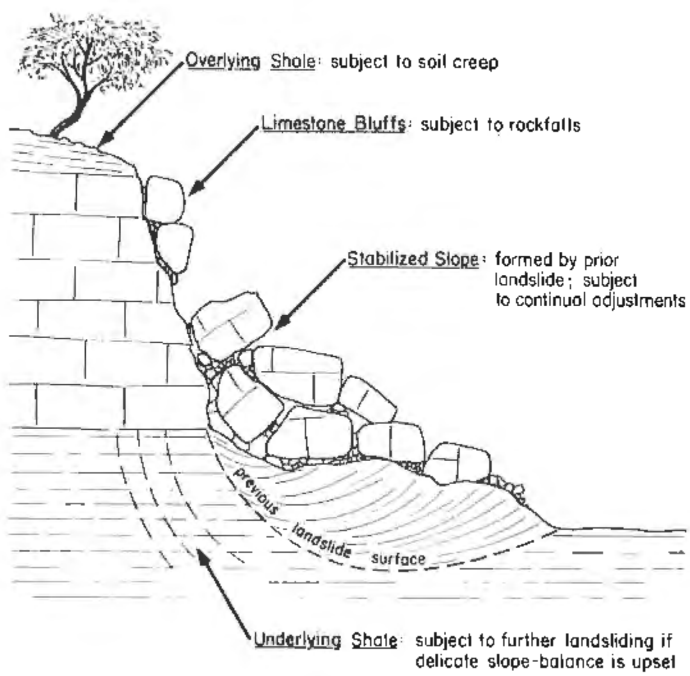

Figure 14. Types of slope failure on Unstable Limestone and Shale Terrane.

Material-Landform Units

SURFACE DEPOSIT SUITE

The surface deposit suite consists of three units: Alluvium and Terrace Deposits (M1), Upland Gravels and Alluvial Plains (M2), and Low-Relief Residuum (M3); examples of these units occur locally throughout the CAPCO region. The units composing the surface deposit suite result from relatively recent erosion, deposition, or weathering at or near the land surface. These deposits are, therefore, relatively thin, tabular veneers overlying diverse bedrock. The materials making up these units are generally granular and poorly cemented. Texture and composition are reflected in the engineering properties of the units. These properties are characterized mainly by high excavation potential and moderate to high permeability values (pl. 2).

Since the lands that are included within the surface deposit suite generally have low slopes and thick, fertile soils, they are particularly valuable agricultural resources. They also are important contributors of aggregate rock products for the construction industry. Even though the units are generally thin (a maximum of about 50 feet thick), they serve as minor aquifers and provide important local water supplies for farms and ranches. Their value as minor aquifers provides the rationale behind many of the use-constraints presented in plate 3.

The properties and terrain of the Alluvium and Terrace Deposits are very similar to the Flood-Prone Areas unit and parts of the Valley Bottom unit; all three units result from recent deposition of sediment by streams and rivers. Alluvium and Terrace Deposits represent former floodplains that are no longer inundated by floodwater because of changes in stream regimes; thus, this unit generally occurs as nearly flat benches adjacent to, but somewhat higher in elevation than, the currently active floodplains.

Upland Gravel and Alluvial Plains are very old stream-laid deposits that occur on uplands far above the present stream levels. In other words, these deposits formed originally in stream valleys, but the rivers have eroded the landscape leaving only remnants of former courses on the uplands. Most of the Upland Gravels and Alluvial Plains occur immediately east of the Balcones Escarpment because resistant gravels characteristic of these alluvial plains are less subject to erosion than are the adjacent mud substrates of the Blackland Prairie.

The Low-Relief Residuum occurs entirely within the Llano area and was formed by weathering of granitic bedrock. Thus, unlike the other members of the surface deposit suite, there has been essentially no transport and subsequent deposition of the individual fragments making up the Low-Relief Residuum. The residuum deposits occur as veneers over resistant granite bedrock that is in places exposed at the surface; generally, however, the depth to bedrock ranges from 15 to 25 feet (4.6 to 7.6 m). Fragments composing Low-Relief Residuum are angular, coarse-grained, pink feldspars and quartz, typical of many Llano granite deposits. Because of sediment characteristics, erosion is a locally significant problem on this terrane, and some streams are choked with weathered granitic detritus.

IGNEOUS-METAMORPHIC ROCK SUITE

The igneous-metamorphic rock suite is composed of rocks that were originally either crystallized from molten material (igneous means derived from fire) or formed by intense heat and pressure, thus changing (metamorphosing), without melting preexisting rocks. This suite of rocks was formed under conditions radically different from those existing at the earth's surface in the CAPCO region today. Most originated deep within the earth or were a result of volcanic eruption; they have been exposed only after long periods of extensive erosion.

Three units on the Land Resources Map constitute the igneous-metamorphic suite: High-Relief Crystalline Rock Terrane (M4), Moderate-Relief Crystalline Rock Terrane (M5), and Basalt Knob (M6). Of these, the High-Relief and Moderate-Relief units occur entirely within the Llano area, whereas the Basalt Knob occurs near the Balcones Escarpment. Terrain conditions constitute the main criteria for distinguishing these igneous-metamorphic units; thus, material properties within each of these units are very diverse (pl. 2). Also, the capability to sustain uses varies markedly, especially within the Moderate-Relief Crystalline Rock Terrane (pl. 3). Most notable among the various activities are the potential for the extraction of economic mineral deposits and the use of scenic, educational (scientific), or recreational resources.

The High-Relief Crystalline Rock Terrane is made up of substrate that is generally granite or related rock types that are very resistant to erosion; characteristic landscapes of this unit commonly are domes or knobs of barren rock extending above surrounding lowlands. There also are, however, lower relief areas that have been dissected by numerous intermittently flowing streams. The dominant process on the hard rock terrane is sheetwash immediately after rains, because thin soil cover, impervious bedrock, and steep slopes preclude any significant infiltration. Slopes are generally stable, but falling rocks may cause problems locally.

The Moderate-Relief Crystalline Rock Terrane includes the most diverse assortment of rock-types and landforms of any land resource unit in the CAPCO region. It is composed mainly of a variety of finely banded metamorphic rock, termed *schist;* the unit also contains marble, serpentinite, gneiss, and igneous rocks similar to granite. Because of its diversity of rock types, this unit contains an assortment of mineral deposits, some of which are potentially valuable. Minerals of economic interest that have been identified in the Llano area include graphite, vermiculite, soapstone (talc), magnetite (iron ore), rare earth deposits, copper, fluorite, asbestos, mica, and even isolated traces of gold and silver (Evans and others, in preparation). There are also occurrences of bulk-rock products, including marble and other ornamental building stone, and aggregate for road-base material.

Basalt Knob occurs entirely in and around Pilot Knob—an area of about 3 square miles (7.8 km^2) south of Austin in the Balcones Fault Zone - Blackland Prairie area. The rocks making up this unit originated from volcanic activity during deposition of the chalky rocks in the Austin area. Although not areally extensive, Basalt Knob is noteworthy as a unique environment in the CAPCO region—an ancient volcanic island. Today, all that remains is hard (basaltic) rock making up the eroded interior (neck) of the volcano and a clay deposit, which is a remnant of weathered volcanic ash. Moreover, some of the limestone deposits adjacent to this knob are similar to reefs that are often associated with modern island volcanos. Thus, this unit is important for reasons beyond its properties of substrate, potential economic minerals, or active processes; it is a significant scientific and educational locality that provides a dramatic clue to part of the geologic history of the region.

LIMESTONE SUITE

Five land resource units compose the limestone suite: Karstic Limestone (M7); High-Relief Interbedded Limestone, Sandstone, and Shale (M8); High- to Moderate-Relief Alternating Beds of Limestone, Dolomite, and Marl (M9); Low-Relief Alternating Beds of Limestone, Dolomite, and Marl (M10); and Chalk/Sandstone Prairie (M11). These units occur throughout the CAPCO-region.

The limestone suite locally contains a diversity of landforms and other rock types besides limestone, including dolomite, chert, marl, chalk, and some sandstones and shales. Nonetheless, the overall composition and properties of the various units in the limestone suite are similar (pl. 2). Moreover, depending on local terrain conditions, soil and vegetative cover are generally similar from one limestone unit to another, regardless of geographic distribution or geologic age of the underlying bedrock. Terrain conditions (slope and relief) vary from one unit to another generally because of large-scale structure or geometry of the constituent rock types, and these terrain differences account for many of the variations in use potential or constraints (pl. 3).

The degree of purity of a limestone rock unit dictates many of its characteristics and potential uses. A high-purity limestone is soluble in rainwater and tends to weather by dissolution, leaving little or no residue to form soil; this process accounts for the thin and stony soils on many limestone terranes that limit agricultural and other uses. The process of weathering by dissolution also results in the formation of caves, thus accounting for underground "plumbing" that provides rapid transport of infiltrated waters. Also, if a limestone consists almost exclusively of the mineral calcite, it may be an economic source of lime, which is a valuable raw material. However, a small amount of impurities will preclude this use.

Locally, Karstic Limestone terrane may have steep slopes (8 to 15 percent), although in many areas Karstic Limestone occupies gently sloping plains pitted with sinkholes similar to Limestone Recharge Areas. The gently sloping plains in the Karstic Limestone unit generally cap hills and plateaus in such a way that infiltrated ground water is not interconnected with the main part of the aquifer. Instead, recharge and ground-water storage occur locally, and discharge occurs from nearby springs, seeps, or shallow wells.

The High-Relief Interbedded Limestone, Sandstone, and Shale unit occurs almost entirely within the Llano area, although some localities are along the western fringes of the Hill Country. Terrain characteristics constitute the major criteria for defining this unit, which is expressed as fault-bound "mountains"—high-relief promontories within the mostly low- to moderate-relief crystalline rock terrane of the Llano area. This unit also contains some moderate relief, low-slope areas which rim the Llano complex. Bedrock consists of a diverse assortment of interbedded limestone, sandstone, and shale. Past deformation due to faulting and folding strongly affects the geometry and the many physical properties of the rocks contained within this unit.

The High- to Moderate-Relief Alternating Beds of Limestone, Dolomite, and Marl unit consists of resistant limestone or dolomite strata that form small bluffs and less resistant marl beds that make up recessive benches. Erosion on these three types of beds has resulted in the "stair-step hills" typical of the Central Texas Hill Country. The Low-Relief Alternating Beds of Limestone, Dolomite, and Marl unit consists of the same three kinds of substrate, so that terrain characteristics are the main criteria whereby these two units are distinguished.

Due to local variability in substrate, physical properties of both "alternating bed" units are expressed as ranges of values (pl. 2). The resistant limestone and dolomite beds have higher slope stability, higher strength, and locally higher permeability than the soft, erodible marl strata. On the other hand, the harder limestone and dolomite interbeds have lower excavation and corrosion potentials compared with the marls. Shrink-swell potential is a property that is not applicable to most of this unit, especially the fraction made up of resistant rocks. However, some degree of shrinking and swelling may occur within the marl units or within the soil cover that is formed on gently sloping parts of the limestone or dolomite strata.

The Chalk/Sandstone Prairie occurs as two separate belts, as can be seen on the map; one lies within the Balcones Escarpment/Blackland area, and the other occurs along the southeastern margin of the CAPCO region. The bedrock that characterizes this unit includes chalk (with some limestone and marl) in the Balcones area and limy sandstone (with some clayey marl) along the southeasternmost part of the region. Despite differences in substrate, however, physical properties in the two areas are generally similar.

Soils formed on Chalk/Sandstone Prairie may be locally more than 4 feet (1.2 m) thick, though in some places this clayey soil may be very thin, and chalk or other limy bedrock may be at the ground surface. The parts of this unit that have thick, clayey soils are a significant agricultural resource. But, since these soils generally have low permeability, low strength, and high shrink-swell properties, the local thickness and texture of these soils adversely affect ground stability conditions.

CLAYSTONE-SANDSTONE SUITE

The claystone-sandstone suite consists of four units: Claystone/Shale Uplands (M12), Clay Rolling Terrane (M13), Sandy Clay Prairie (M14), and Muddy Sand Prairie (M15). These units are similar to each other in many aspects of terrain, processes, vegetation, and bedrock. Moreover, general land conditions within these units are similar to some of the terrane conditions in the Coastal Plain Recharge Areas and in the Sand and Sandstone Recharge Areas. For all of these units, bedrock consists of some combination of claystone (or possibly shale) and sandstone. The components may be alternating beds of nearly pure clay and nearly pure sands within the same unit, or they may be admixed clay-sand beds. Subtle differences in amounts of clay, silt, and sand account for differences in physical properties (pl. 2) as well as most differences in use-potential (pl. 3).

All of these units are notable because they represent land that is generally well suited for solid-waste landfill operations. These are the only localities within the CAPCO region that will sustain this use without costly mitigating measures.

Within the claystone-sandstone suite, only the Claystone/Shale Uplands unit occurs west of the Balcones Escarpment. Its discontinuous fault-bound exposures appear mainly in Burnet County along the upper reaches of Lake Travis or along nearby tributaries to the Colorado River. Although most of the Claystone/Shale Uplands unit consists of clay-sized material that is locally thinly bedded (shale) and locally massive (claystone), there are also lenses of very well cemented sandstone that generally stand out as areas of high topographic relief surrounded by the more easily eroded claystone and shale.

The Clay Rolling Terrane unit makes up most of the Blackland Prairie, one of the most productive agricultural areas in the State. However, the clays making up soil and substrate of this unit are generally weak foundation materials; therefore, the main processes that occur on the Clay Rolling Terrane are landsliding, slumping, shrinking and swelling of soils, and erosion. The low strength and high shrink-swell potential of this soil are evidenced by cracked building foundations and buckled "washboard" roads.

The Sandy Clay Prairie unit occurs exclusively within the Gulf Coastal Plain. It is made up of a series of long, narrow, low-relief prairies, colloquially termed *string prairies,* which appear on the Land Resources Map as narrow belts trending northeast-southwest mainly across Bastrop and Lee Counties, but also across parts of Caldwell and Fayette Counties. Bedrock underlying the Sandy Clay Prairie terrane is mostly clayey but does not have a uniform composition. Instead, substrate is an admixture of muddy sands and sandy muds, with an overall predominance of clay. Expansive clays in both soil and substrate cause the formation of a kind of "microrelief" denoted by tiny ridges and valleys with relief up to 18 inches (45.7 cm) (Gustavson, 1975). This high shrink-swell activity is evidenced by washboard roads, broken foundation slabs, and other damage to man-made facilities.

The Muddy Sand Prairie unit occurs entirely within the Gulf Coastal Plain and consists of varied bedrock types that are represented by three bands occurring mainly across Fayette and Lee Counties on the Land Resources Map. Substrate of the Muddy Sand Prairie consists predominantly of sandy sediments, but these are admixed in varying proportions with different types of clays. Furthermore, some localities contain nearly pure deposits of clay or sands, significant occurrences of lignite (St. Clair and others, 1976), and weathered volcanic ash deposits. Overall terrane conditions of this unit are similar to those of the Coastal Plain Recharge Areas, although some of the land within the Muddy Sand Prairies unit has been so highly eroded that "badlands" topography covers broad hillside areas. Badlands are areas having numerous gullies of low relief but of locally steep slope.

Natural Resource Areas

GENERAL

The five natural resource areas have been described to provide a summary of the diverse resources in the CAPCO region (fig. 12). Moreover, for each natural resource area, a review of overall land conditions and a survey of actual land use practices, problems, and potentials reinforce the premise that *natural features influence the prudent use of land.* This review shows that possible uses of the land are reflected in the varied, successful economic activities of people in the different resource areas.

LLANO AREA

Summary of Natural Conditions

The Llano area makes up about 16 percent of the CAPCO region. It covers 1,340 square miles (3,470 km^2) and includes all of Llano County and parts of Blanco and Burnet Counties (fig. 15). The area is part of a larger geologic/physiographic province (the Central Mineral Region) that extends beyond the CAPCO region into several other counties of Central Texas (fig. 16). Overall population density is low in the Llano area; people are concentrated in the towns of Llano, Marble Falls, and Kingsland, as well as in unincorporated developments along the Highland Lakes.

The landscape of the Llano area is characterized by gently rolling uplands, and ruggedly dissected areas such as high-relief granite domes and other "mountains." The Llano area lies entirely within the Colorado River watershed, and the Colorado River cuts across the easternmost part of this area. However, the Colorado River bottom is now mostly inundated by the man-made Highland Lakes. The Llano River and Sandy Creek are the primary tributaries to the lakes in this area. These streams form broad, sandy watercourses that flow from west to east, and their drainage basins encompass most of the Llano area.

The main types of substrate that define the Llano area are (1) igneous and metamorphic rocks, (2) mixed strata composing the fault-bound highlands, and (3) granite residuum occupying broad, low terrain. Of these, the principal land resource units are Upland Sandstone Recharge Areas; Low-Relief Residuum; High-Relief Crystalline Rock Terrane; Moderate-Relief Crystalline Rock Terrane; and High-Relief Interbedded Limestone, Sandstone, and Shale. There are also other land resource units not unique to the Llano area. They include, among the process units, Flood-Prone Areas; Valley Bottoms; Limestone Recharge Area; and Mixed Rock Recharge Areas. Among material-landform units are Alluvium and Terrace Deposits; one occurrence of Uplands Gravels and Alluvial Plain; Karstic Limestone; High- to Moderate-Relief Alternating Beds of Limestone, Dolomite, and Marl; and Claystone/Shale Uplands.

Potentials and Problems

Land within the Llano area is used mainly for farming and ranching, rock and mineral production, recreation and tourism, and residential development. Ranching is the dominant economic activity in the area, and deer hunting is a major seasonal recreational use of ranch land. In fact, Llano County is the leading county in Texas for deer hunting (Dallas Morning News, 1973). Mineral extraction and residential development, on the other hand, locally supplant ranching and place more intensive demands on the land than does ranching.

Other valuable attributes of the land are the special scenic, scientific, and educational resources that make selected areas premium park land. Examples include granite domes

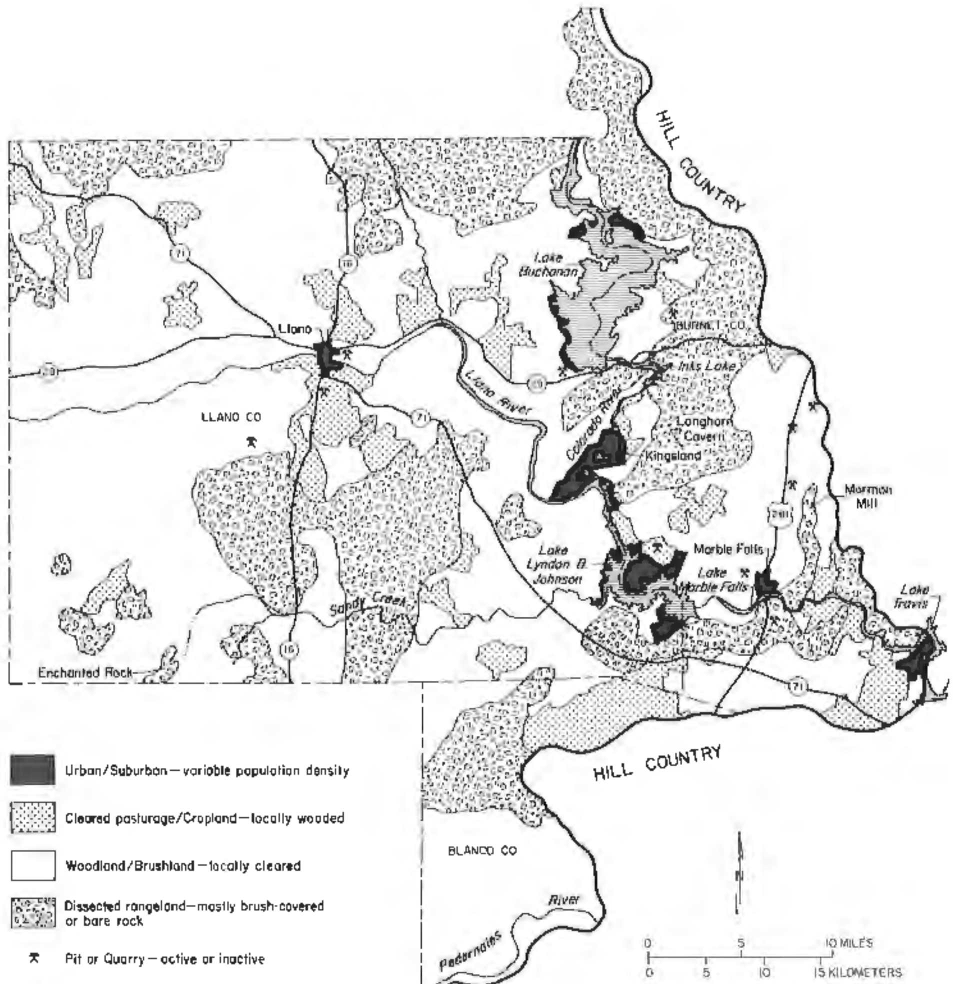

Figure 15. Llano natural area showing generalized land use patterns.

such as Enchanted Rock; the rugged "mountains," such as Packsaddle and Riley Mountains; rock, mineral, and fossil collecting localities; caves such as Longhorn Cavern; scenic stream reaches; waterfalls such as Mormon Mill; and the many areas having noteworthy plant or animal life.

Aside from agricultural problems that arise from local range conditions or from soil characteristics, the major problems associated with using the land in the Llano area relate to either quantity or quality of water supplies. Most of the land in this area provides stable and secure sites for construction, but many intensive uses of the water may deplete local water supplies or harm water quality.

Local water-supply problems exist because much of the bedrock in this natural resource area has very low permeability, so that little underground water is available to feed surface streams during dry periods; many streams flow for only brief periods after rains. Limitations imposed by inadequate water supply greatly hamper many intensive uses of land in areas far from the large man-made lakes on the Colorado River.

Another part of the water-supply issue is water quality. This problem occurs mainly in those intensively used lands along the Highland Lakes and largely relates to the use of septic tanks for domestic waste disposal. Other activities such as mineral extraction, solid-waste disposal, and feedlot operation may adversely affect water quality.

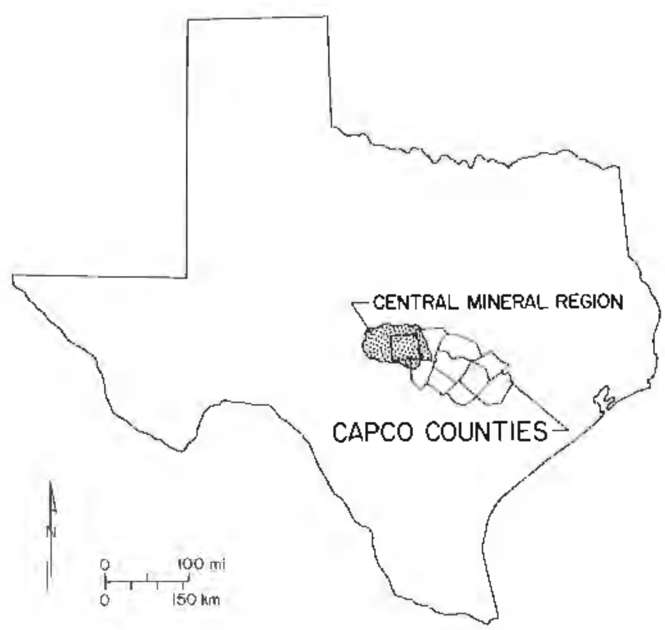

Figure 16. Central Mineral Region—an extension of the Llano area beyond the CAPCO counties.

HILL COUNTRY

Summary of Natural Conditions

The Hill Country is the most extensive natural resource area within the CAPCO region. It covers 3,192 square miles (8,267 km^2), which is about 38 percent of the region, and includes parts of Blanco, Burnet, Hays, Travis, and Williamson Counties (fig. 17). This natural resource area includes parts of two major natural provinces as defined by Hill (1900); the Lampasas Cut Plain, which extends north from the Colorado River, and the dissected parts of the Edwards Plateau to the south (fig. 18). The Hill Country is used mostly as ranching land; therefore, population density there is generally low. As with the Llano area, however, local residential developments are concentrated along the lakes and near towns and cities. Hill Country towns include Burnet, Blanco, Johnson City, and the western parts of Austin, San Marcos, and Georgetown.

The three main types of Hill Country terrain are stream bottoms, dissected hills, and plateau-like uplands (fig. 19). Land resource units representing stream bottoms are Flood-Prone Areas, Valley Bottoms, and Alluvium and Terrace Deposits. The dissected hills are characterized on the Land Resources Map as High-Relief Alternating Beds of Limestone, Dolomite, and Marl and as Low-Relief Alternating Beds of Limestone, Dolomite, and Marl. The plateau-like uplands that occur in the Hill Country are made up mainly of two land resource units: Limestone Recharge Areas and Karstic Limestone.

Although the Hill Country is predominantly a limestone terrane, there are exceptions. Along Lake Travis near the boundary with the Llano area there are occurrences of Claystone/Shale Uplands. Near the boundary with the Balcones/Blacklands area, Unstable Limestone and Shale Terrane and Chalk/Sandstone Prairie also occur.

The Colorado River cuts through the middle of the Hill Country; the Pedernales River is its largest tributary within this area. Other significant Hill Country rivers are the Blanco River (part of the Guadalupe watershed) and the north and south forks of the San Gabriel River (part of the Brazos system).

As in the Llano area, certain localities within the Hill Country are of special scenic or scientific interest; they include caves, springs, waterfalls (Hamilton Pool), incised canyons and other scenic water courses (parts of Blanco and San Gabriel Rivers), and important wildlife habitats ("cedar brakes" that shelter the endangered golden-cheeked warbler).

Potentials and Problems

Most of the Hill Country is currently used as rangeland, which is well suited to the thin soils and generally steep slopes. As in the Llano area, this ranch country supports notable wildlife populations, making seasonal deer hunting an important activity.

The other current uses in the area include rock and mineral extraction and residential development, both of which have a potential for expansion. Mineral extraction is strictly limited by bedrock conditions and proximity to a market for the resource. However, residential development can potentially occur almost anywhere in the area as evidenced by the major expansion of housing developments into the Hill Country along the Highland Lakes west of Austin.

There are now few major water-supply problems in the Hill Country, although such problems could increase with population growth. Currently, water is supplied from surface-water bodies, such as the Highland Lakes, or from aquifers that underlie the area. The western part of the Hill Country is underlain by shallow water-bearing sands; in the eastern part of the Hill Country, wells may tap these same sands at greater depth, or shallow, locally cavernous limestone aquifers may be the water source. However, some ground water is unpalatable because of excessive amounts of dissolved salts, resulting, for example, in "sulfur water" produced by local water wells.

The main problems that result from intensive human occupation of the Hill Country relate more to water quality than to water supply. Some water-quality problems result from natural factors, but most are probably related to human activities. Adverse effects on water quality stem mainly from the use of septic tanks in an area in which thin soils and steep slopes predominate (Woodruff, 1975). In some localities septic-tank effluent may pollute the lake or shallow ground water. In other places, especially near the Balcones Fault Zone, there is the danger of wastewater recharging the cavernous Edwards aquifer.

If the wastewater problems are solved, then the Hill Country can provide stable and scenic homesites. The only other major constraint imposed by the natural setting is possible flooding along stream reaches; however, this problem can be largely overcome by not building along stream bottoms.

BALCONES/BLACKLAND AREA

Summary of Natural Conditions

The Balcones/Blackland area encompasses about 16 percent of the CAPCO region (1,350 square miles or 3,496.5 km^2) and includes parts of Bastrop, Caldwell, Hays, Travis, and Williamson Counties (fig. 20). Municipalities within this area include Austin, Georgetown, Granger, Kyle, Lockhart, Round Rock, San Marcos, and Taylor. The Balcones/Blackland area includes all the land from the Balcones Escarpment on the west to the oak-covered sandy hills that border the Blacklands on the east. It is part of a more extensive Blackland belt that extends beyond the CAPCO region in an arc that almost bisects the State from Uvalde County on the southwest to the area northeast of Dallas (fig. 21). The part of this belt that falls within the CAPCO region is a population center and contains prime agricultural land; it has the highest population density as well as the highest agricultural productivity of any natural resource area within the CAPCO region, and this is due to natural characteristics of the land (Bybee, 1952).

Rocks underlying the area are either limestones, chalks, limy clays, or stream-deposited gravels principally composed of limestone fragments. Various bedrock types are juxtaposed within the complex mosaic of the Balcones Fault Zone in the western part of the area. Thick clay strata or gravel plains compose the Blacklands to the east.

Near the escarpment, the most important geologic control on population patterns has been the presence of a few large springs that served as water supplies and power sources for early settlements. San Marcos Springs in Hays County is the second largest system of springs in Texas; the springs provided water and power that spurred the settlement of San Marcos. Likewise, Barton Springs in Travis County afforded one of the amenities for the original settlement in what is now

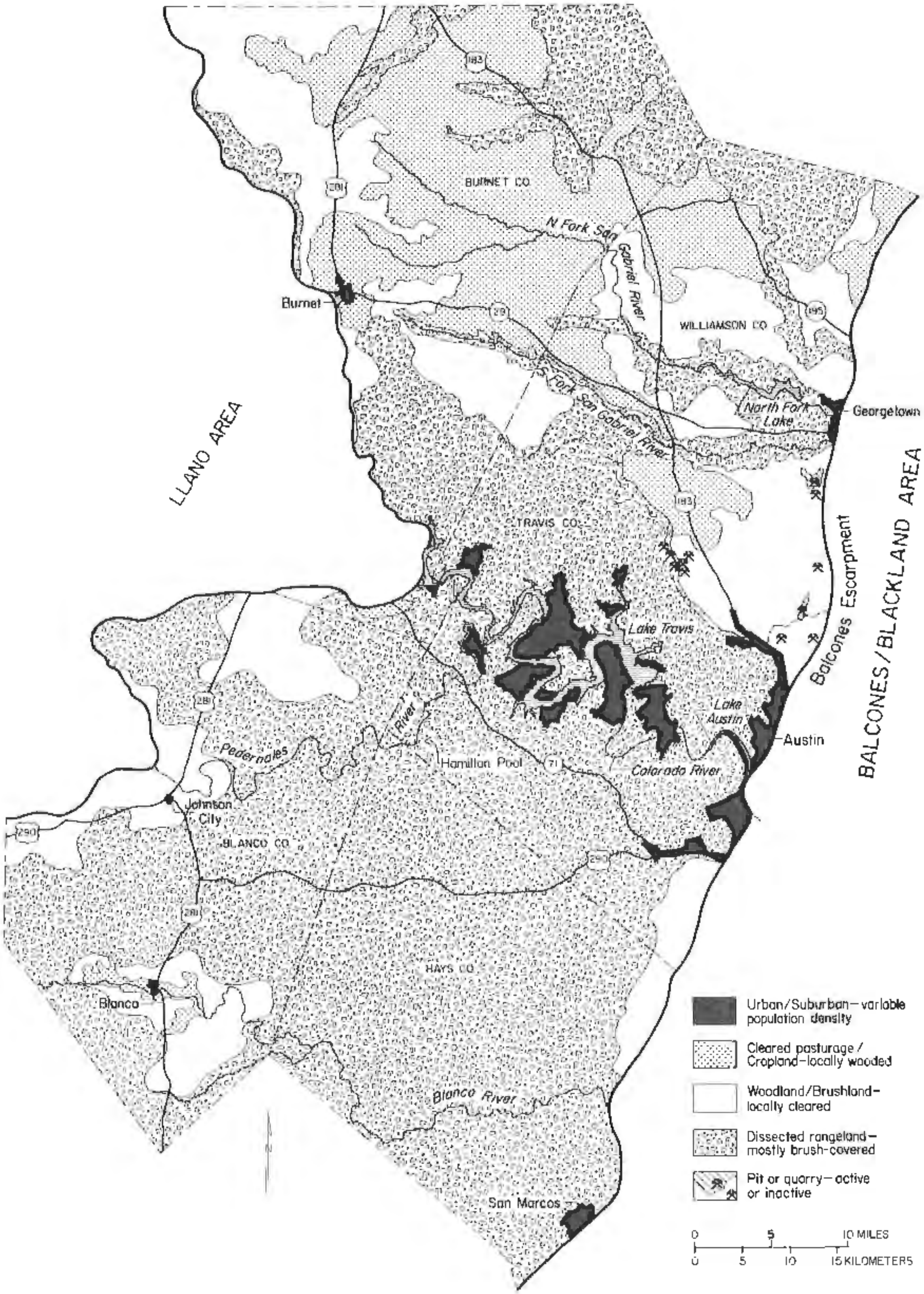

Figure 17. Hill Country natural area showing generalized land use patterns.

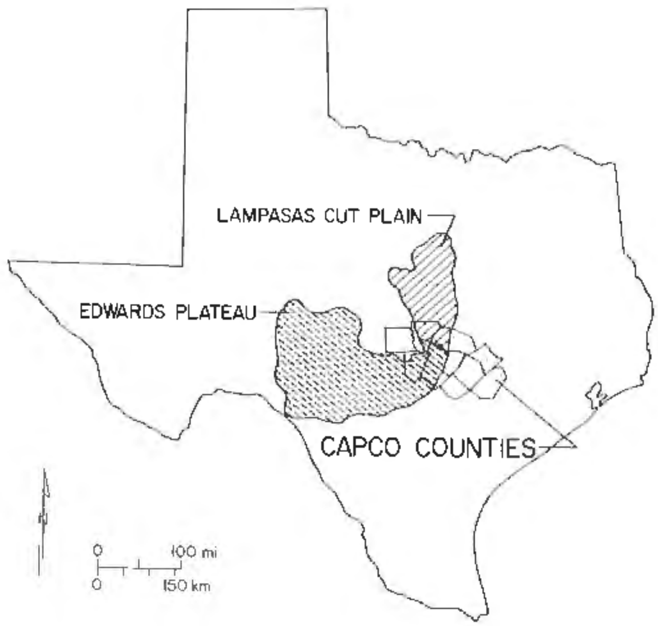

Figure 18. Edwards Plateau and the Lampasas Cut Plain (after Hill, 1900)—extensions of the Hill Country beyond the CAPCO counties.

Figure 19. Oblique areal photograph showing the three characteristic terrain features of the Hill Country: (a) incised stream valleys, (b) dissected hills, and (c) plateau lands (photograph of Guadalupe River in Comal County immediately south of the CAPCO region).

Austin. Other smaller springs, which influenced human occupation along the Balcones Fault Zone, exist near the escarpment elsewhere in Travis, Hays, and Williamson Counties.

Farther east from the escarpment, soil and terrain conditions are also important reasons for the intensive use and subsequent value of this natural area. Especially notable are the thick, waxy, organic-rich, calcareous soils that have formed on underlying clays, marls, and gravels. Nearly flat to gently rolling prairie terrains make the land ideally suited for agriculture. Williamson County, which includes the broadest extent of the Blackland belt, ranks first among all CAPCO counties in total value of agricultural products (Texas Crop and Livestock Reporting Service, 1975).

Land resource units most typical of the Balcones/Blackland area include Unstable Limestone and Shale Terrane and part of the Chalk/Sandstone Prairie, both of which occur within the fault zone adjacent to the escarpment. Farther east, on the Blacklands, typical units include Unstable Clay Terrane, Upland Gravel and Alluvial Plain, and Clay Rolling Terrane. Other units that occur across the Blacklands are (1) Flood-Prone Areas, Valley Bottoms, and Alluvium and Terrace Deposits along present streams; (2) Low-Relief Alternating Beds of Limestone, Dolomite, and Marl, and Limestone Recharge Areas along the boundary with the Hill Country; and (3) Coastal Plain Recharge Areas along the border with the Gulf Coastal Plain. One land resource unit, Basalt Knob, occurs at a single locality within the Balcones/Blackland area.

Localities of scenic or scientific importance associated with the fault zone include the Balcones Escarpment, certain streams that cross the fault zone, and springs that issue forth where the Edwards aquifer has been breached. The best topographic expressions of faulting occur in part of northwest Austin and southeast of San Marcos; there visible changes in terrain, soils, biota, and human uses have occurred because of fault displacement of bedrock during the geologic past. Streams that cross the fault zone have exposed faulted bedrock and have adapted their flow and erosive regimes to local fault-produced changes in bedrock. Springs occupy scenic localities and provide abundant water supplies, which contribute to making certain areas ideal for parkland; too, they are important habitats for rare plants and animals that are adapted to the spring water.

Other significant natural localities within the Balcones/Blackland area are Pilot Knob and the few remaining native stands of grasses that once occupied the Blackland Prairie. As mentioned previously, Pilot Knob is the eroded plug of a long-dormant volcano. The remaining native grasslands have both scenic and scientific values and provide a historical view of the once extensive prairies that now exist only in isolated patches because of human agricultural success.

Potentials and Problems

The Balcones/Blackland area is the most intensively used land in the region. Moreover, activities in the area approach the fullest potential in relation to the land's capability. The fault zone is ideally suited for human habitation because of abundant water supply, large areas of stable substrate, and aesthetic characteristics of the landscape. The Blacklands contain the most fertile soils in the region; therefore, the area is used almost entirely as farmland. Moreover, because some local areas contain rock and mineral products such as sand and gravel, limestone, and raw material (chalk and clay) for the manufacture of cement, these commodities are produced here.

Low slope stability, improper location of septic tanks, or dangers from flooding cause problems with local residential development in the Balcones/Blackland area. Of these problems, flooding is the most severe because it recurrently endangers life and property. Locally, within the fault zone,

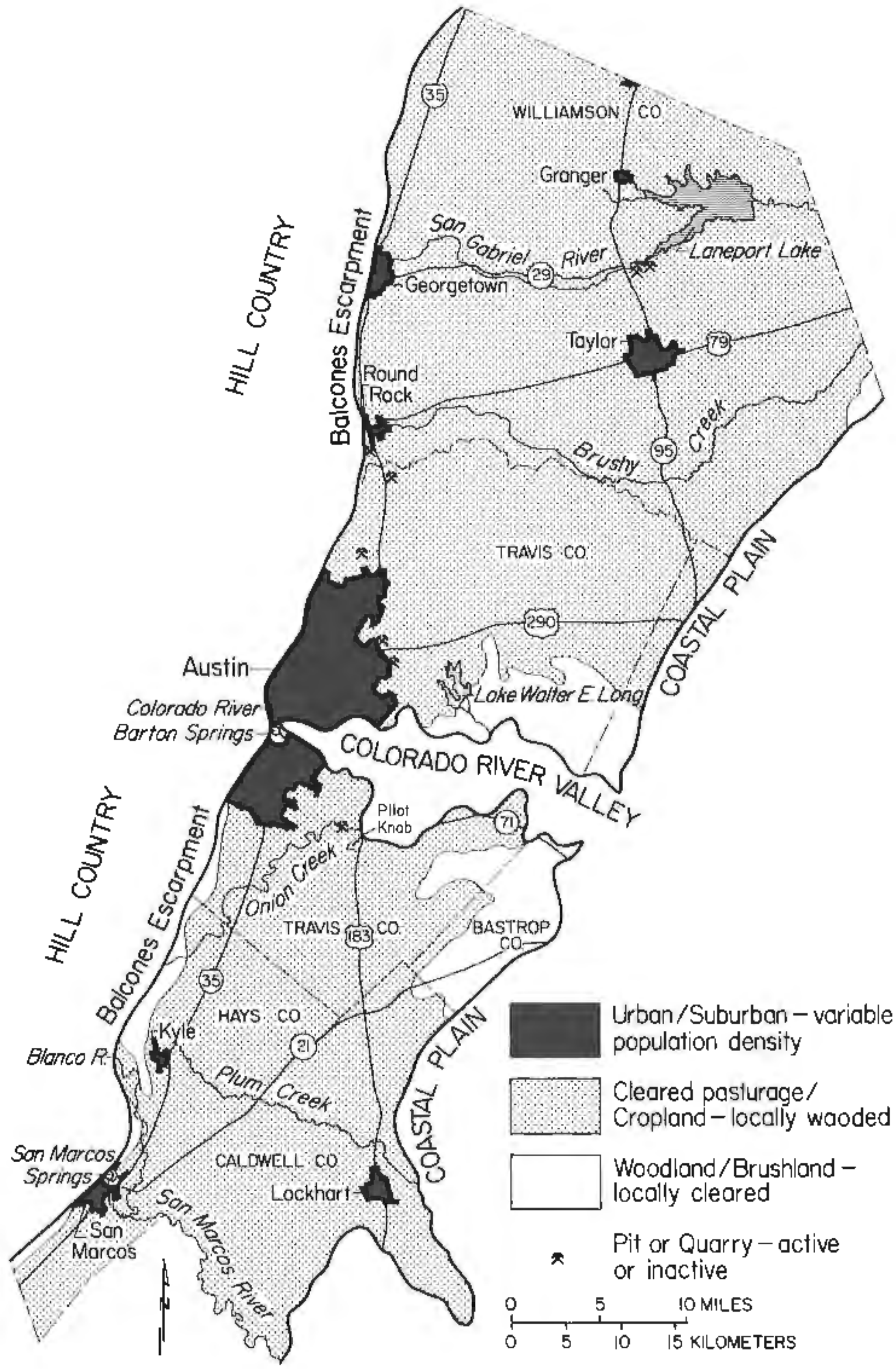

Figure 20. Balcones/Blackland natural area showing generalized land use patterns.

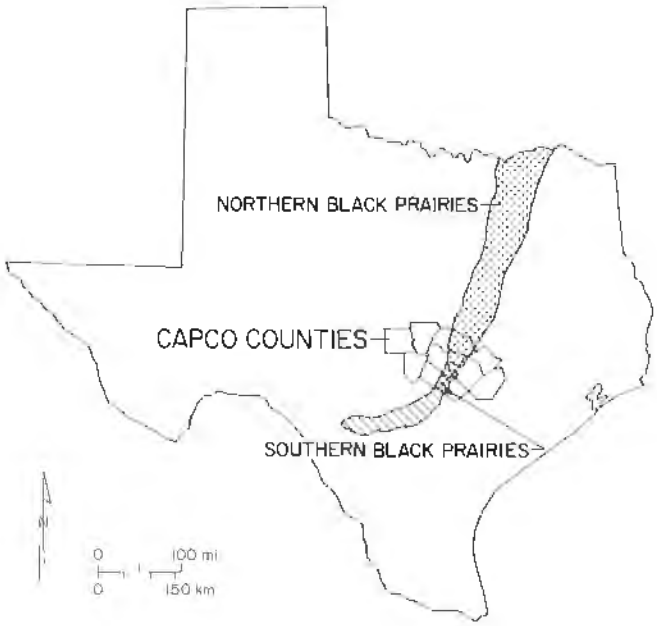

Figure 21. Northern and Southern Black Prairies (after Johnson, 1931)—extensions of the Balcones/Blackland areas beyond the CAPCO counties.

small streams have potential for extremely hazardous flash flooding. Plum Creek in Caldwell and Hays Counties, Brushy Creek in Williamson County, and Onion Creek in Travis and Hays Counties are notorious for recurrent floods. A history of flood problems also exists for the larger streams in the area—Blanco, San Marcos, San Gabriel, and Colorado Rivers.

Other problems include the competition between the expansion of urban structures and the extraction of construction minerals (for example, stone or sand and gravel), and the conflicts created by residential development on prime cropland. One effect of rapid urban growth covering rock and mineral resources is that, by eliminating local sources for raw material, it increases the distances over which construction minerals must be transported to market. For high-bulk construction commodities, transportation costs are a significant part of the price a consumer pays for housing or for public works (Flawn, 1965; Garner, 1976). Suburban growth east of Austin competes with agriculture for use of the Blackland belt. The clay substrate and soils characteristic of this area pose engineering (foundation) problems for homes and drainage problems for septic tanks. However, low ground stability is merely a short-term nuisance compared with the irreversible loss of cropland to homesites.

COASTAL PLAIN

Summary of Natural Conditions

The Coastal Plain extends from the eastern edge of the Blackland Prairie to the southeastern limit of the CAPCO region and beyond; it is part of a larger physiographic province that reaches all the way to the Gulf of Mexico and extends laterally for thousands of miles along an arcuate band from Mexico through the southern and southeastern United States to the middle Atlantic coastal region (fig. 22). The part of the Coastal Plain that is in the CAPCO region covers 2,520 square miles (6,527 km^2), which is approximately 30 percent of the region and which includes all of Lee County, as well as parts of Bastrop, Caldwell, Fayette, and Williamson Counties (fig. 23). It is bisected by the Colorado River Valley natural resource area. Municipalities in the Coastal Plain are Elgin, Flatonia, Giddings, La Grange, Luling, and Schulenburg; the overall population density of the area is low outside these towns.

The Coastal Plain provides examples of subtle interactions among substrate, terrain, soils, and vegetation, all of which result in distinctive features of the land. This area is generally characterized by soft-rock, easily erodible substrate consisting mainly of sand or mud or some admixture of these materials. The terrain consists of a series of low ridges with escarpments facing west and gentle slopes trending toward the coast, but there are also a few promontories of moderate height. Soils are usually thick, consisting of various combinations of clay, loam, and sand, depending on substrate. Vegetation is mainly either post oak-dominated assemblages or open grasslands with encroachments of mesquite, oak, elms, and a variety of other woody vegetation. The post oak assemblage is typical of the sandy soils and occurs in the hilly terrain that occupies part of the area. The grassland assemblage is characteristic of prairie lands that occur interspersed between the sand hills, whereas a live oak savanna is in the southeastern part of the area.

Most of the Coastal Plain within the CAPCO region is drained by the Colorado River system. However, tributary streams to the Brazos, Lavaca, and Guadalupe Rivers also occur in this natural resource area. Notable among these are West Yegua Creek, Middle Yegua Creek, and East Yegua Creek, all of which drain into the Brazos River. The headwaters of East Navidad River and West Navidad River occur in southeastern Fayette County; both of these streams are part of the Lavaca River system. Plum Creek and San Marcos River are both part of the Guadalupe watershed.

Land resource units characteristic of the Coastal Plain area are Coastal Plain Recharge Areas, Sand and Sandstone Recharge Areas, Sandy Clay Prairie, and Muddy Sand Prairie. Other units occurring in the Coastal Plain, but not unique to the area, are local Flood-Prone Areas, Valley Bottoms, Chalk/Sandstone Prairie, Unstable Clay Terrane, Alluvium Terrace Deposits, Upland Gravels and Alluvial Plains, and Clay Rolling Terrane.

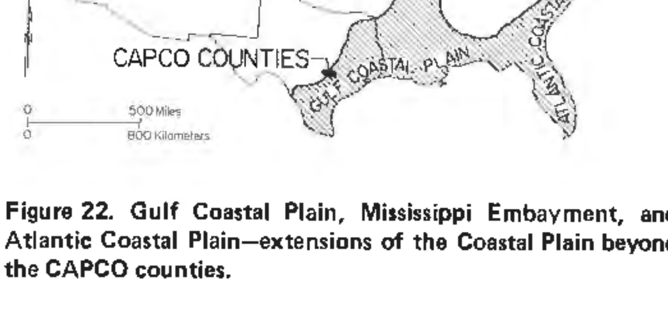

Figure 22. Gulf Coastal Plain, Mississippi Embayment, and Atlantic Coastal Plain—extensions of the Coastal Plain beyond the CAPCO counties.

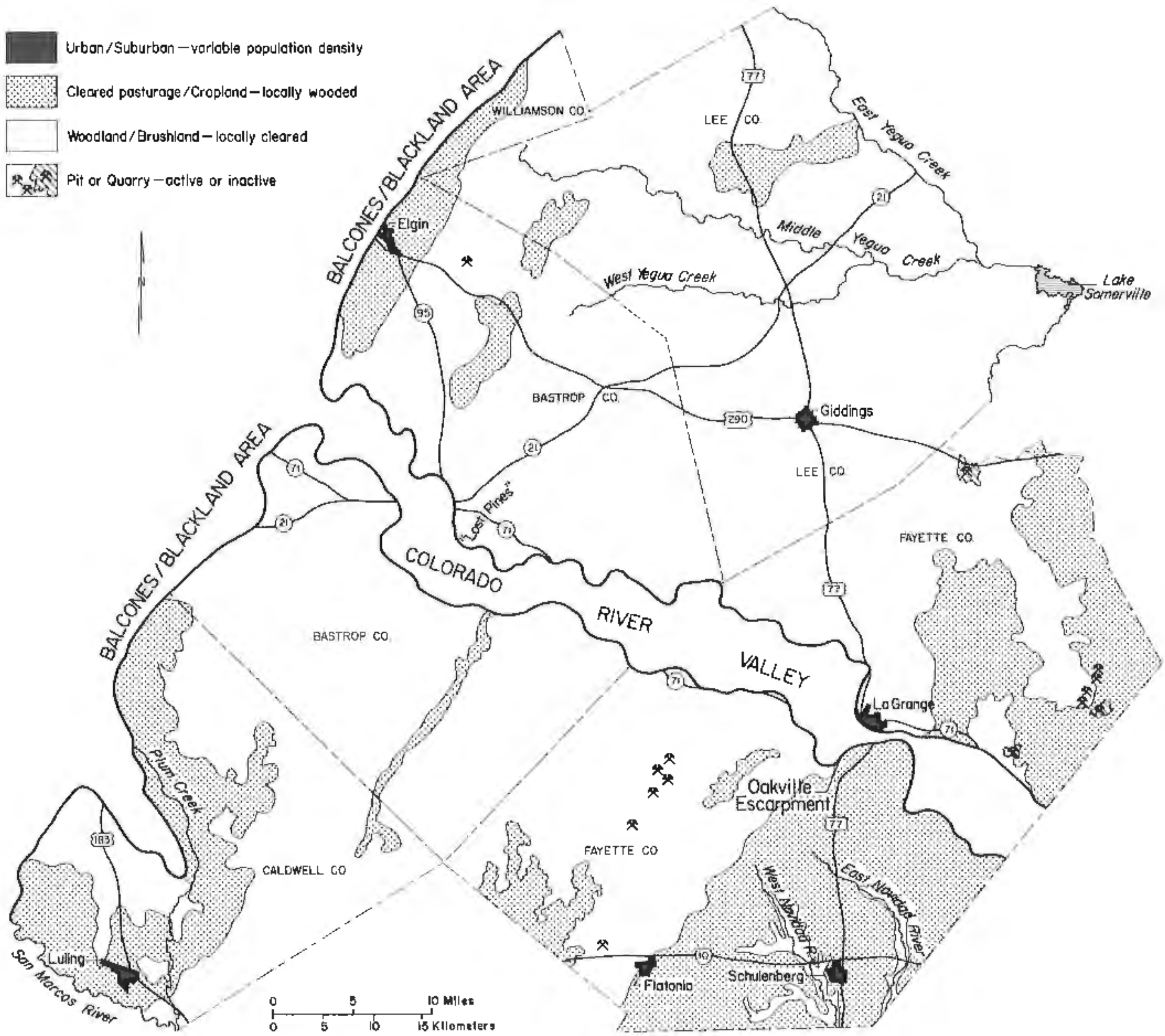

Figure 23. Coastal Plain natural area showing generalized land use patterns.

Areas of high scenic value or of high scientific interest are not as well known in the Coastal Plain area as in other natural areas. The survey of significant rural natural areas published by the Texas Parks and Wildlife Department, Comprehensive Planning Branch (1975) includes only one site in this area: the stand of loblolly pines near Bastrop. The "lost pines" extend beyond Bastrop and Buescher State Parks and are widely recognized for the biotic assemblages that are anomalous for this part of Texas. Other notable natural sites include the limy sandstone bluffs that make up the Oakville Escarpment near La Grange in Fayette County and numerous rock and fossil collecting localities. R. L. Folk, in an undated report, notes the educational value of traverses across certain country roads in the area. Specifically, he states, "The dirt road . . . from Delhi east to Cistern offers one of the most remarkable transects anywhere in Texas, showing the effect of geology upon soils, topography, vegetation, culture, and population." The interactions are real enough, but the relationships are more subtle than the dramatic vistas, waterfalls, and other scenic elements seen in the Llano area, the Hill Country, and along the Balcones Escarpment.

Potentials and Problems

Perhaps the greatest unrealized potential of the Coastal Plain is the presence of economic mineral resources. The area contains potentially minable near-surface and deep-basin deposits of lignite and extensive strata that contain uranium (St. Clair and others, 1976). North of the CAPCO region in Milam County, lignite is presently mined from extensions of the same map units that occur in Lee, Bastrop, and Caldwell Counties. Similarly, the potential uranium-bearing strata are equivalent to rocks that yield uranium ore farther to the southwest in Karnes and Live Oak Counties. A few small oil and gas fields are also in this part of the CAPCO region, and conceivably, more petroleum could be found. Moreover, there are localities that produce special-purpose clays such as bentonite for filler material and for driller's mud, whereas sand and gravel are presently produced from the alluvial plains in Lee and Fayette Counties. A potential source of crushed aggregate for the construction industry exists in the southeastern parts of the Chalk/Sandstone Prairie; currently, some of this crushed limy sandstone is shipped from Brenham in Washington County to the Houston vicinity.

Besides mineral extraction, another potential of the Coastal Plain is the expansion of agriculture. Land in Fayette County is already intensively used; the presence of a broad Blackland belt there has resulted in the county's being ranked second highest of all CAPCO counties for total value of agricultural products (Texas Crop and Livestock Reporting Service, 1975). All Coastal Plain counties contain land that is not presently used for agriculture; but much of this nonproductive land reflects low soil fertility or other problems that heretofore have prevented intensive cultivation. The hilly woodlands are generally associated with leached, sandy soils (Tharp, 1944), so large investments of effort and money would be needed not only for clearing and cultivating these localities but also for fertilizing. Because of low crop yield, certain areas would not be worth this investment.

Further development of either mineral or agricultural resources may result in problems. Surface mining could cause large-scale disturbance of the terrain, thereby deteriorating surface- or ground-water quality and destroying soils and established plant cover as well as creating aesthetic problems. Present laws, however, enforce water-quality standards, and, for lignite and uranium mining, reclamation of the land is ensured. Difficulties resulting from more intensive agricultural uses may be less severe than those associated with mineral extraction. But there is the potential for soil erosion, nutrient depletion, and water-quality deterioration owing to runoff or infiltration of agricultural chemicals, or to an increase in stream sediment resulting from erosion.

COLORADO RIVER VALLEY

Summary of Natural Conditions

The Colorado River Valley begins as a recognizable physiographic entity near the Balcones Escarpment. It extends beyond the CAPCO region to the mouth of the river at the Gulf of Mexico (fig. 24). This area includes parts of Bastrop, Fayette, and Travis Counties; municipalities include Bastrop and Smithville as well as parts of Austin and La Grange (fig. 25). The part of the river valley within the CAPCO region encompasses less than 1 percent of the region (approximately 25 square miles or 65 km^2).

In terms of characteristic features of the land, the Colorado River Valley is the least complex of all the natural areas in the CAPCO region. It is defined by nearly flat terrain consisting of sand, gravel, and mud sediment formed by and occurring adjacent to the Colorado River. Thus, the area is a narrow, linear feature made up of only two land resource units: Flood-Prone Areas and Alluvium and Terrace Deposits. Yet, the Colorado watershed is the third largest river basin in

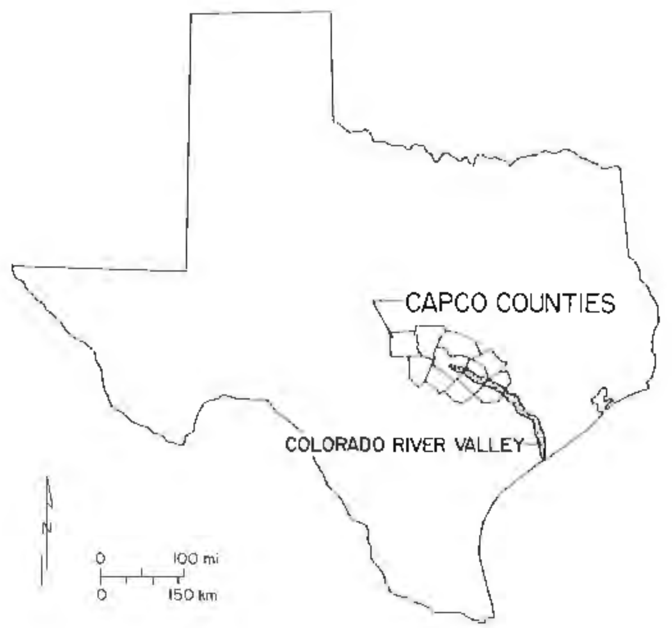

Figure 24. Colorado River Valley beyond the CAPCO counties.

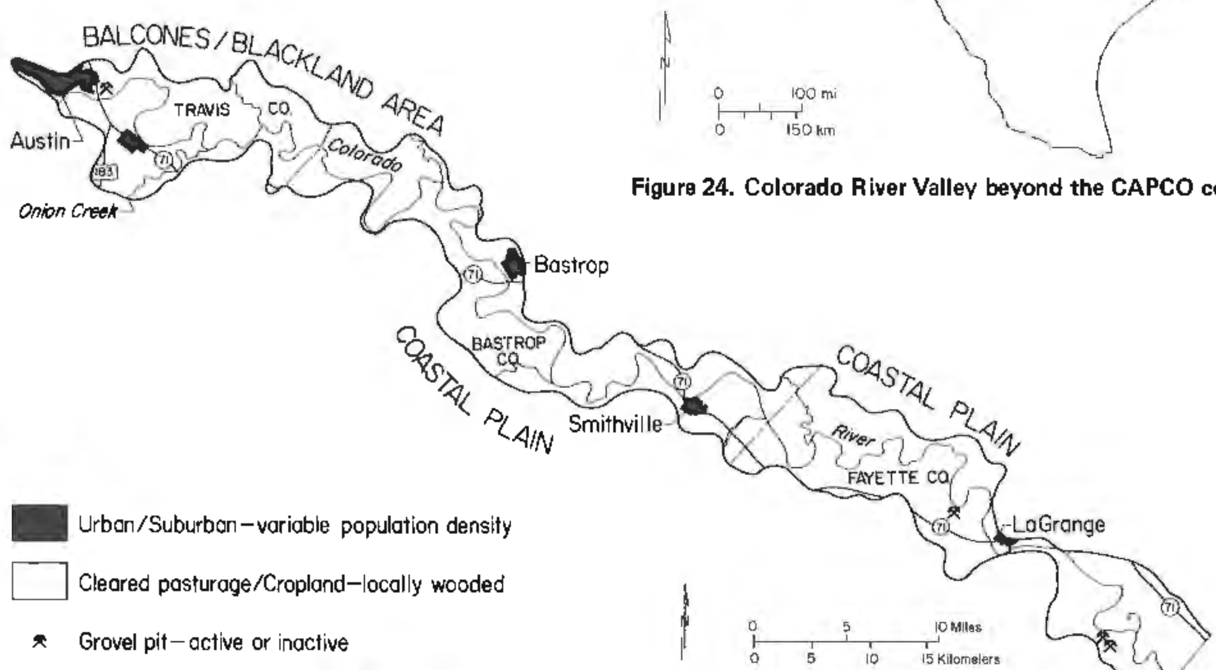

Figure 25. Colorado River Valley natural area showing generalized land use patterns.

Texas, and it drains several varied and complex geologic regions. The river sediment as well as the plant and animal assemblages reflect conditions throughout the river's watershed, but they also reflect local conditions of climate, bedrock, and terrain.

The river and its tributaries constitute the main scenic and scientific resources in this natural area. The area affords recreational opportunities for hunting and fishing and is a scenic corridor used by boaters and canoeists.

Potentials and Problems

The Colorado River, the main source of potable water for the CAPCO region, is intensively used for drinking water especially in the Austin vicinity; yet farther downstream sufficient water remains to supply still other demands. During times of normal climatic conditions, more intensive uses could be made of this water source. The local water-quality problems that do exist, such as in Town Lake adjacent to Austin, are largely abated only a few miles downstream.

Being very fertile, most land adjacent to the river is used for agriculture, but some is used as a source of sand and gravel. Thus, there are few localities within this area that are not currently used. Because of recurrent flooding or possible deterioration of the surface-water quality, more intensive uses might invite problems.

Conclusions

Diverse types of land result from complex interactions among bedrock, climate, processes, topography, soils, and vegetation. The varied natural features afford different potentials and impose various problems with using the land at specific localities. It has been the purpose of this report to present the differing land characteristics from place to place in the CAPCO region and, on the basis of these variations, to explain why the land naturally sustains different human activities. The variations in land resources have been presented from three perspectives: (1) a view of the region as a whole; (2) a detailed view of individual land resource units; and (3) a view of natural resource areas, each made up of a distinct set of land resource units.

The Land Resources Map of the Capital Area Planning Council Region is the primary focus of this report. Designed for planning the most effective uses of resources from a regional or county vantage point, the map depicts properties of the land. Although the scale of the map is too small to permit detailed site-specific evaluations, it provides general information for local assessment of land capabilities.

There are 24 land resource units defined on the basis of bedrock characteristics, landform features, and active or potentially active processes, all of which influence human activities. Two major categories of land resource map units include process units and material-landform units, which are, in turn, subdivided into seven suites of units. The surface-water process suite, the aquifer suite, and the slope process suite are all part of the larger class of process units. Material-landform units include the surface deposit suite, the igneous-metamorphic rock suite, the limestone suite, and the claystone-sandstone suite.

The regional survey provides a compilation of generalized information on geology, mineral deposits, climate, physiography, water, soils, and vegetation. These resources are depicted on a series of schematic maps in order to present an overview of the different natural resources in the region. These generalized maps show that in the CAPCO region there are five sub-regional divisions defined by several overlapping resource themes. These sub-regions, termed *natural resource areas,* are the Llano area, the Hill Country, the Balcones/Blackland area, the Coastal Plain, and the Colorado River Valley.

The natural resource areas are almost identical in areal extent to physiographic provinces. However, they are presented separately to emphasize the interaction and overlap among the resources other than terrain. Thus, the survey of natural areas results in a review of both the region-wide schematic presentations and the assessment of individual land resource units. The natural resource areas are further discussed with consideration to actual land use patterns as well as to problems and potentials of human activities. In this way, the realities of current land use are compared with the mapped assemblages of land resource units.

The natural resource areas provide a means for reiterating the basic theme of this report—all land is not the same, and different kinds of land sustain different uses. The delineation of natural resource areas shows how cultural patterns reflect natural conditions of the land.

Acknowledgments

The Land Resources Map is the heart of this report. Thus, Dan F. Scranton deserves foremost mention for his skills in constructing this map. I owe further thanks to numerous other members of the cartographic staff at the Bureau of Economic Geology, who, under the supervision of James W. Macon, drafted my illustrations.

Part of the initial study was supported by the Capital Area Planning Council under a grant from the U. S. Department of Housing and Urban Development. Robert C. Lentz assisted me in collecting data during the early stages of the project, and Christine R. Gever helped me with final compilation of the map.

The manuscript was read critically by L. E. Garner, C. Robertson Handford, E. G. Wermund, and William A. White of the Bureau of Economic Geology. Critical review was also provided by Susan Souby of CAPCO, Ann E. St. Clair, formerly of the Bureau of Economic Geology, and by B. Kern Ewing and Doran G. Williams, both former colleagues of mine at the Texas General Land Office.

Glossary

(Note: These definitions are in part modifications of those by Gary and others, 1972, Kier and others, 1977, and St. Clair and others, 1975.)

acre-ft (acre-foot). The volume of water required to cover 1 acre to a depth of 1 foot (325,851 gallons).

aggregate. Hard rock or mineral fragments used by the construction industry for concrete, road base, or asphalt; examples include sand, gravel, and crushed stone.

alluvial plain. A broad, nearly flat surface formed by the deposition of sediment by rivers.

alluvium. General term for clay, silt, sand, gravel, or similar unconsolidated sediment deposited by a stream or other body of moving water during relatively recent geologic time.

aquifer. Rock formation that contains water and can yield a significant supply of ground water to wells or springs.

arroyo. A dry wash; a small gully that is usually dry but that contains flowing water after heavy rainfall.

asbestos. Commercial term for fibrous minerals associated with some metamorphic rocks.

ash. Fine sediment erupted from a volcano.

basalt. Hard, dark, dense, fine-grained volcanic igneous rock, largely composed of iron and magnesium-rich silicate minerals.

biota. All forms of animal and plant life.

bedrock. General term for material that underlies soil or other surficial deposits.

bentonite. Soft, plastic, clay formed by weathering of volcanic ash.

calcite. Mineral composed of calcium carbonate; principal constituent of limestone.

caliche. Calcium-rich material deposited in soil or sediment by evaporation of percolating waters.

cemented. Rock particles bound by minerals that formed in pore spaces.

chalk. Soft, fine-grained limestone mainly composed of shell material.

chert. A hard, dense, very fine grained rock composed of silica (SiO_2); commonly associated with limestone and dolomite deposits (synonymous with flint).

clay. General term for extremely fine grained natural materials that are soft and plastic when wet and that are usually composed of various clay minerals; clay can refer either to soil or to substrate.

claystone. A homogeneous rock composed mostly of clay minerals or clay-sized particles, similar to shale but without the fine laminations (layering).

conglomerate. Rock composed of rounded rock fragments, most of which are gravel sized or larger (greater than 2 mm in diameter).

consolidated. General term applied to coherent sedimentary rock that has undergone such processes as compaction and cementation.

corrosion potential. Measure of chemical reactivity between soil or substrate and buried structures, such as pipes, foundations, and cables.

creep. Slow downslope movement of soil or substrate.

crushed aggregate. Rock crushed for construction purposes.

crystalline rock. General term for igneous or metamorphic rocks in which constituent mineral grains form interlocking boundaries with generally low porosity and permeability.

deciduous. Pertaining to trees that shed their leaves and are bare during the winter.

deposition. Accumulation of any rock material by a natural agent (such as sand and gravel laid down by running water).

detritus. Collective term for loose rock and mineral material, such as sand, silt, and clay, that is moved from its place of origin.

dimension stone. Rock that is quarried and cut into blocks for building purposes.

discharge. Generally refers to water yielded by a stream or spring; may also refer to sediment carried by water.

dissected. Refers to landscape that has been eroded by streams to produce uplands separated by stream valleys.

dolomite. Mineral or rock composed of calcium and magnesium carbonate; commonly associated with limestone.

drainage basin. The entire catchment area for a stream system, bounded by a drainage divide; synonymous with river basin and watershed.

drainage net. Map view of all stream courses making up a river system; interconnecting pattern of streams is usually in the form of a net.

dune. Hill or ridge composed of sand-sized particles deposited by wind.

elevation. Refers here to the height above sea level of a point on the ground.

embayment. A recess caused by region-wide downwarping of part of the earth's crust.

erosion. General processes active at the earth's surface that wear away and remove rock, soil, and sediments.

escarpment. Elongate bluff or steep slope produced by erosion or faulting.

excavation potential. A measure of the ease whereby a natural substance can be dug from the ground (synonymous with rippability).

fault. Break in the earth's crust along which movement has occurred; may be active and undergo movement periodically or may be inactive and be stable for millions of years.

flint. Dense, hard rock composed of very fine grained silica (SiO_2) (synonymous with chert).

floodplain. Generally low, flat area that is flooded when a stream overflows its banks.

flood-prone. Subject to repeated flooding.

fluorite. A mineral composed of calcium fluoride, used in the steel, glass, and chemical industries; the principal source of fluorine.

fluvial. Related to rivers and streams.

foundation strength. A measure of the load that can be imposed on soil or substrate without ground rupture.

fracture. Break or crack in the earth's crust; movement may have occurred along the fracture, and thus it is a fault; if no movement has occurred, then it is a joint.

gaging station. A location on a body of water where various properties such as flow rates and sediment yield are measured.

gneiss. Coarse-grained metamorphic rock characterized by banded zone composed of different minerals.

granite. Coarse-grained igneous rock composed mainly of quartz and potassium- and sodium-rich silicate minerals.

graphite. Dark, soft mineral composed of carbon and occurring mainly in metamorphic rocks; used in pencils, lubricants, and refractory products.

gravel. Rounded rock or mineral fragments intermediate in size from coarse sand to fine cobbles (2 to 75 mm in diameter).

ground failure. General term for rupture and movement of soil or substrate due to imposed loads.

ground water. Water that occurs in pore spaces, fractures, or cavities underground in rocks or sediments.

igneous rocks. Rocks that solidify from molten material on or beneath the earth's surface.

incised. Deeply cut by stream erosion; entrenched.

infiltration. Process by which fluids seep into and move through soil or substrate at shallow depths.

ironstone. Dense, dark red rock that contains significant amounts of iron compounds.

karst. Type of landscape denoted by sinkholes and caves; produced by solution of bedrock (adjective is karstic).

landforms. Any form or feature of the earth's surface produced by natural processes; associated landforms make up a landscape.

land resource unit. Mappable entities determined by local characteristics of the land (processes, substrate, landforms, soils, biota, human modifications, or any combinations of these characteristics) that naturally support certain levels of human activities without appreciable environmental harm or human hazard.

landslide. Sudden, rapid failure and downslope movement of soil or substrate.

lens. A deposit bounded by converging surfaces, thick in the middle and thinning toward the edges.

lenticular. Roughly lens-shaped.

lignite. Brownish-colored, low-rank coal containing abundant plant material; it has low heating value and high moisture content and is intermediate in quality between peat and bituminous coal.

lime. Calcium oxide; produced by heating limestone; used as soil additive, for water treatment, and in the chemical and metallurgical industries.

limestone. Sedimentary rock composed predominantly of calcite in the form of grains, interlocking crystals, or shells or other fragments of organic origin.

limy. Containing a significant amount of calcium carbonate; for example, a "limy soil."

loam. Permeable, workable soil composed of approximately equal proportions of sand, silt, and clay.

magnetite. A black, heavy mineral composed of iron oxide.

marble. Metamorphic rock composed of coarse-grained, recrystallized calcite and dolomite.

marl. Soft sedimentary rock composed of calcite and clays in varying proportions.

mass wasting. General term for any downslope movement of soil or substrate; includes creep, block falls, landslides, mudflows, and others.

materials. General term for the natural ingredients of the land; may be soil, bedrock, or loose sediment.

matrix. A tabular presentation for comparison of many items; it is usually in the form of a grid-like chart where two sets of entities may be compared using rows or columns corresponding to the various items listed.

metamorphic rocks. Rocks formed by alteration of preexisting igneous or sedimentary rocks by heat, pressure, or fluids without melting of the rocks.

mica. Group of minerals of complex composition that occur in tabular, sheetlike forms.

mineral. In general, a natural substance taken from the earth that has economic value; more specifically, a mineral is a naturally formed solid substance having a definite chemical composition and a characteristic internal form.

motte. A thicket, grove, or clump of trees; for example, oak motte.

mud. Structureless or thinly layered sediment composed primarily of a mixture of clay- and silt-sized particles.

mudstone. A sedimentary rock made up of mud but lacking the laminated bedding of shale.

oblique. A high angle less than 90 degrees; pertains here to photographs that depict landscape from the air at an angle other than vertical.

ore. Naturally occurring material from which a metal can be extracted for profit.

permeability. Measure of the ease with which a fluid can move through a material.

physical properties. Characteristics of soils or substrate that affect their general stability in a given environment and that especially affect construction activities.

physiography. General form of the land surface; applies to terrain features such as geometry of hills, valleys, and plains; described by elevation, relief, and slope.

plain. Broad, nearly flat surface feature of the earth.

plastic. Description of a soil or substrate that continually deforms under stress; especially refers to properties of certain clays that easily deform when wetted.

plateau. Elevated plain.

porosity. Percentage of open space within soil or substrate.

prairie. Extensive tract of flat to rolling grassland (synonymous with savanna).

process. Refers to natural phenomena that produce continuous or periodic changes in materials, structures, and landforms of the earth; processes in CAPCO region related mainly to the work of water.

promontory. A high point on the earth's surface.

quartz. Hard, transparent to milky mineral composed of silica (SiO_2).

reef. A ridge or mound of sedimentary material formed under water by shell-secreting organisms.

relict. A remnant; something representative of past conditions of the earth (for example, a relict river course).

relief. Difference between maximum and minimum elevation in an area.

residuum. A product of weathering that remains in place, not eroded and transported.

rippability. The property of soil or substrate to be extracted without use of explosives (see excavation potential).

rock. Any naturally occurring, consolidated or semiconsolidated material that underlies soil; made up of an assemblage of one or more minerals.

sand. Rock or mineral particles ranging in size from coarse silt (0.063 mm) to fine gravel (2 mm).

sandstone. Sedimentary rock made up predominantly of grains of sand that have been cemented to some degree.

savanna. Subtropical grassland with scattered trees.

schist. Finely banded metamorphic rock composed of platy to elongate minerals.

seam. A thin layer or stratum of rock; usually refers to a minable deposit (for example, a seam of coal).

sedimentary rock. Rock formed by consolidation of rock or mineral fragments (sediments) deposited by water, wind, or ice.

sediments. Rock or mineral particles deposited in rivers, oceans, glaciers, the atmosphere, or formed by living organisms.

serpentine. Group of dense, dark metamorphic minerals composed of magnesium silicates and characterized by a silky luster and greasy texture.

serpentinite. Metamorphic rock made up largely of serpentine.

shale. Sedimentary rock made up of finely laminated (fissile) clay or silt particles.

sheetwash. Rapid sediment transport produced by a thin layer of running water; common on steep slopes during rainstorms.

shrink-swell potential. Measure of the volume of change that occurs in soil or substrate as a result of wetting or drying.

silica. Oxide of silicon, SiO_2; the composition of quartz, chert, and flint.

silicates. Largest group of rock-forming minerals; contains silicon and oxygen plus various metals such as calcium, sodium, magnesium, aluminum, and iron.

silt. Rock or mineral particles intermediate in size between clay and very fine sand (0.004 to 0.063 mm).

siltstone. Sedimentary rock composed mainly of silt.

sinkhole. Depressions in the land surface produced by solution and collapse of soluble bedrock such as limestone.

slope. Steepness of the land surface measured in degrees or as a ratio or percent of change in elevation to horizontal distance.

slope failure. Slumping of soil or substrate on sloping ground.

slope stability. Resistance of soil or substrate to failure under its own weight on a natural or man-made slope.

slopewash. Same as sheetwash.

soil. Rind of organically active, unconsolidated, solid material at the earth's surface; defined differently by different disciplines: for agronomists, the defining criterion is that it supports plant growth; for engineers, that soil be excavated without blasting; for geologists, that soil be weathered in place from an underlying parent material.

soil horizon. A layer of soil distinguishable from adjacent soil layers by color, structure, texture, or composition.

strata. Layers of rock or sediment.

structure. Natural large-scale arrangement of rock; commonly refers to folding, faulting, and attitude of bedrock relative to a horizontal plane; may also refer to small-scale features within a soil.

substrate. Rock or sediment below the soil zone.

talc. Soft mineral composed of magnesium aluminum silicates and characterized by a soapy, greasy texture; used as a filler and for talcum powder.

terrace. Elevated, nearly flat area adjacent to a stream course; usually a relict floodplain, though low terraces may be inundated by high-magnitude floods.

terrain. Natural landscape; refers to conditions of topography (such as slope, relief); for example, a rolling terrain.

terrane. Combined geologic and physiographic setting; refers to both bedrock and landforms; for example, a karstic limestone terrane.

texture. Small-scale, grain-to-grain geometrical aspects of rock or soil; may refer to characteristics of any surface, small or large.

topography. Measure of the elevation and configuration of the land surface.

vermiculite. A group of platy, mica-like clay minerals that are composed of water-bearing magnesium and of iron aluminum silicates; they are characterized by expansion when exposed to high temperatures making them valuable as lightweight aggregate or as insulation.

volcanic. Relating to a volcano, its processes of eruption, or deposits ejected from it.

watershed. Same as drainage basin.

weathering. The process by which rocks or sediments at or near the earth's surface are changed in place by atmospheric agents (mainly water, ice, and wind); weathering often prepares material for removal by the processes of erosion.

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