EXERCISE 17

Geology and Regional Planning

INTRODUCTION

"The social value of geology increasingly derives from the environmental tensions created by the resource and land-use needs of an expanding population. Quality of life for the eight or ten billion people who will inhabit the planet by the end of the coming century will depend on how well these unavoidable tensions are managed. Thus, our scientific agenda is inextricably bound not just to geological phenomena, but also the relation between those phenomena and the behavioral patterns of human beings."

—SAREWITZ, 1996

"Obedience to nature could well be the motto of every planning agency."

—LEGGET, 1973

"Sooner or later we all pay, directly or indirectly, for unintelligent use of land."

—MCGILL, 1964

In this exercise the objective is to understand the geologic controls on land use, and the steps in and geologic information for regional planning. In Part A we look at the environmental factors in disposal of municipal solid waste; in Part B, we select suitable sites for several land uses in Waco, Texas, using properties of geologic formations or units, basic data maps, and resource capability maps. We begin with an overview of regional planning.

GEOLOGY AND LAND USE

Human use of the physical environment must consider our need to avoid hazards and maximize resource availability. Hazards, as explored in Section II of this book, topography, soil strength, depth to bedrock, and resources (gravel, rock, water, and agricultural soils) all impact land-use decisions.

An acre or hectare of land may have the potential to provide multiple resources for humans—both simultaneously and sequentially. Potential land uses include mineral extraction, forestry, groundwater supply, water reservoirs, waste disposal, and cemeteries in addition to those resource uses listed in Table 17.1. In some cases there is a definite best use of the land because the resource is not found elsewhere in the region.

COMPREHENSIVE REGIONAL PLANNING

In regional assessments for resource use, planning agencies must consider more than geologic hazards and resources; they must include biological, social, political, and historical data, too. By inventorying, analyzing, and displaying these data, knowledgeable land-use options can be made.

There are many approaches to regional planning. These are the basic steps in one common approach:

1. Analysis of goals and objectives of the region (public input)
2. Collection of basic data
   a. inventory of geologic and biologic factors in the environment
   b. inventory of economic, social, cultural, and political factors
3. Analysis of resource capability (using 2a)
4. Analysis of resource suitability (using 3 and 2b)
5. Synthesis of data to develop goals and objectives, in the form of alternate plans for the region
6. Selection of the best regional plan (public input)
7. Determination of techniques for implementing the plan.

Capability usually is defined as the ability of the land to provide a resource; maps depicting capability are called resource capability maps. An area that is

TABLE 17.1 Basic Geologic Data Needed for Evaluating Resource Uses in a Region

Factor (Basic Data)	Function (Resource Use)									
	Golf	Camp-ground	Trails	Picnic	Agri-cuture	Septic Tanks	Resi-dential	Comm. Indust.	Transport.	Utilities
Slope	×	×	×	×	×	×	×	×	×	×
Bedrock depth					×	×	×	×	×	×
Permeability	×				×	×				
Flooding	×	×	×	×	×	×	×	×	×	×
Water-table depth	×				×	×	×	×		×
Stoniness					×	×	×	×		
Shrink-swell							×	×	×	×
Frost action						×	×		×	×
Water supply	×	×		×	×	×	×	×		
Corrosion potential					×			×		×

physically and biologically capable of providing an identified resource may not be acceptable for other reasons (such as those listed in 2b above). Some planners make a distinction between capability and suitability, using the term suitability for regions that are capable (geologically) and also acceptable in terms of economic, social, political, and cultural factors.

Maps such as geologic maps and topographic maps are known as basic data maps. Examples of how geologic variables affect various resource uses are given in Table 17.1. Note that if septic tanks are to be used for home sewage treatment, bedrock depth, soil permeability, slope, flooding, water-table depth, and stoniness are considered to be important. However, simply knowing that these are important factors in the use of the land for septic tanks is not enough if we want to make a map showing which areas are actually capable of this resource use. We also need limiting values for the factors that have an impact on septic tank use. For example, what bedrock depth would be deleterious for septic tank use? Usually such values for any factor are quantified into a threefold classification as most capable, capable, and not capable. For example, in Table 17.2 water-table depth as it affects residential development is classified as most capable (>5 ft), capable (2.5–5 ft), and not capable (<2.5 ft). Sometimes these capabilities are depicted by a color system on a map, with red = not capable, yellow = capable with some restrictions, and green = most capable. This color system is known as the stoplight code.

Each factor important in residential development must be evaluated for each small unit of the map area. If a unit on the map contains a "not capable" value for a factor for residential development, then that area has to be excluded from the capable category of the resource capability map. Other criteria for residential development are evaluated on a weighted basis to determine the overall capability of a site.

TABLE 17.2 Defining Factor Limits for Determining Resource Capability for Residential Development

Factor (Basic data class)	Most Capable	Capable	Not Capable
Water-table depth	>5 ft	2.5–5 ft	<2.5 ft
Bedrock depth	>5 ft	3.3–5 ft	<3.3 ft
Flooding	none	rare	frequent/occasional
Shrink-swell	low	moderate	high
Frost action	low	moderate	high
Groundwater availability	>10 gpm	5–10 gpm	<2–5 gpm
Slope	4–9%	0–3%, 10–15%	>15%

The geologist's primary role in planning is to provide basic data and resource capability maps to the planner. The geologist may also assist the planner in integrating them with other data and maps to produce resource suitability maps which will be the basis for a long-range regional plan. Such a plan is subject to change but does provide guidance in making wise decisions about land use.

PART A. SITING A SANITARY LANDFILL

Management of municipal solid waste presents a growing problem for urban regions. The sanitary landfill is now the most common way to "dispose" of this waste, although incineration, composting, and traditional recycling are also used. Municipal solid waste includes food waste, beverage containers, yard and garden waste, automobiles and parts, appliances, furniture, newspapers, and disposable diapers, etc. As this waste decomposes it produces leachate, a nasty liquid that contains components of the soluble materials in the landfill—from heavy metals to organics. Leachate in poorly constructed landfills can travel beyond the sanitary landfill causing pollution of soils, groundwater, and surface water. Methane and other landfill gases may cause problems when they migrate underground into surrounding buildings.

The number of geologically suitable sites for sanitary landfills is limited. As a result, landfill sites are expensive to acquire and to engineer for environmental protection. In 1970 in North America, 85 percent of municipal solid waste was disposed of in a dump, many located in old pits and quarries. In these dumps waste was not covered regularly; open burning and leachate runoff were common. About this time, the environmental damages and hazards from these dumps were recognized and legislation was enacted for sanitary landfills. A **sanitary landfill** is a method of disposing of refuse on land without creating nuisances or hazards to public health or safety. Engineering techniques are used to confine the waste to the smallest practical volume, to cover it daily, and to prevent leachate, gas, blowing debris, and rodent and odor problems.

The sanitary landfill system is expensive. Disposal fees and limited space in some areas make it economical to ship solid waste many miles by truck or train for disposal in a landfill. Waste from New York City goes to Ohio and other states; Toronto, Ontario, has sent some of its waste to Michigan. In addition to the geologic factors that control the siting of landfills, social factors that must be considered have also increased costs for disposal sites. The terms NIMBY (Not In My Back Yard), LULU (Locally Unwanted Land Uses), and NIMTO (Not In My Term of Office) exemplify the social response to proposed landfills.

Several factors of the physical environment must be considered in selecting a site for a sanitary landfill. These include the following:

Climate. In cold climates freezing of the soil restricts excavation and availability of cover material. A low-lying site may be undesirable in areas of heavy rainfall because of flooding and muddy working conditions. Windy sites need special consideration because of dust problems and blowing paper.

Bedrock geology. The type of bedrock is important; sandstone, conglomerate, and limestone could rapidly transmit water containing pollutants, while shale and igneous and metamorphic rocks would not. Rock structures (e.g., faults and joints), the dip of rock strata, and underground mines must be considered.

Hydrology. Possibilities of groundwater pollution from leachate and surface-water pollution from leachate and runoff, the seasonal fluctuation of the water table, and the direction of groundwater movement are all important factors. Well-head areas, recharge zones for aquifers, and floodplains should also be considered in siting landfills.

Topography. Surface slopes before and after development must be considered, since erosion of cover materials may expose trash. Floodplain proximity and flood level must be taken into account, as well as the effects of topography on surface and underground drainage.

Regolith and soil conditions. A sufficient quantity of easily workable compactible cover material must be available. The type of regolith (i.e., alluvium, glacial drift, clay soils, etc.) must be considered.

Other factors in site selection include economics, transportation routes, engineering techniques to reduce offsite impact, adjacent historical, cultural, and environmental values, and politics.

QUESTIONS 17, PART A

Trashmore is a hypothetical city of about 40,000 in the Great Lakes region of North America. The gently rolling landscape has been glaciated and the regolith contains silty-clay till, outwash gravels, glacial lake deposits of clay, and modern alluvium over bedrock at depths of 0 to 100 feet. The bedrock consists of limestone and shale formations. Trashmore has a sanitary landfill that will run out of space in two years. As a member of Trashmore's City Council you have been asked to assist the regional planners in selecting a suitable site for a new sanitary landfill. You consult a portion of a geologic map and cross section of the region (Figure 17.1) and recognize three excavated sites. If one of these pits and quarries could be used, you think you could save on excavation costs.

1. What geologic resource (rock or sediment) was extracted at each of the three sites?

State Aggregate:

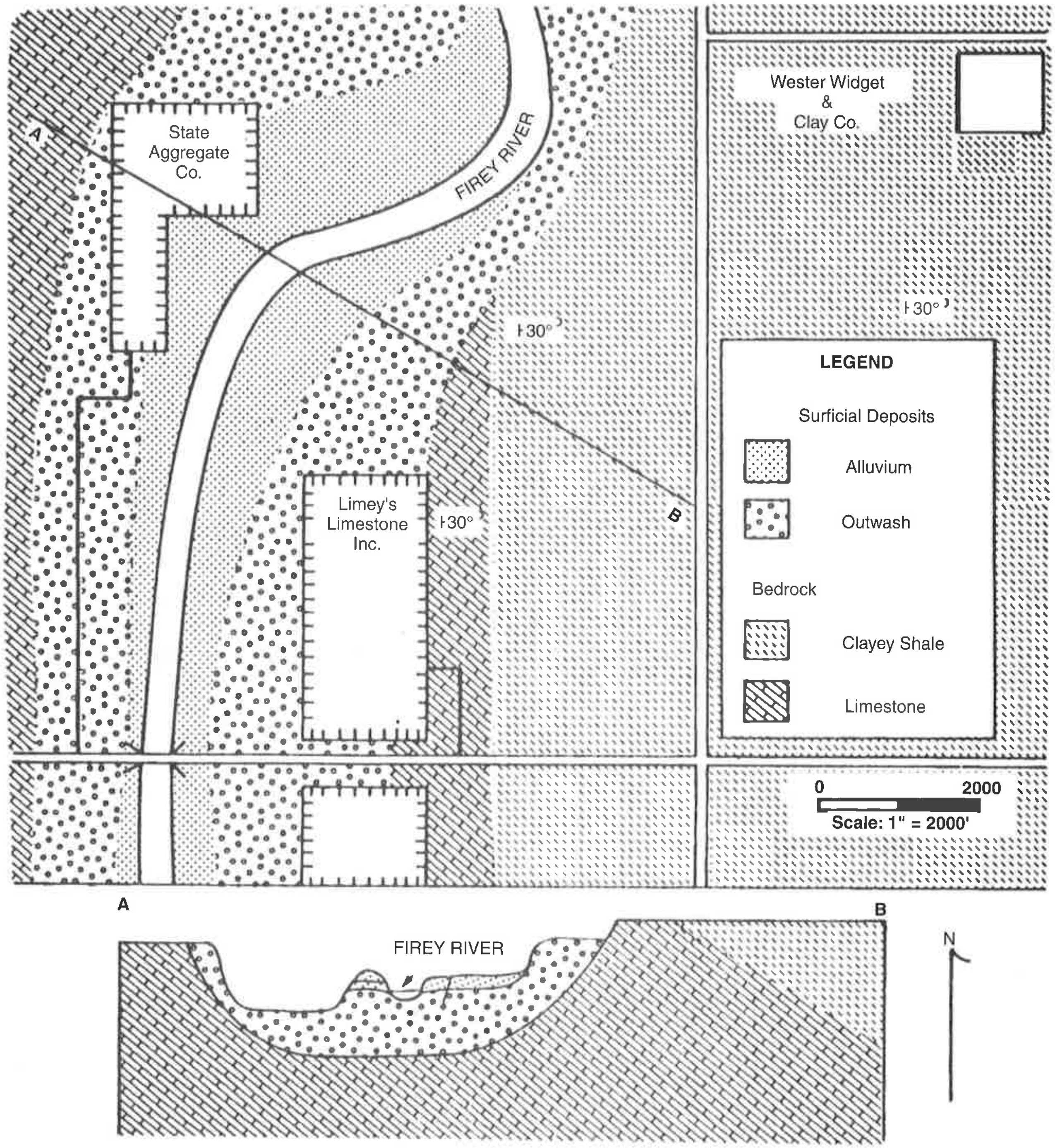

FIGURE 17.1 Geologic map and cross section of western Trashmore.

Western Widget:

Limey's Limestone:

2. a. Which of the three excavated sites was your first choice for the new landfill? (Consider the physical environmental factors, described in the Introduction to this exercise, that are important in selecting sanitary landfill sites.)

b. What physical environmental factors were important in making your selection of a landfill site?

c. Explain why your number one factor is important.

3. List the problems that are associated with each of the *other two* sites not selected in Question 2a.

a. Site: ______________; Problems:

b. Site: ________________; Problems:

4. If you were to excavate to a deeper level at the State Aggregate pit, what additional geologic material could you obtain?

5. Sanitary landfills must be covered daily (and after they are closed) with a low permeability material to keep out precipitation and runoff. (Otherwise, they do not meet the regulations for sanitary landfills.)

a. Which of the four (4) materials shown in the legend of Figure 17.1 might be suitable for covering the waste daily? Why?

b. Trashmore's regolith has been deposited on bedrock by glacial processes. Thus the unconsolidated material at the surface might include outwash gravel, lake silt and clay, clayey till, and wind-blown silt. What low permeability material from the region might be suitable for landfill cover?

6. Which way is the bedrock dipping at Limey's Limestone and what is the approximate angle of dip? (Hint: Use the cross section and a protractor or use the symbols on the map.)

7. In Figure 17.2, a landfill is in an outwash valley on a flood plain. Many such sites were selected in glaciated environments because a gravel pit was available.

a. Complete the water table (dashed line) on both sides of Firey River.

b. Place arrows to show the flow of groundwater in your profile. (See Exercise 12 for assistance, if needed.)

c. Knowing that, to be classified as a sanitary landfill, trash cannot be dumped into standing water, would this site be a suitable place for an unlined sanitary landfill?

d. List the problems that this site by the river would present if it were selected as a modern sanitary landfill. Refer to the guidelines given in the Introduction.

PART B. PLANNING AND GEOLOGY IN WACO, TEXAS

Waco, Texas, is situated in central Texas, between Austin and Dallas, on the Bosque escarpment or fault-line scarp and is underlain by eastward-dipping bedrock of the Gulf Coastal Plain. The Upper Cretaceous formations outcropping in Waco include Taylor Formation (Kta), Austin Chalk (Kau), South Bosque Shale (Ksb), Lake Waco Formation (Klw), and Pepper Shale (Kpe). Lower Cretaceous formations include Del Rio Clay (Kdr) (which outcrops) and the Georgetown Limestone and Edwards Limestone, which are in the subsurface, outcropping to the west of the city. Tertiary rocks outcrop to the East; Quaternary sediments occur in the Bosque and Brazos rivers and terraces and in the alluvium of these rivers. The cities of Austin, Dallas, and San Antonio are also underlain by the same Upper Cretaceous rock formations as found in Waco.

Surface bedrock formations in the Waco area affect city growth because of their effect on topography, engineering properties, soils, drainage, and construction; subsurface formations may be important for water and mineral resource extraction. The properties of these geologic units are given in Table 17.3.

QUESTIONS 17, PART B

Use information in Figure 17.3 (Waco map at back of book) and Table 17.3, to answer the following questions.

1. a. List the geologic symbols of formations or units (Table 17.3) that might be used for extraction of sand and gravel in the Waco area.

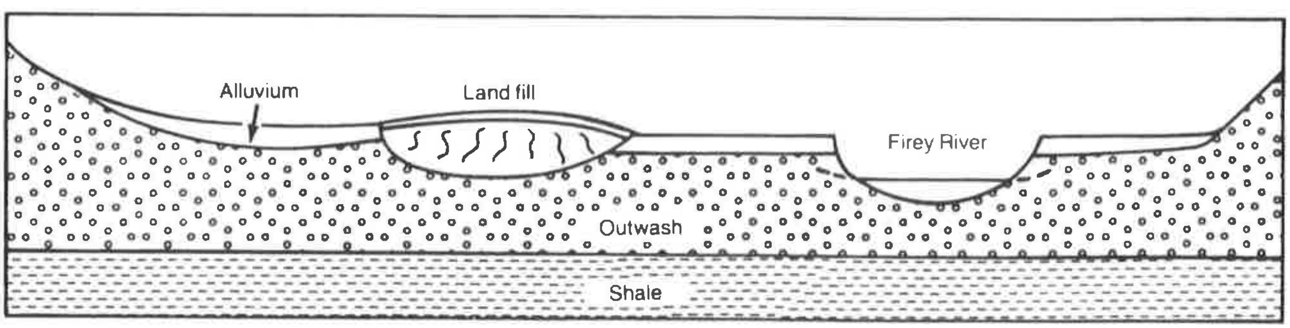

FIGURE 17.2 Cross section through a landfill on an alluvial plain.

TABLE 17.3 Properties of Geologic Units in Waco, Texas (after Burket, 1965; Elder, 1965; and Rupp, 1976)

Geologic Formations (w/symbols)	Max. Thick. (ft)	Rock Unit	Slope Stability	Excavation Difficulty	Bearing Capacity[I]	Infiltration Capacity	Rock/Mineral Resource Potential	Ground-Water Potential	Flood Potential
Alluvium (floodplain) Qal	?	Silt and clay; some gravel	Moderate (>10°)	Slight	Moderate to low, piers for heavy structures	Interm. to High	Minor sand and gravel	Low; irrigation and domestic use	Very high
Bosque/Brazos Flood Plain = Qbof and Qbrf Terrace = Qbot, Qbr 1, Qbr2, Qbr3 and Qbr4	?	Sand and gravel	Moderate (>10°)	Low except for Qbot and Qbr2 (N. of Lake Waco) Intermediate	Moderate; low in some Qbot sands	High	Major sand and gravel	Intermed./low; irrigation and domestic use	Qbof/Qbrf high; terraces none
Taylor Kta	1170	Marl with some sand-stone and limestone	Low (<10°)	Slight	Moderate to low, pier support for heavy structures	Low	None	Low	None
Austin Kau	295	Chalk, Marl	High (>45°)	Severe	High	Moderate	Subgrade for roads	None	None
South Bosque Ksb	140	Salt, Shale	Very low in upper 40 ft, low in lower 120 ft	Slight	Low; flotation or pier support	Low	Expanded aggre-gate	None	None
Lake Waco Klw	145	Calcareous shales, thin limestone interbeds	Low to moderate	Intermediate	Moderate; some pier support	Low	None	Domestic quantities	None
Pepper Kpe	100	Noncalcare-ous shales, sand	Very low. fails when wet if slope <10°	Slight	Very low; flotation or deep piers	Low	Possible ceramic materials	Low	None
Del Rio Kdr	85	Blue clay, calcareous siltstone	Moderate to low	Intermediate	Moderate to low (in middle part)	Low	Possible ceramic materials	None	None
Georgetown	210	Nodular limestone, shale	High (>45°)	Intermediate	High	Moderate	Marginal subgrade 5 miles from Waco	None	None
Edwards	45	Limestone, siltstone	Not exposed	Not exposed	Not exposed	Not exposed	Very good dimension stone 15 miles from Waco	Low	None

I. Very low and low require piers and floating foundations for heavy structures; intermediate allows significant part of foundation load of heavy structures on footings or beams; high allows conventional footings for heavy structures, but local faulting and joints could modify these conditions.

b. On Figure 17.3, select and mark (with "S&G") three sites where sand and gravel that could be used as aggregate might occur.

2. a. From what formation could you obtain ceramic grade materials?

b. On Figure 17.3, select and mark ("CM") a potential site for extraction of high-quality (ceramic-grade) clays.

3. a. What geologic formation would provide "dimension" building stone for Waco?

b. Why can you not mark such a site on the geologic map (Figure 17.3)?

4. From the information given in Table 17.3, determine the geologic units that might be investigated as potentially acceptable sites for a sanitary landfill in the West Waco area. Justify your choices by completing the table below.

5. In which geologic units (Table 17.3) in Waco would the greatest potential exist for contamination of potable groundwater by leachate from sanitary landfills or abandoned dumps?

6. a. Refer to your answer to question 4 and select a possible site for a sanitary landfill. Outline this area on the Waco West Quadrangle (Figure 17.3). Place the symbol "SL" in the center of the area. (Or describe the location and geologic material at the site).

b. State the most important factor that resulted in your decision and a possible minor problem for the site.

RESOURCE-CAPABILITY MAPS AND BASIC-DATA MAPS

7. By now you probably have determined that consulting basic data tables and maps and evaluating these data for a specific resource use can be confusing and time consuming. Resource capability maps are often used to ease the problem of determining the best use of the land from data in tables. Figure 17.4 is a resource capability map showing capability for septic-tank tile fields. It has been drawn using the following basic data or basic data maps:

soil permeability: low permeability is a severe limitation
depth to bedrock: less than 10 ft is a severe limitation
slope: over 10 percent is a severe limitation
flood hazard: soils with any degree of overflow present a severe limitation

Using the information in Figure 17.4, determine the potential for using septic tank systems with drain fields in the following areas (Figure 17.3) that are being considered for subdivision development.

a. X, 1.7 miles NE of the dam of Lake Waco, on Qbr1:

b. Y, immediately SW of Heart O'Texas Fairground, on Kau:

c. C, east of the Brazos River, on Qbr2:

8. Using the resource capability maps (Figures 17.4, 17.5, and 17.6), basic data map (Figure 17.7), and basic data for the geologic units in Table 17.3, evaluate *one* of the following areas in Figure 17.3 for possible residential development: A, D, or Z (Kta). Describe the problems and advantages for low-density housing in the area you select. Begin by reviewing the characteristics of each site. Then select one for your evaluation. Note: "A" is on the west side of the curve in the road on Kpe; "Z" is on Taylor Marl, Kte.

Geologic Unit	Material	Infiltration	Rock and Mineral Resources	Groundwater Potential

9. a. As an engineering geologist you are asked to assist in the selection of possible sites for construction of a large distribution-center warehouse. It will be supported by conventional footings resting below the weathered or soil zone. Considering only geologic factors, which two of the following geologic settings would you suggest to your client for further study? See Table 17.3.

Site 1,	on Austin Chalk (Kau)
Site 3,	on South Bosque Shale (Ksb)
Site c,	on Brazos Terrace (Qbr2)

b. Explain the reasons for your two choices, and your rejection of the third option.

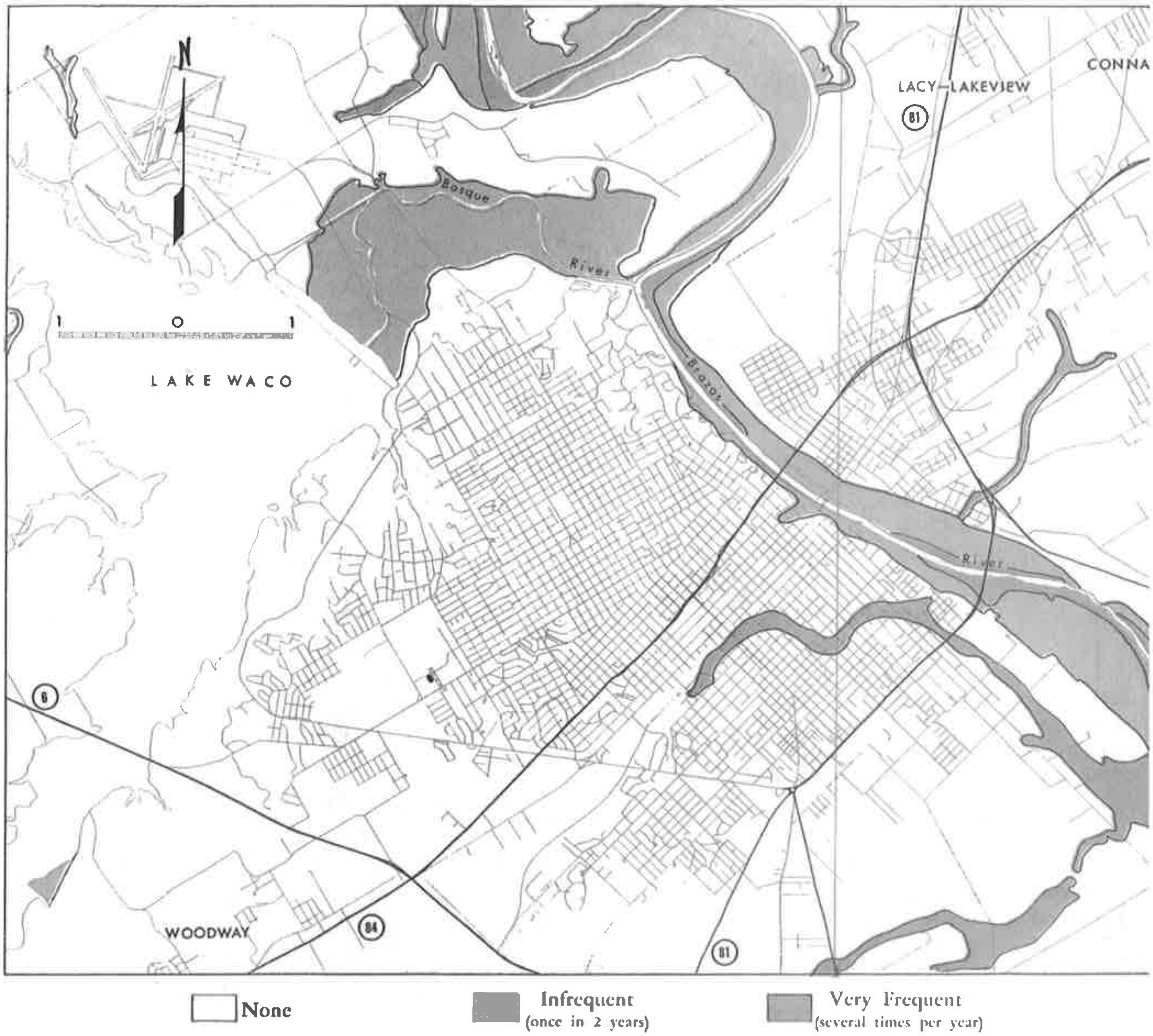

FIGURE 17.4 Capability of soils for septic drain fields, Waco area. The capability classification is based on the three categories of limitations shown in the explanation for the map: *slight, Moderate and Severe. Slight* translates to a capable area, *Moderate* to a *Moderately Capable* area with some limitations, and *Severe* to a Not Capable or Low Capability area. Limitations (capability) are based on normal density of residences and soil permeability (very slowly permeable soil is severe limitation), depth to bedrock (soil less than 10 inches thick is severe limitation), slope (soil with >12 percent slope is a severe limitation), and flood hazard (any degree of overflow is a severe limitation). Much of this map is in the severe category; classification does not apply to Lake Waco.

(Modified from Elder, 1965; used with permission).

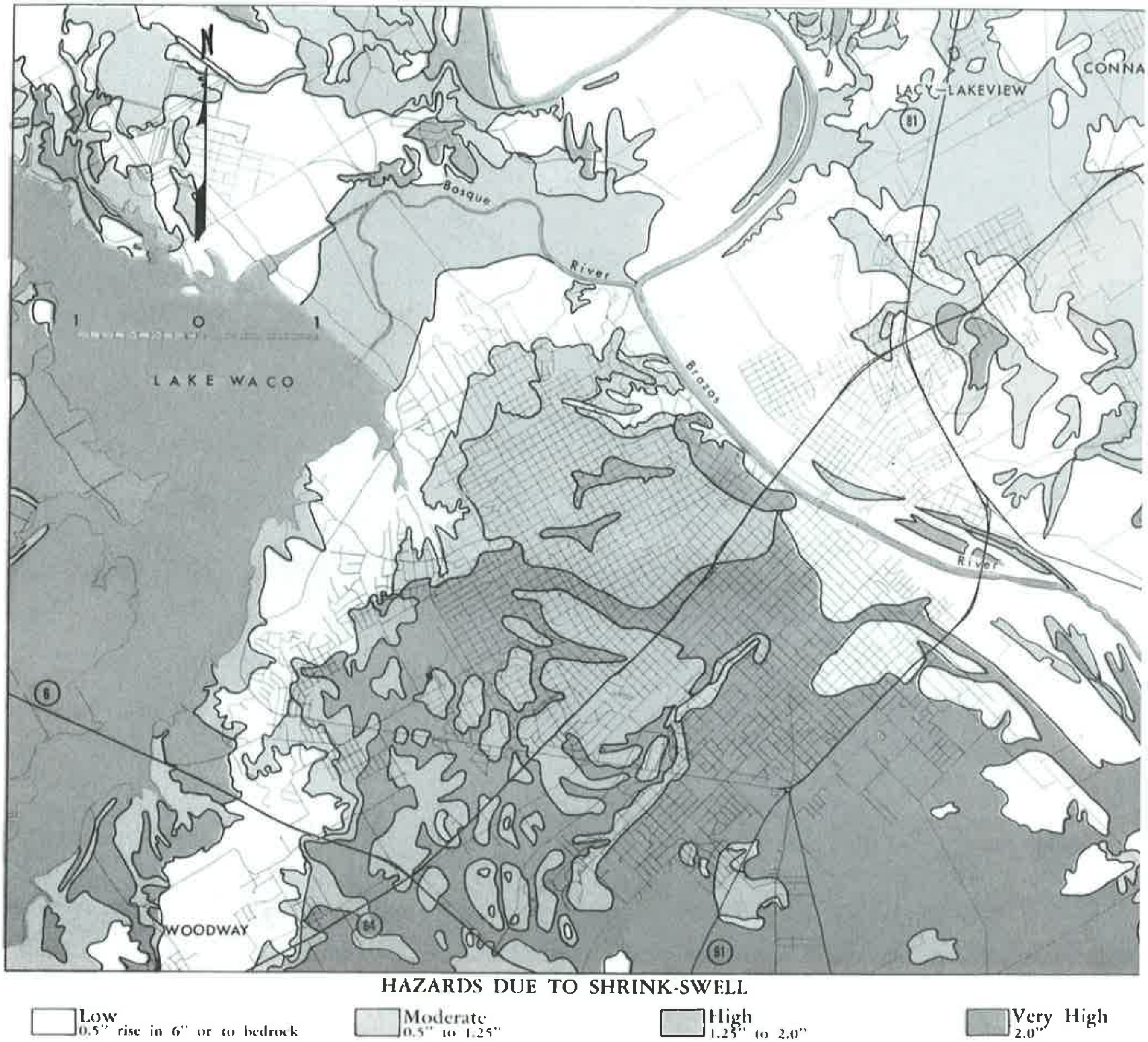

FIGURE 17.5 Capability of soils for residential foundations based on shrink-swell potential. The most capable soils have a *low shrink-swell,* here defined as less than 0.5 inch rise (in 6 feet of soil or to bedrock) when a fully dry soil is thoroughly wetted. The least capable soils have a *very high shrink-swell* hazard with a rise of more than 2 inches. Soil thickness, clay type and amount of clay influence shrink-swell. Climate, on-site mangement of water, drainage and vegetation also influence the hazard.

(Modified from Elder, 1965; used with permission.)

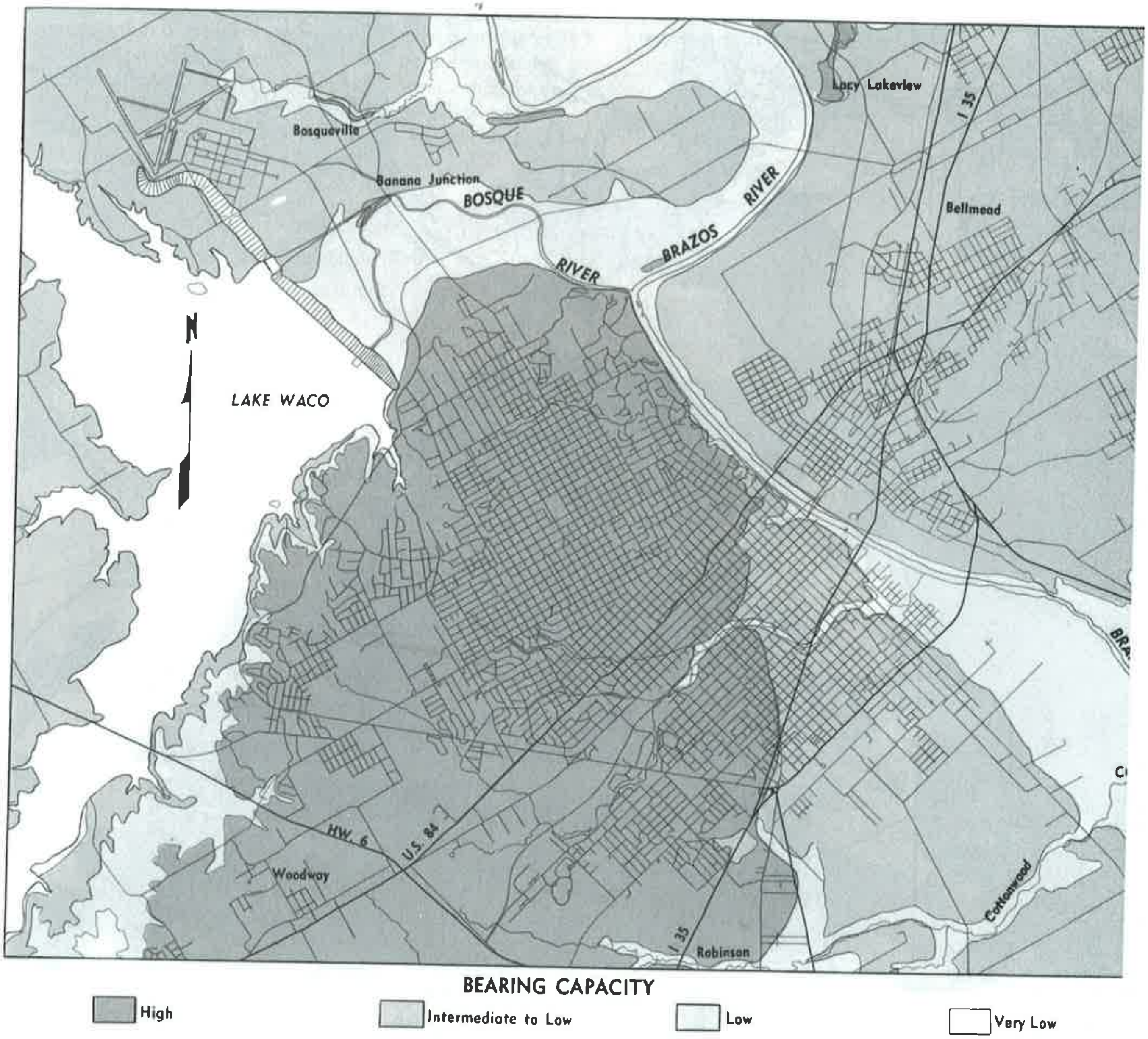

FIGURE 17.6 Bearing capacity of bedrock formations for heavy structures in the Waco area. High bearing capacity means that the formation allows heavy structures to be supported by conventional footings and grade beams and generally no pier or caisson support is required (jointing or faulting could modify these conditions). A *high bearing capacity* area represents a high capability area for this resource use (large structures).The Austin Chalk and limestone units of the Georgetown Formation are in this category. *Low to very low bearing capacity* requires heavy structures be supported by piers (into adjacent more resistant units or floating foundations. The Pepper Shale and some units of the South Bosque Shale, the Lower Taylor Marl, and the Del Rio Clay are low to very low bearing capacity and thus of low capability for large sructures. See Table 17.3 for further explanation.

(Modified from Font and Williamson, 1970; used with permission.)

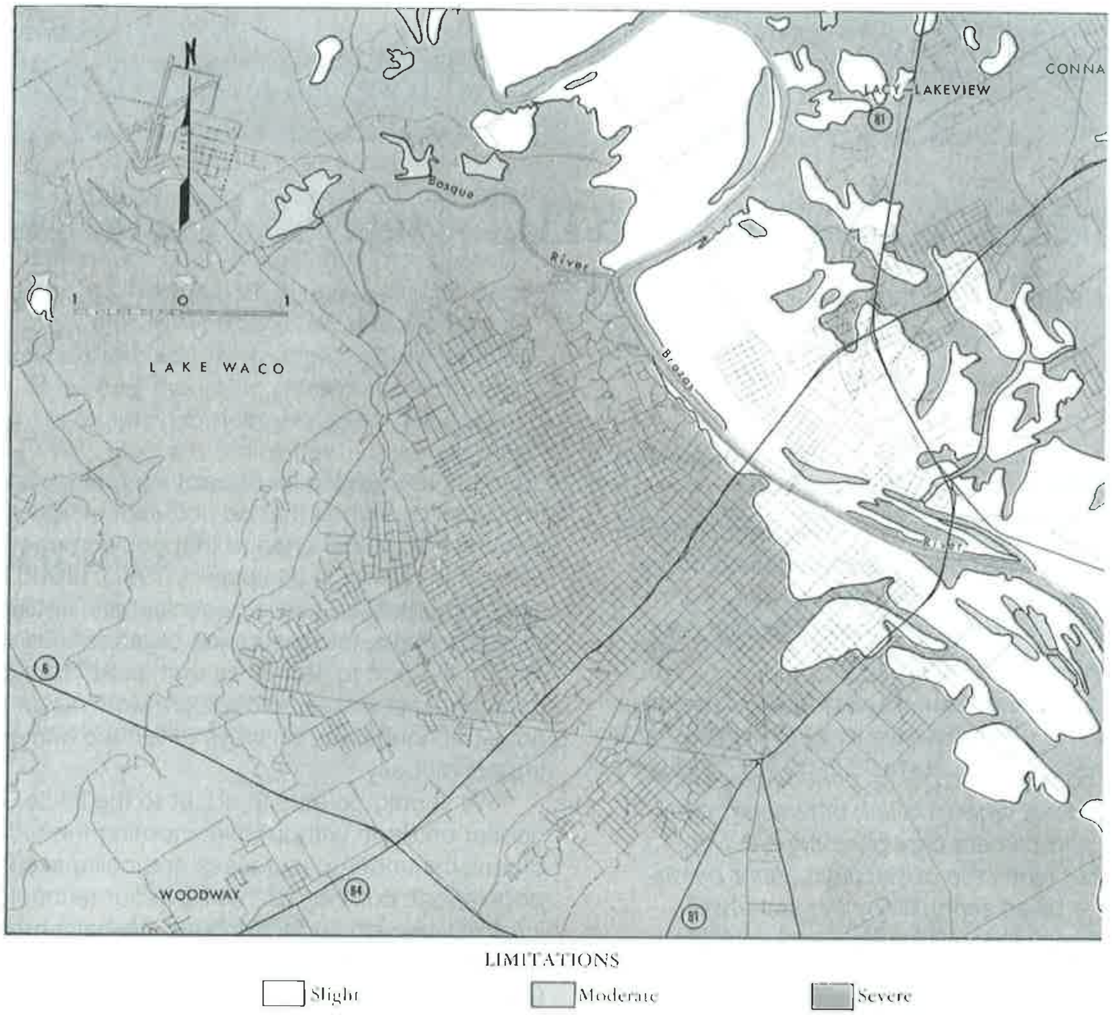

FIGURE 17.7 Flood hazard for soils, Waco area. Three degrees of hazard are shown: None, Infrequent (about once in two yeras), and Very Frequent (several times per year). Changes in flood detentation basins and other water management works could change the hazard regions on the map.

(Modified from Elder, 1965; used with permission.)

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