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Area Environmental Characterization Report Of the Dalhart and Palo Duro Basins In the Texas Panhandle

Volume I. Dalhart Basin

Technical Report

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ABSTRACT

This area report describes the environmental characteristics of the Dalhart and Palo Duro basins of the Texas Panhandle portion of the Permian basin. Both basins are rather sparsely populated, and the overall population is decreasing. The economic base is centered on agribusiness and manufacturing. Most of the potentially conflicting land uses in both basins (i.e., parks, historic sites) occupy small land areas, with the exception of a national grassland in the Dalhart and military air training routes in both basins. Ground transportation in the Dalhart basin is adequate, and it is well developed in the Palo Duro basin.

In both basins irrigation constitutes the principal water use, and groundwater is the principal source. However, the dominant aquifer, the Ogallala, is being depleted.

Both basins consist primarily of grasslands, rangelands, and agricultural areas. No critical terrestrial or aquatic habitats have been identified in the basins, though several endangered, threatened, or rare terrestrial species occur in or near the basins. Aquatic resources in both basins are limited because of the intermittent availability of water and the high salt content of some water bodies. Playa lakes are common, though usually seasonal or rain dependent.

The climate of the area is semiarid, with low humidity, relatively high wind speeds, and highly variable precipitation. Restrictive dispersion conditions are infrequent. National ambient secondary air quality standards for particulates are being exceeded in the area, largely because of fugitive dust, although there are some particulate point sources.

FOREWORD

The National Waste Terminal Storage (NWTS) program was established in 1976 by the U.S. Department of Energy's (DOE) predecessor, the Energy Research and Development Administration, to develop the technology and provide the facilities for the safe, environmentally acceptable, permanent disposal of high-level nuclear waste.

The DOE's responsibility for the long-term management of highly radioactive nuclear wastes is defined by federal laws. The laws specify that the DOE must provide facilities for the successful isolation of high-level waste from the environment in federally licensed and federally owned repositories for as long as the wastes present a significant hazard.

Highly radioactive nuclear wastes include wastes from both commercial and defense sources, such as spent (used) fuel from nuclear power reactors, the accumulation of wastes remaining from the production of nuclear weapons, and solidified wastes from fuel reprocessing.

To meet its major objective of isolating high-level waste, the DOE is developing a technical program that will meet all relevant radiological protection criteria and other applicable regulatory requirements.

NWTS program activities include providing the technology and facilities for terminal isolation of these wastes. The DOE's program emphasizes disposal in mined repositories deep underground in stable geologic formations. Several types of rock are being studied in several states. Rock types include bedded salt deposits, salt domes, basalt (solidified lava), tuff (compacted volcanic ash), and "crystalline" rocks.*

Steps leading to the permanent dispoal of high-level waste are as follows:

- Studying, characterizing, and recommending potential sites for repositories
- Designing, licensing, and operating commercial repositories
- Providing waste-packaging facilities
- Developing transportation requirements
- Developing the technology to support these steps
- Studying alternative disposal methods as long-range options to geologic disposal.

Four separate but coordinated projects are involved in the HLW disposal program: the Office of Nuclear Waste Isolation (ONWI), the Basalt Waste Isolation Project (BWIP) at DOE's Hanford Reservation in the State of Washington, the Nevada Nuclear Waste Storage Investigations (NNWSI) at the federal Nevada Test Site, and the Subseabed Disposal Project. ONWI, BWIP, and NNWSI focus on different rock types and conduct

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*"Crystalline" rock is a general term for igneous and metamorphic rocks, as opposed to sedimentary rocks. Granite is one type of a crystalline rock.

studies in site evaluation, technology development, facility design, and field testing. These programs share data and information of general benefit. ONWI coordinates site exploration studies on non-DOE land. The Subseabed Disposal Project is assessing the technical, environmental, engineering, and institutional feasibility of disposing of processed highly radioactive nuclear waste and/or repackaged spent fuel in geologic formations beneath the sediments of the oceans.

Identifying possible sites for geologic repositories and evaluating their potential involves the collection and analysis of detailed geologic and environmental data and the comparison of such data against predetermined site performance criteria (i.e., geologic characteristics, environmental protection, and socioeconomic impacts). The site-selection process consists of a series of increasingly detailed steps to obtain environmental and geologic information. The steps are (1) a national survey of one or more rock types with potential for waste containment, (2) the identification of regions containing potentially suitable rock types, and (3) the recommendation of study areas and locations. At the conclusion of each screening step, the focus narrows to smaller land areas, and the amount of data collected increases. Screening steps will identify potential sites at several locations, leading to the next phase, site characterization, which assesses a site's suitability for a repository. The process culminates in DOE's application to the U.S. Nuclear Regulatory Commission (NRC) for authorization to construct and operate the first repository.

The first federal repository for the isolation of high-level nuclear wastes is expected to be in operation between 1998 and 2006 following the site-selection process outlined, field testing and technology development programs, and the fulfillment of licensing requirements. The DOE expects to choose one site from among several qualified sites and apply to the NRC in 1988 for a license to construct the first repository; several repositories are planned.

Throughout the repository siting and construction process, opportunities are provided for public and peer review and comment. The DOE maintains an open information program for nuclear-waste-management activities and is committed to a policy of consultation with state and local officials. Information is provided to both technical and nontechnical groups and to government officials through the review of major reports, briefings, conferences, public meetings, and printed material. Additional opportunities for public comment will occur at public hearings and reviews that are part of the licensing process.

The following documents and statements provide policy and technical guidance in the definition and planning of the NWTS program:

1. <u>President's Nuclear Policy Statement</u>, October 8, 1981

2. <u>DOE Record of Decision</u> (to adopt the mined geologic disposal strategy and develop repositories), May 14, 1981

3. <u>National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment</u> (Draft), February 1982

4. <u>Final Generic Environmental Impact Statement</u> (U.S. DOE, 1980a)

5. Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking) - Statement of Position of the U.S. Department of Energy, April 15, 1980

6. Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking) - Cross-Statement of the U.S. Department of Energy, September 5, 1980

7. Report to the President by the Interagency Review Group on Nuclear Waste Management, March 1979 (IRG, 1979).

8. Earth Science Technical Plan for Mined Geologic Disposal of Radioactive Waste (ESTP) (U.S. DOE et al., 1979)

Both the IRG report and the FEIS evaluate alternative waste-disposal concepts and conclude that mined geologic disposal will be available the earliest. The IRG report recommends that near-term program activities should be based on the tentative assumption that the first disposal facilities will be geologic repositories. The FEIS provides a detailed evaluation of 10 methods for waste disposal and concludes that the technology for the emplacement of radioactive wastes in geologic formations can likely be developed and applied with minimal environmental consequences. The ESTP, which is the product of a cooperative effort by the DOE and the U.S. Geological Survey, furnishes detailed programmatic guidance for implementing research addressing specific earth science issues associated with geologic waste disposal.

REFERENCES FOR FOREWORD

Interagency Review Group on Nuclear Waste Management, 1979. Report to the President, TID-29442, Washington, D.C., March.

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U.S. Department of Energy, 1981. "Program of Research and Development for Management and Disposal of Commercially Generated Wastes; Record of Decision (to adopt a strategy to develop mined geologic repositories ...)" Federal Register, Vol. 46, No. 93, May.

U.S. Department of Energy, 1980. Final Environmental Impact Statement--Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-F, Washington, D.C., October.

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Introduction

This report describes the environment of the Palo Duro and Dalhart Basins in the Texas Panhandle portion of the Permian Basin. The information is based on data and literature available during 1979. The principal data sources included State of Texas natural resources offices and departments, federal agencies, state universities, and published research reports. This report covers demography; economics; historic and archaeological resources; land, water, energy, and mineral resource use; meteorology and air quality; and background radiation. Discussions on groundwater use are limited to use and availability. Detailed geologic and hydrologic data are not included here, but are part of the geologic characterization studies. Although field studies were not conducted for the preparation of this report, they will be conducted during the location and site characterization phases.

This report is not intended to be a complete and thorough analysis of the Permian environment. Because of the large area (13,000 square miles), much of the information presented here is by necessity general in nature. It is intended to provide an overview of the Permian environment in sufficient detail to allow screening to locations and to plan future studies.

Consistent with the screening process described above, this report follows in sequence the regional geologic and environmental characterization studies of the Permian Basin that have already been completed. The results of these studies are contained in reports by Bachman and Johnson (1973), Johnson (1976), and NUS Corporation (1979a). The information contained in these regional reports is summarized in the Regional Summary and Recommended Study Area for the Texas Panhandle Portion of the Permian Basin, NUS (1979b). Figure I-1 shows the relationship of this report to completed, ongoing, and proposed activities.

Based on the preliminary results of the geologic and environmental studies noted above, the Palo Duro and Dalhart Basins in the Texas Panhandle were selected for the next phase of studies (Figure I-2).

The Governor of Texas has designated the Texas Energy and Natural Resources Advisory Council (TENRAC) to consult and coordinate with the DOE regarding the Nuclear Waste Terminal Storage program in Texas. In accord with this function, on December 15, 1981, the DOE requested that TENRAC review a draft of this report. Comments from TENRAC and the DOE's responses are included as Appendix B.

REFERENCES FOR INTRODUCTION

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Johnson, K. S., 1976. Evaluation of Permian Salt Deposits in the Texas Panhandle and Western Oklahoma for Underground Storage of Radioactive Wastes, Y/OWI/SUB-4494/1, prepared for Union Carbide Corporation, Nuclear Division, Office of Waste Isolation.

NUS Corporation, 1979a. Environmental Characterization of Bedded Salt Formations and Overlying Areas of the Permian Basin, ONWI-27, prepared for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

NUS Corporation, 1979b. Regional Summary and Recommended Study Areas for the Texas Panhandle Portion of the Permian Basin, ONWI-28, prepared for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

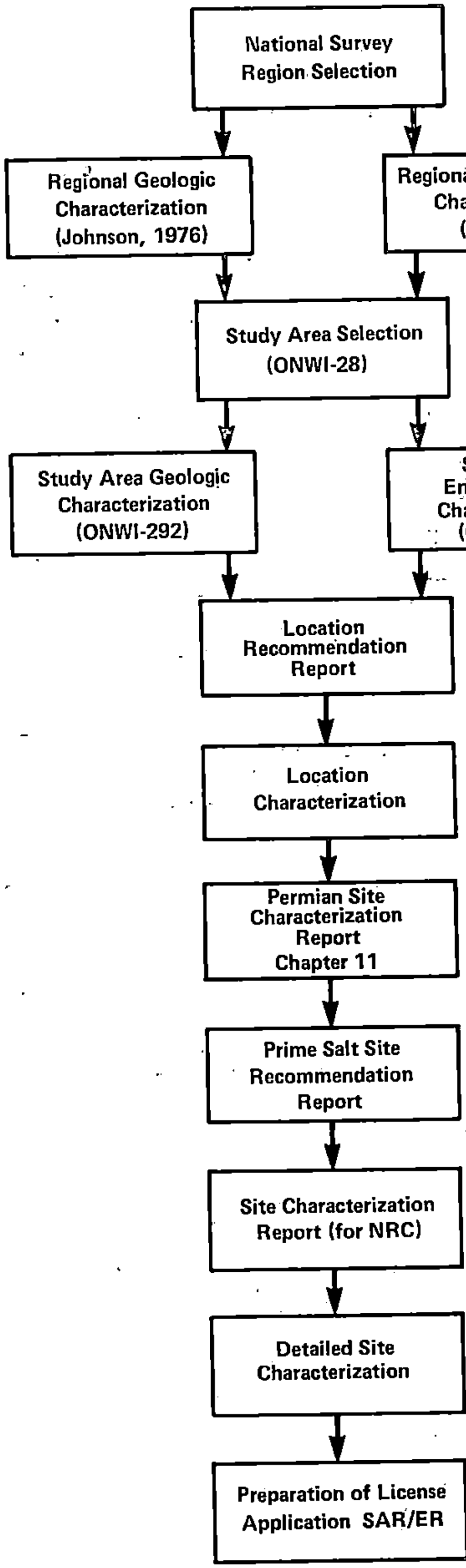
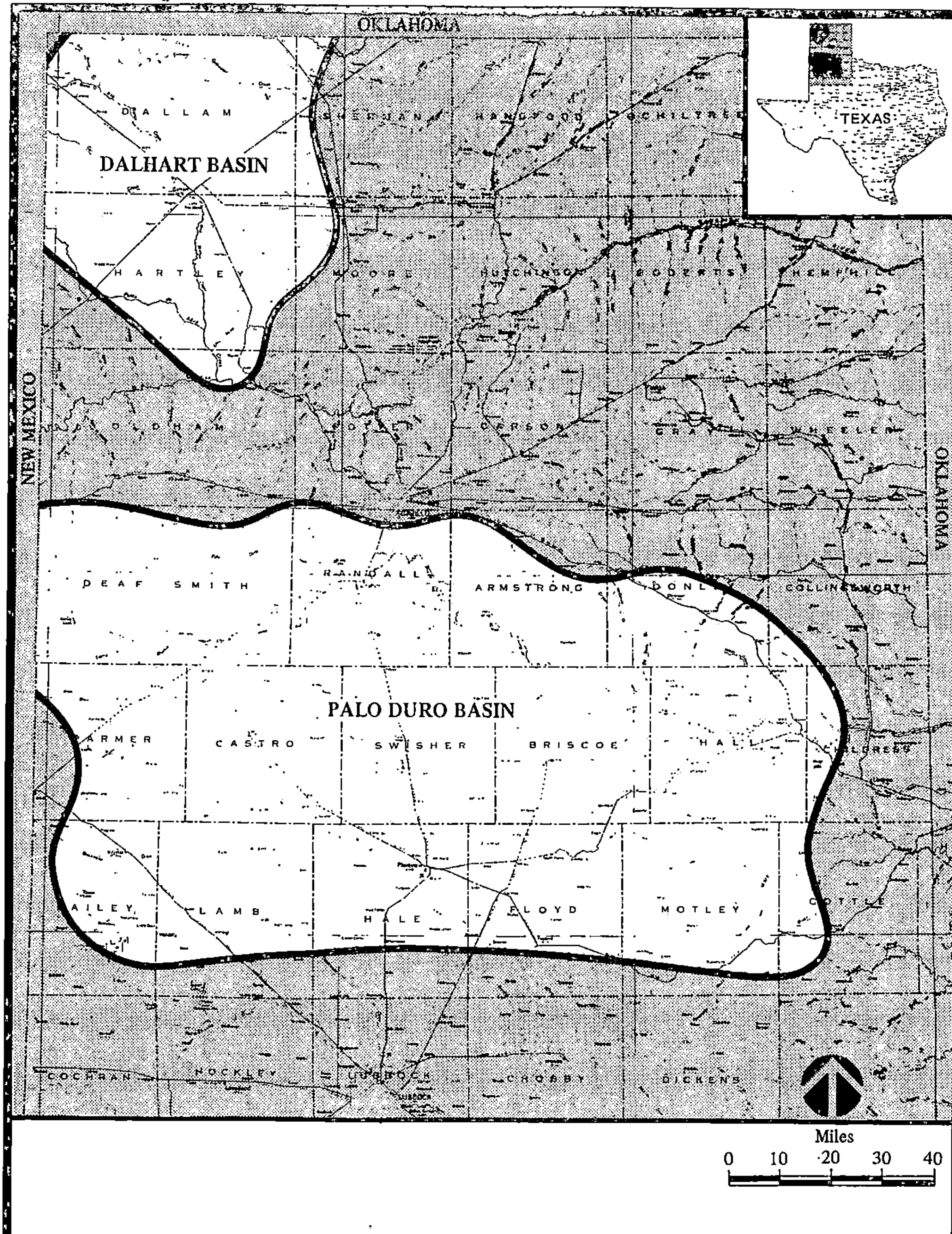


Figure I-1. Permian Basin Site Characterization Reports.



Source: Nicholson (1960); USGS (1965).

Figure I-2. Environmental Study Area--
The Dalhart and Palo Duro Basins in the Northern Texas Panhandle.

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Dalhart Basin Summary

DEMOGRAPHIC, SOCIOECONOMIC, AND LAND-USE SYSTEMS

The Dalhart basin, located in the northwestern corner of the Texas Panhandle, is sparsely populated, with the largest population center (the Town of Dalhart) having 6342 inhabitants. The populations of the other communities in the basin range from 60 to 446 persons. Projections indicate that the population of the basin is likely to decline in the future.

The economic base of the Dalhart basin is limited because of the small population. Manufacturing is the largest employment sector in the basin, accounting for about 22 percent of total employment. Per capita income for the five counties wholly or partly included in the basin averaged $4836 in 1975. Projections by the U.S. Water Resources Council indicate that per capita income should increase 73 percent from 1980 to 2000 and remain approximately 94 percent of the U.S. average.

Potentially sensitive or conflicting land uses within the Dalhart basin include three recreational and natural areas; five historic structures designated by the Texas Historical Commission; numerous small airports; and two military air training routes. The Rita Blanca National Grassland covers 22 percent of the basin; the area under military air routes is about 22 percent of the basin.

Rail and highway facilities within the Dalhart basin are adequate but not extensive. There is no major railhub or interstate highway within the basin. There are approximately 154 miles of single-track rail lines and 195 miles of Federal and state highways within the basin.

The principal water use in the Dalhart basin is irrigation, with groundwater being the principal source. It is projected that this will remain true through the year 2030; however, the total amount of water use is projected to decline because of the depletion of water in the Ogallala aquifer.

TERRESTRIAL ECOLOGY

The terrestrial environment of the Dalhart basin is characterized in terms of soils, vegetation, wildlife, and agriculture. Emphasis is given to important species. Data and conclusions are based on published and unpublished literature, reports from state and Federal agencies, and interviews with local biologists and game officials.

The Dalhart basin consists primarily of grassland, rangelands, and agricultural areas. Wetlands are scarce, occurring principally as rivers or intermittent playa lakes. Wetlands are probably the most important habitats in the basin, mainly because of their limited distribution. Although there are no critical habitats in the basin, several endangered, threatened, or rare species occur in or near the basin in varying numbers, either as migrants, winter residents, or permanent residents. Several of these important species occur in mixed brush areas or wetlands; relatively few are found in agricultural lands or in overgrazed areas.

AQUATIC ECOLOGY

The aquatic resources of the Dalhart basin are limited. Most streams in the basin are intermittent, and sport fisheries are largely restricted to reservoirs. Playa lakes provide mostly seasonal aquatic habitats and generally do not support fisheries.

A small portion of the Canadian River and two other permanent streams run through the Dalhart basin. The Canadian River has been classified by the U. S. Fish and Wildlife Service as a high-priority fishery resource. However, sport fishing in the Canadian River and the two other streams is apparently very limited. Lake Rita Blanca has an experimentally managed fishery including largemouth bass, crappie, flathead catfish, and channel catfish. The numerous playa lakes in the Dalhart basin are shallow (often dry) water bodies that do not support a fishery. However, the playas temporarily support organisms such as fairy, tadpole, and clam shrimp and salamanders (fauna of invertebrates and amphibians). Some of the playa lakes are known to sustain vector mosquito species during certain periods of the year.

There are no known rare or endangered aquatic species in the Dalhart basin. Important species include various sport fish (especially largemouth bass, crappie, and several catfish), which are heavily dependent on the largely managed ecology of each of the reservoirs or the flow of the few permanent streams in the basin.

The aquatic ecology of the basin is heavily controlled by the lack of water or its intermittent availability and the high salt content of many water bodies. Organic pollution problems from agriculture are present in a few areas.

ATMOSPHERE

The climate of the Dalhart basin is generally semiarid; the basin is located between the dry, desert climate to the west and the wet, humid climate to the east and southeast.

There are large variations from normal in the total annual precipitation. Persistent periods of extreme cold or heat are rare. Average relative humidities are low in the basin. Wind speeds are high on the average. The high winds, the sparse vegetation, and the low normal precipitation prevalent throughout much of the basin create a potential for wind erosion and dust storms.

Fundamental changes in the climate of the basin have occurred over the last million years (the Pleistocene Epoch). During this period there have been four ice ages, the most recent of which ended about 10,000 years ago. Although glaciers did not extend to the basins, the climate was probably cooler, wetter, and stormier than at present. Flooding was probably more frequent. The current epoch (Holocene) is considered to be interglacial. However, there are indications that a long-term global cooling trend is under way at present.

The maximum 24-hour rainfall associated with a 100-year recurrence interval averages 6.0 inches across the area of the Dalhart basin. This value is rather typical for the contiguous United States. There is an average of approximately 3.5 tornadoes per year in the Dalhart basin. Its location is west and south of the area of the United States that is associated with relatively frequent tornadoes. The 100-year-recurrence extreme wind is 85 mph for the basin. This value is consistent with most areas of the midwestern United States. Restrictive dispersion conditions are infrequent in comparison with most of the contiguous United States.

Air-quality statutes and regulations restrict development in areas that are not attaining the national ambient air-quality standards (unless certain offsetting criteria are satisfied) or where emissions would result in violations of the standards or would exceed increments established by the Clean Air Act Amendments of 1977. Data indicate that the national ambient air-quality secondary standards for particulates are being exceeded in the vicinity of the Dalhart basin. These particulate concentrations can be attributed largely to fugitive dust, although there are some particulate point sources along major highways and near major towns.

The limited data available for the Dalhart basin reveals no anomalous external dose rates from background radiation. Dose rates in the Dalhart basin range from 111 to 119 millirem per year, with a mean of 114.

Data on background-radiation levels in such media as air, water, and milk are extremely limited for the Dalhart basin. The basin has been characterized by compiling data from sampling locations mostly outside the basin, but surrounding the area. Data from sampling stations in Texas, Oklahoma, and New Mexico are taken to reflect typical background-radiation levels in air, water, and milk--levels that can be expected to be applicable to the Dalhart basin as well. The data indicate that levels of radioactivity in environmental media are not constant, but vary both spatially and temporally.

1 Demographic, Socioeconomic, and Land-Use Systems

The Dalhart basin is predominantly rural and sparsely populated. The total 1976 population for the five counties included within the boundaries of the basin did not reach 31,000 persons.

This area of the Permian Basin is under the jurisdiction of three regional planning agencies: the Panhandle Regional Planning Commission, the South Plains Association of Governments, and the Nortex Regional Planning Commission. Each city has its own governmental framework. The economic infrastructure of the basin is related largely to agriculture and population centers.

Land outside the population centers is largely used for cropland and grazing land. There are some major recreational and natural areas within the basin. The largest is the Rita Blanca National Grasslands, whose 77,000 acres cover approximately 4 percent of the Dalhart basin. The basin does not contain any potentially interactive uses that would significantly affect the operation of a repository; however, there are four airfields and two low-altitude training routes in the basin that could affect the repository. The transportation system available in the basin consists of a good spatial distribution of railroads and major highways, a small air-traffic hub in the Amarillo-Borger area, and many smaller airports throughout the basin. There are no navigable waterways in the basin.

1.1 DEMOGRAPHY

The distribution of population is important in assessing a variety of potential impacts on people and their activities. At the study-area level, the demographic characteristics that are pertinent to the evaluation of possible socioeconomic impacts are considered to be represented on an appropriate scale by the number and distribution of urban places. Population-density data are used to indicate relative potential radiological impacts.

The Dalhart basin lies in the northwest corner of the State of Texas. It covers all of Dallam County, most of Hartley County, and small portions of Moore, Oldham, and Sherman Counties (see Table 1-1). The total population in the five-county study area increased by more than 7 percent from 1970 to 1976 to nearly 31,000 persons in 1976. Most of the people in this sparsely populated area live in small towns scattered throughout the basin.

Population projections prepared for the U.S. Water Resources Council (1974) indicate that the total population in and around the basin (in the Bureau of Economic Analysis (BEA) Economic Area 122, Amarillo, Texas) is likely to decline in the future. A decrease of approximately 7 percent is forecast for the period from 1980 to 2000. Most of this decrease is expected to occur in rural areas.

1.1.1 POPULATION CENTERS AND URBAN PLACES

Geographers and urban planners have long observed that there exists a hierarchy of urban places and the services they offer. The hierarchy of urban places is based on population size, which can be an indicator of the level and the type of services offered. Generally, the larger the size, number, and variety of urban places in an area, the greater the quantity and variety of services offered, including the size of the labor force, recreational opportunities, and commercial activities. An area with many large and small urban places may be better able to meet the labor-force and socioeconomic needs associated with the development and operation of a repository than can an area with only a few small urban places.

It should be noted that urban places both within and near the boundaries of the area may be within the repository's zone of influence.

As shown in Figure 1-1, there are eight identified population centers in the Dalhart basin: Channing and Hartley in Hartley County; Conlen, Kerrick, Perico, Texline, and Ware in Dallam County; and Dalhart, which straddles the Hartley-Dallam county line. The largest of these, the Town of Dalhart, has a population of 6342. The remaining 7 communities have populations of 60 to 446 persons. The town of Dumas (population 10,333), just outside the eastern boundary of the basin, is the only urban place adjacent to the basin.

Population estimates by county and town for 1970 and 1976 are given in Table 1-2, which also indicates the percent change from 1970 to 1976 for each county. Major population centers within 40 miles of the basin are listed in Table 1-3.

1.1.2 POPULATION DENSITY BY COUNTY SUBDIVISION

Population densities in county subdivisions can affect the radiological impacts of a radioactive-waste repository in two ways. Population densities in counties through which major transportation routes pass provide a measure of potential population doses resulting from the transportation of radioactive wastes. In assessing transportation routes, the number and population of cities along such routes are also of importance, since large numbers of people could be exposed to transported radioactive material at relatively small distances. Population densities are also important in evaluating the potential radiation doses resulting from radioactivity releases from a repository.

1.1.2.1 Population Densities

The population densities of county subdivisions in the Dalhart basin (as of July 1976) are based on estimated subcounty populations. The densities are evaluated using current county projections by the Bureau of the Census (USDC, 1971; USDC, 1979b). It has been assumed that since the 1970 census each county subdivision has changed population at the same rate as its county. The areas of the subcounties involved were obtained from information provided in several sources (USDC, 1965; USDC, 1971; The Dallas Morning News, 1977).

In addition to the population densities of county subdivisions, the population densities of counties that are in the general vicinity of the study area, but completely outside the Dalhart basin, have been calculated (USDC, 1979b; The Dallas Morning News, 1977). The objective was to present a more meaningful overall area characterization; this would be of particular importance if the locations chosen in the next step leading to a candidate site are close to the boundaries of the basin. Such information is also important in that it indicates the population densities in counties through which major transportation routes pass.

Tables 1-4 and 1-5 present the subcounty and county population densities in tabular form; Figure 1-2 presents the data on a map coded to population density increments. Because Potter and Randall Counties include Amarillo, they have high population densities. The population densities in all other county subdivisions in the Dalhart basin and in neighboring Texas counties are low.

1.1.2.2 Major Transportation Routes

The major transportation routes, both highways and railways, passing through and in the general vicinity of the Dalhart basin are shown in Figure 1-2. The information was obtained from a number of sources (USDOT, 1975; Rand-McNally, 1977; The Dallas Morning News, 1977) and is discussed further in Section 1.3.3. No navigable waterways pass through, or in the vicinity of, the Dalhart basin.

1.1.2.3 Cities and Towns

The towns and villages that are along the major transportation routes in, or in the vicinity of, the Dalhart basin are shown in Figure 1-2. These locations have been identified in a recent edition of a road atlas (Rand-McNally, 1977) and also on a map issued by the U.S. Department of Transportation (1975). The populations are given in several references (Rand-McNally, 1977; USDC, 1979b; The Dallas Morning News, 1977); some of the cities and their populations are listed in Tables 1-2 and 1-3.

1.2 SOCIOECONOMICS

Socioeconomic parameters are indicators of the economy of the area and of its social patterns. These kinds of parameters indicate the capability of the community to meet the needs generated by the construction and operation of a repository. At the area level, economic base and mean per capita income are used to characterize the socioeconomic systems.

1.2.1 ECONOMIC BASE

In addition to characterizing the area by demographic and land-use parameters, it is also important to identify components of the economic base of the area that would affect, or be affected by, the construction and operation of a repository. The economic base serves as an indicator of the adequacy of the area's labor pool and related economic resources to meet the needs associated with the development and operation of a repository.

Owing to the low population base, the Dalhart basin has a limited economic infrastructure. It also has a limited labor force with skills in mining and construction. As shown in Tables 1-6 and 1-7, manufacturing is the primary employment sector in the study area, accounting for approximately 1350 employees, or 22 percent of the total employment in the five-county area. There is some contract construction employment, but very little employment in mining.

Federal civilian employment accounted for about 3 percent of the total identified employment in 1977 (USDC, 1979a). In 1978, the study area's civilian labor force was 12,508 persons, of whom 445, or 3.6 percent, were unemployed (Table 1-8).

Total employment in the BEA Economic Area 122 is expected to decline by more than 4 percent from 1980 to 2000, with the largest percentage decrease occurring in the rural portion of the area (Table 1-9). The five-county study area makes up approximately 16 percent of the land area of BEA Economic Area 122.

Projections of earnings for BEA Economic Area 122, as shown in Table 1-10, indicate that total earnings for all industries are expected to increase by more than 56 percent from 1980 to 2000, and several industrial sectors will constitute larger portions of total earnings in 2000 than they did in 1980--namely, manufacturing, finance and related areas, services, and government. The percent of total earnings contributed by agriculture, forestry and fisheries, and mining is projected to decline from 1980 to 2000.

1.2.2 INCOME CHARACTERISTICS

Average per capita money income by county in 1975 was $4836 for the study area, an increase of 75 percent since 1969. Average figures for the State of Texas were $4641 and 66 percent, respectively. Family incomes in the study area in 1970 were near State averages. Additional details on income characteristics for the counties wholly or partly contained in the basin and average values for the basin and for the State of Texas are provided in Table 1-11.

Projections indicate that per capita income for the study area will increase by nearly 73 percent from 1980 to 2000 and will remain approximately 94 percent of the U.S. average (see Table 1-9 for additional details).

1.3 LAND USE

1.3.1 RECREATIONAL, NATURAL, ARCHAEOLOGICAL, AND HISTORIC AREAS

The Dalhart basin contains three recreational and natural areas that are larger than 1000 acres (Table 1-12 and Figure 1-3). The largest of these, the Rita Blanca National Grasslands along the Texas-Oklahoma border, has more than 77,000 acres in the basin. These grasslands comprise approximately 4 percent of the area of the basin; the other two areas constitute 1 percent or less.

The Texas Historical Commission has designated five structures in the Dalhart basin as Recorded Texas Historic Landmarks (Table 1-13 and Figure 1-3). The basin does not contain any sites listed in the National Register of Historic Places and Natural Landmarks. One proposed National Register Natural Landmark is located within the Dalhart basin.

No geologic areas of special interest have been identified by either Federal or state agencies at this time.

1.3.2 POTENTIALLY INTERACTIVE USES

The airports located in the Dalhart basin are listed in Table 1-14. There are only four airfields within the basin boundaries and another seven within 15 miles of the basin (USDC, 1979c,d,e). All of these are non-tower-controlled facilities, and two of them are privately owned. There are no tower-controlled airfields or commercial air hubs in the basin (see Figure 1-4).

There are no military airfields, other military installations, or military operations areas in the Dalhart basin. Restricted airspace and low-altitude military training routes are shown on Figure 1-5. Information about these routes is also presented in Table 1-15. There is no restricted airspace in the Dalhart basin itself. Only two military air training routes pass through the basin. In total, these routes occupy about 22 percent of the total area of the basin.

There are no nuclear power plants in the basin, and none are under construction. No other nuclear industries are present.

County general highway maps and U.S. Bureau of the Census data on county business patterns were reviewed to determine the likelihood of other potentially interactive uses within the basin. The Texas State Department of Highways was also consulted. These sources indicated that no major concentrations of interactive industries would be present, except perhaps in Moore County, which does have some chemical manufacturing plants.

1.3.3 TRANSPORTATION SYSTEMS

The level and diversity of the transportation network determine the accessibility of an area to materials, labor, housing, and other social and economic amenities. The transportation routes in the Dalhart basin consist of highways and railroads as well as the airport facilities described in Section 1.3.2.

1.3.3.1 Highway System

Most areas in the Dalhart basin are generally accessible by major highways and secondary roads. Within the basin there are approximately 192 miles of U.S. highways and 3 miles of state highways.*

The major north-south U.S. highways in the basin include 385 and 87, which travel through the entire basin from north to south, and U.S. Highway 287 which traverses the eastern part of the basin in a north-south direction. Additional details are provided in Table 1-16 and Figure 1-6.

1.3.3.2 Railroads

There are no major rail hubs within the basin (the closest one is Amarillo), but it is traversed by approximately 154 miles of single tracks, which are owned by three different railroad companies (see Table 1-17 and Figure 1-7). There is no double track or track with rights shared by two or more railroads.

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*State highway total does not include state park roads, farm or ranch-to-market roads, or recreational roads. In 1979, there were nearly 200,000 miles of rural roads in Texas, of which 69 percent were county, 19 percent were farm-to-market, and 12 percent were state highways.

1.3.3.3 Waterways

There are no navigable waterways in the Dalhart basin.

1.3.4 INDIAN RESERVATIONS

There are no Indian reservations in the Dalhart basin.

1.3.5 LAND-USE PATTERNS

Figure 1-8 is a composite illustration of certain land use factors that have been presented in Chapter 1 and in other sections of the report. The factors selected are those uses of land that are either of particular significance in the Texas Panhandle region or factors considered to be more sensitive to the siting of a repository. As the figure indicates, there are certain areas of land within the basin where none of these uses occur.

If suitable geologic conditions can be found, it would then appear that the south-southwestern portions of the basin may offer a contiguous area that would warrant in-depth study in the follow-on location and specific site investigations. Although land uses identified in this section may not exclude repository siting in other parts of the Dalhart basin, it does appear that the above portions of the basin, may be (pending further study), more free of conflicting land uses.

1.4 USES OF NATURAL RESOURCES

1.4.1 ENERGY AND MINERAL RESOURCES

Extensive petroleum or deep mineral extraction, either existing or potential, makes an area less desirable for repository placement. The presence of a repository may preclude certain types of extraction within given distances, thereby eliminating possible resources for beneficial use. Thus, it is preferable that repositories and deep extraction sites, particularly those for oil and gas mining, not be in close proximity.

This section presents the geographic distribution of energy and mineral resource extraction in the Dalhart basin and provides some description of potential future resource recovery.

1.4.1.1 Energy Resources

The Dalhart basin is located on the western edge of the largest contiguous natural gas field in Texas. The value of natural gas produced in 1974 (Table 1-18) in the five counties lying partially or totally within the basin exceeded $100 million. Nearly 80 percent of the five-county total value of oil was produced in Moore County where major natural gas fields cover much of the area. The portion of the Dalhart basin extending into Moore County lies predominantly outside the areas considered to be major natural gas fields (Figure 1-9).

The second largest natural gas producer in the five-county area is Sherman County with almost 19 percent of the total in 1974. Like Moore County, most of Sherman County lying within the Dalhart basin is not within the major natural gas fields.

The remaining three counties (Dallam, Hartley, and Oldham) each have some areas that are considered major natural gas producing fields.

A fairly large major oil field extends to the southeast of the basin, running parallel to the natural gas field, but there are no major oil production fields within the Dalhart basin where the principal oil-producing stratum is Pennsylvanian in age. The five-county area provided less than $5 million worth of oil in 1974.

In addition to oil and gas, some helium is produced in Moore County.

Hydrocarbon production is small in the Dalhart basin and it is not considered to be an area for major exploration efforts.

Coal-bearing strata have not been identified in the Dalhart basin although some rather extensive bituminous deposits have been mapped in north-central Texas. The lignite-bearing strata occur as a belt paralleling the Gulf Coast and extending from the center of the eastern border to the southern border and into Mexico. A few active lignite mines are located within this area. Significant future coal production is not expected within the Dalhart basin.

1.4.1.2 Mineral Resources

Metal ores presently are not being mined within the Dalhart basin and only limited metal production occurs throughout Texas. Economically recoverable deposits of metal ores are not expected to be discovered within the basin, although Handford (1979) notes the possibility of base metal mineralization in outcrops of middle to upper Permian strata as has been found in Oklahoma.

The potential for uranium in the entire Permian Region is sketchy (ERDA, 1976). Uranium has been found in Oldham County in the Dalhart basin. There has been some some mining in this county but production was small because of the limited size of the deposits (Butler et al., 1962). The National Uranium Resource Evaluation Program is being carried out by the U.S. Department of Energy to evaluate uranium resources in surface and shallow subsurface deposits in the Panhandle region of Texas (Handford, 1979).

The only surficial deposits being mined in the five-county area in 1973 were sand and gravel in Oldham County (Figure 1-10). Volcanic ash is found sporadically across the Texas Panhandle and potash has been reported from wells drilled in Oldham County (Cunningham, 1934). Stone, sand and gravel, clay, and lime are all mined directly to the south; therefore, surficial resources can also be expected in the Dalhart basin. These surficial resources are extracted from depths usually less than a few hundred feet; thus, extraction would not affect the salt deposits under consideration.

1.4.2 WATER USE

This section describes the availability of surface water in the Dalhart basin, the current use of both surface water and groundwater, and the water requirements projected for the future. Data on water quality are presented in Section 3.

For planning purposes, the Texas Water Development Board has divided the State's river basins into zones. The Dalhart basin lies in Zone 2 of the Canadian River basin, with a very small portion extending into the western edge of Sherman County in Zone 1 (Figure 1-11).

1.4.2.1 Water Availability

The mean annual precipitation in the Canadian River basin in Texas is about 19 inches, ranging from 15 inches in the west to 22 inches in the east. The mean annual precipitation in the Dalhart basin ranges from 16 inches in the west to 18 inches in the east (Carr, 1967) (Figure 1-12). About 80 percent of the total annual precipitation occurs from May through October.

The precipitation in the Canadian River basin is more variable than indicated by annual and monthly averages. An analysis of data collected by the U.S. Weather Bureau for the period 1931 to 1960 has shown that the total annual precipitation in the High Plains varied by more than 25 percent from the normal for 10 years out of the 30 studied (TWDB, 1966). The annual rainfall at Amarillo ranged from 9.94 inches in 1956 to 37.21 inches in 1941, and in 1965 monthly totals ranged from 0.07 inch in November to 10.73 inches in June. Precipitation so unevenly distributed in time, especially in an area of low rainfall and low but rapid runoff, does not sustain streamflow (TWDB, 1966).

Low precipitation, wind, and extreme ambient temperatures lead to a high rate of evaporation. The average annual net lake-surface evaporation rate varies between 50 and 60 inches over the Canadian River basin. The evaporation rate in the Dalhart basin is between 50 and 55 inches (TWDB, 1977).

The mean annual runoff, as shown in Figure 1-13, varies from about 0.25 to about 1.0 inch per square mile in the west and the east, respectively. The extremely low runoff values illustrate the aridity of the western portion of the Dalhart basin.

Data on streamflow are presented in Section 3, which also discusses the two major reservoirs (storage capacities of more than 5000 acre-feet) in the Dalhart basin: Lake Meredith, owned and operated by the Canadian River Municipal Authority (storage capacity 1,407,600 acre-feet, surface area 21,693 acres) and Lake Rita Blanca (storage capacity 12,100 acre-feet, surface area 524 acres).

Current water use and projected water requirements have been tabulated for each zone within each basin (TWDB, 1977). These data have been used to characterize the surface-water use for the Dalhart basin. In addition, a limited amount of historical use data for the five counties all or partially contained in the Dalhart basin are presented to indicate more closely the current water use (TWDB, 1975; TNRIS, 1979).

1.4.2.2 Current Water Use

The economy of the Canadian River basin is based on agribusiness, on the production of oil and gas, and on various manufacturing activities. These industries determine the quantity and the location of water requirements in the basin. Irrigation is the principal water use, with groundwater sources providing most of the supply.

As shown in Table 1-19, the total quantity of water used in the Canadian River basin in 1974 was 2,007,200 acre-feet, with groundwater sources supplying 1,985,900 acre-feet (99 percent of the total use). Of this total, 1,915,900 acre-feet (95 percent) was used for irrigation, with groundwater supplying all but 400 acre-feet (TWDB, 1977).

Municipal water use in the Canadian River basin totaled only 30,800 acre-feet in 1974 (2 percent of the total basin use). Zone 2 accounted for 26,400 acre-feet (86 percent of the total municipal use), with groundwater supplying 14,400 acre-feet. Almost half the municipal water requirement in Zone 2 was attributed to the City of Amarillo, in Potter County. Groundwater pumpage for municipal and industrial use in the years 1974, 1975, and 1976 is shown in Table 1-20.

Manufacturing industries in the Canadian River basin used 34,200 acre-feet of water in 1974 (2 percent of the total use). Manufacturing use in Zone 2 was almost totally concentrated in Gray, Hutchinson, and Moore Counties. The manufacturing industries in these counties, including the chemical and petroleum-refining industries, accounted for 91 percent of the total manufacturing water use. Groundwater sources supplied 30,400 acre-feet (89 percent) of the total manufacturing water use in Zone 2 (Table 1-19).

Steam-electric power generation in the Canadian River basin withdrew approximately 6000 acre-feet (0.3 percent of the total water use) in 1974. Zone 2 accounted for the entire 6000 acre-feet, with groundwater as the sole source of supply (Table 1-19).

Irrigation in the Canadian River basin required 1,915,900 acre-feet of water in 1974 (95 percent of total use), with groundwater supplying all but 400 acre-feet. Zone 2, which contains about 673,000 acres of irrigated land, used 947,000 acre-feet (49 percent of the total irrigation use) in 1974. Data on irrigated acreages and irrigation water use in the five counties wholly or partially contained in the Dalhart basin are given in Tables 1-21, 1-22, and 1-23.

Mining operations in the Canadian River basin used 4900 acre-feet of fresh water in 1974 (0.24 percent of the total use). Mining water use in the basin was solely for the extraction of petroleum and natural gas. Zone 2 accounted for 3000 acre-feet (61 percent of the total mining water use), with groundwater supplying 2900 acre-feet. The most intensive use of water for fuel production (39 percent of the total mining use) occurs in Hutchinson County, which is outside the Dalhart basin.

Livestock water use in the Canadian River basin totaled 15,400 acre-feet in 1974 (0.77 percent of the total use). Of this total, groundwater provided approximately 10,300 acre-feet. Zone 2 used 8700 acre-feet (56 percent of the total livestock water use), with groundwater sources supplying 5400 acre-feet (Table 1-19).

1.4.2.3 Projected Surface-Water Use

The economy of the area is expected to be based, as it is now, on large-scale agribusiness, and various manufacturing activities. Changes in the economic base, should they be caused by growing market demands, the availability of resources, and technological advances, can be expected to dictate the quantity and the location of future water requirements. (See Table 1-19).

Irrigation will continue to be the principal water use, with groundwater as the principal source of water. However, because of the decrease in the availability of water from the Ogallala aquifer, water use in the Canadian River basin is expected to decrease from the 1974 total of 2,007,200 acre-feet to 1,456,600 acre-feet by 2030, with irrigation requirement decreasing from 1,915,900 acre-feet (95 percent of the total use) to 1,222,900 acre-feet (84 percent). Water supplied from groundwater sources is projected to decrease from the 1974 total of 1,985,900 to 1,416,100 acre-feet by 2030 (from 99 to 97 percent of the total use) (TWDB, 1977). The depletion of the Ogallala aquifer will eventually affect the agricultural practices of the area. An increase in the amount of acreage under dry-land farming can be expected (Wyatt et al., 1976).

Municipal water requirements in the Canadian River basin are projected to increase from the 1974 total of 30,800 to 51,800 acre-feet by 2030 (from 2.0 to 3.6 percent of total use). Zone 2 is projected to account for 42,700 acre-feet (82 percent of the total municipal use), with groundwater supplying 30,800 acre-feet by 2030. The projected increase in municipal water requirements can be attributed largely to expected expansion in Potter and Sherman Counties.

Manufacturing water requirements are projected to increase 232 percent by 2030, from the 1974 total of 34,200 to 113,600 acre-feet (from 2.0 to 7.8 percent of the total use).

Over 99 percent of the manufacturing water requirements are and should remain in Zone 2. Groundwater is expected to supply 91 percent of the requirement. Petroleum refineries and agricultural chemical plants are expected to be the major water users, but substantial requirements are also projected in the manufacturing of machinery and equipment for construction, oil and gas, and materials handling.

Water requirements for steam-electric power production in the Canadian River basin will continue to increase steadily in the future. It is projected that, by the year 2030, 37,000 acre-feet will be withdrawn annually. Groundwater will supply 93 percent of this requirement. Zone 2 is projected to account for all of the steam-electric power generation.

Irrigation water requirements are expected to decrease. Inadequate water supplies, because of the depletion of the Ogallala aquifer, may necessitate a cutback in irrigation acreage. The 2030 projection of 1,222,900 acre-feet (84 percent of the total use) is a 36 percent decrease in irrigation water use from the 1974 total of 1,915,900 acre-feet (95 percent of the total use). Zone 2 is projected to irrigate 581,600 acres and use 668,800 acre-feet of water. Essentially the entire requirement will be supplied by groundwater (Table 1-19).

Mining water use in 1974 in the Canadian River basin totaled 4900 acre-feet (0.24 percent of the total use). This requirement is expected to increase to 5500 acre-feet (0.38 percent of the total use) by 2030. The Canadian River basin portion of the mining water used in the State of Texas (2 percent in 1974) is expected to decline to 1 percent by 2030.

Livestock water requirements in the Canadian River basin are projected to increase from 15,400 acre-feet in 1974 (0.77 percent of the total use) to 25,800 acre-feet (1.8 percent of the total use) by 2030. Zone 2 is expected to require 14,500 acre-feet (56 percent of the total livestock use) by 2030, with groundwater supplying 65 percent (Table 1-19).

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Table 1-1. County area as an approximate percentage of the Dalhart basin in Texas; basin area as an approximate percentage of county area

County	County area (acres)	Percent of county in Dalhart basin	Percent of Dalhart basin in county
Dallam	956,160	98	47
Hartley	952,320	83	40
Moore	581,760	13	4
Oldham	945,920	6	3
Sherman	586,240	19	6

Table 1-2. Population estimates for counties, cities, and towns in the Dalhart basin study area

County/town or city	Population[a] April 1970	July 1976	Percent change 1970 to 1976
Five-county study area	28,769	30,910	7.4
Dallam County	6,012	6,672	11.0
Texline		446	
Perico		NA	
Ware		NA	
Dalhart (part)		4,662	
Conlen		61[b]	
Kerrick		60[b]	
Sherman County[c]	3,657	3,734	2.1
Hartley County[c]	2,782	3,315	19.2
Channing		339	
Dalhart (part)		1,680	
Hartley		370[b]	
Moore County[c]	14,060	14,590	3.8
Oldham County[c]	2,258	2,599	15.1

Abbreviation: NA = Population estimate not available.

[a]From (except where noted in footnote b) USDC (1979b), Table 1.

[b]Population estimate from The Dallas Morning News (1977).

[c]All towns and cities in the county are located outside the basin boundaries.

Table 1-3. Major population centers within 40 miles of the Dalhart basin

Town or city	State	Population[a] July 1, 1976	Location[b]
Amarillo	Texas	141,484	40 miles south of the basin
Borger	Texas	14,503	40 miles east of basin
Dumas	Texas	10,333	5 miles east of basin
Guymon	Oklahoma	8,895	35 miles east of basin

[a]From USDC (1979b), Table 1.
[b]Locations approximated from the Rand McNally Road Atlas, 1977.

Table 1-4. Subcounty population densities[a]

County	County subdivision[b]	July 1976 county subdivision population[c]	County subdivision area[d] (mi^2)	County subdivision population density (people per mi^2)
Dallam	Dalhart	5,940	1,231	4.8
	Texline	734	263	2.8
Hartley	Channing	1,043	476	2.2
	Northwest Hartley	2,273	1,013	2.2
Moore	Dumas	12,324	666	18.5
	Sunray	2,270	248	9.2
Oldham	Vega East	2,170	836	2.6
	Vega West	429	630	0.7
Sherman	Stratford East	1,055	548	1.9
	Stratford West	2,679	366	7.3

[a]Population densities of county subdivisions are given for counties partially or fully within the Dalhart basin.

[b]From Table 10 of USDC (1971).

[c]From Table 10 of USDC (1971) and Table 1 of USDC (1979b).

[d]From Table 1 of USDC (1965), Table 9 of USDC (1971), and The Dallas Morning News (1977), pp. 257-367.

Table 1-5. Population densities in Texas counties near the Dalhart basin[a]

County	July 1976 county population[b]	County area (mi^2)[c]	County population density ($people/mi^2$)
Armstrong	2,019	909	2.2
Carson	6,542	900	7.3
Collingsworth	4,477	899	5.0
Deaf Smith	19,887	1,507	13.2
Donley	3,843	909	4.2
Gray	25,801	934	27.6
Hansford	6,241	907	6.9
Hemphill	3,949	904	4.4
Hutchinson	25,625	875	29.3
Lipscomb	3,768	934	4.0
Ochiltree	9,263	907	10.2
Potter	92,290	901	102.0
Randall	63,074	911	69.2
Roberts	1,055	899	1.2
Wheeler	6,157	914	6.7

[a]Population densities of counties are given for those counties in the general vicinity of, but completely outside, the Dalhart basin.

[b]Information from Table 1 of USDC (1979b).

[c]Information from The Dallas Morning News (1977), pp. 257-367.

Table 1-6. Major industry employment for the five counties in the Dalhart basin study area[a]

Industry	Number of employees for week including March 12, 1977	Percent of total
Agricultural services, forestry, fisheries	19-175	0.3-2.8
Mining	20-137	0.3-2.2
Contract construction	430-588	6.9-9.0
Manufacturing	1,349-1,368	21.8-22.1
Transportation and other public utilities	412	6.7
Wholesale trade	838	13.6
Retail trade	1,576	25.5
Finance, insurance, and real estate	278-395	4.5-6.4
Services	979	15.8
Nonclassifiable establishments	23-80	0.4-1.3
Total industrial employment for five-county study area	6,178	

Note: See Table 1-7 for employment data by county and explanation of data source in footnote b.

[a]From USDC (1979a), Table 2.

Table 1-7. Employment and payroll by major industry by county in the Dalhart basin study area[a]

County/industry	Number of employees for week including March 12, 1977	Annual payroll ($1,000)
Dallam County	1,393	11,705
Agricultural services, forestry, fisheries	0-19	(b)
Mining	--	--
Contract construction	20-99	(b)
Manufacturing	246	2,386
Transportation and other public utilities	91	1,178
Wholesale trade	288	2,785
Retail trade	422	2,686
Finance, insurance, and real estate	104	1,026
Services	192	1,283
Nonclassifiable establishments	0-19	(b)
Sherman County	491	4,444
Agricultural services, forestry, fisheries	0-19	(b)
Mining	--	--
Contract construction	20-99	(b)
Manufacturing	15	102
Transportation and other public utilities	67	751
Wholesale trade	106	1,239
Retail trade	142	853
Finance, insurance, and real estate	20-99	(b)
Services	59	354
Nonclassifiable establishments	1	9
Hartley County	393	3,053
Agricultural services, forestry, fisheries	0-19	(b)
Mining	0-19	(b)
Contract construction	50	483
Manufacturing	0-19	(b)
Transportation and other public utilities	34	375
Wholesale trade	52	551
Retail trade	43	358
Finance, insurance, and real estate	0-19	(b)
Services	187	1,025
Nonclassifiable establishments	0-19	(b)

Note: See footnotes at end of table.

Table 1-7. Employment and payroll by major industry by county in the Dalhart basin study area[a] (continued)

County/industry	Number of employees for week including March 12, 1977	Annual payroll ($1,000)
Moore County	3,632	38,830
Agricultural services, forestry, fisheries	20-99	(b)
Mining	20-99	(b)
Contract construction	323	2,981
Manufacturing	1,088	17,008
Transportation and other public utilities	204	2,855
Wholesale trade	316	3,357
Retail trade	883	5,180
Finance, insurance, and real estate	154	1,359
Services	509	3,371
Nonclassifiable establishments	22	68
Oldham County	269	1,945
Agricultural services, forestry, fisheries	0-19	(b)
Mining	0-19	(b)
Contract construction	17	135
Manufacturing	--	--
Transportation and other public utilities	16	221
Wholesale trade	76	660
Retail trade	86	401
Finance, insurance, and real estate	0-19	(b)
Services	32	151
Nonclassifiable establishments	0-19	(b)

Note: -- = no activity reported.

[a]From USDC (1979a), Table 2. Note that figures for number of employees and annual payroll do not include government employees, self-employed persons, farm workers, domestic and service workers, railroad employees, and employees on oceanborne vessels or in foreign countries. Therefore, much of the economic activity occurring in agriculture and other industrial sectors in the basin may not be reflected in this table.

[b]Figures withheld to avoid disclosure of operations of individual establishments.

Table 1-8. Civilian labor force characteristics of the Dalhart basin study area

County	Civilian labor force (annual average) Total number of persons	Number employed	Number unemployed	Percent unemployed
Dallam	1,916	1,839	77	4.0
Sherman	1,379	1,331	48	3.5
Hartley	951	920	31	3.3
Moore	7,476	7,207	269	3.6
Oldham	786	766	20	2.5
Five-county study area				
1978	12,508	12,063	445	3.6
1977	12,666	12,183	483	3.8
1976	12,012	11,545	467	3.9

Source: Texas Employment Commission; county figures are for 1978.

Table 1-9. Employment and personal income in the Dalhart basin and surrounding area[a]

Parameter/geographic area[b]	Year 1970	1980	1990	2000	Percent change 1980-2000
Total employment					
BEA Economic Area 122 (Amarillo)	171,679	170,300	163,900	163,300	-4.1
Standard Metropolitan Statistical Area (SMSA) 009 (Amarillo)	60,177	63,600	62,900	63,900	+0.5
Non-SMSA portion of BEA Economic Area 122	111,502	106,700	101,000	99,300	-6.9
Per capita income, 1967 dollars (per capita income relative, U.S. = 1.00)					
BEA Economic Area 122 (Amarillo)	3,387	4,400	5,700	7,600	+72.7
	(.97)	(.94)	(.93)	(.94)	(-)
SMSA 009 (Amarillo)	3,337	4,500	5,800	7,700	+71.1
	(.96)	(.95)	(.95)	(.95)	(-)
Non-SMSA portion of BEA Economic Area 122	(.98)	(.93)	(.92)	(.93)	(-)

[a]From U.S. Water Resources Council (1974).

[b]The BEA Economic Area 122, Amarillo, Texas, includes the Amarillo Standard Metropolitan Statistical Area (SMSA), which is comprised of Randall and Potter counties, 23 other counties in the Texas Panhandle, 3 adjacent counties in Oklahoma, and 7 adjacent or nearby counties in New Mexico. The Dalhart basin is located in the north-central portion of the BEA area.

Table 1-10. Earnings by industry for BEA Economic Area 122, Amarillo, Texas[a]
(earnings in thousands of 1967 dollars)

Industry	1980		2000	
	Total earnings	Percent of total earnings	Total earnings	Percent of total earnings
Agriculture, forestry, and fisheries	254,200	18.5	293,000	13.6
Mining	41,300	3.0	37,500	1.7
Contract construction	64,600	4.7	101,100	4.7
Manufacturing	199,100	14.5	349,900	16.2
Transportation, communications, and public utilities	115,100	8.4	182,000	8.4
Wholesale and retail trade	227,600	16.6	323,900	15.0
Finance, insurance, and real estate	54,800	4.0	100,000	4.6
Services	198,300	14.4	383,100	17.8
Government	218,800	15.9	384,000	17.8
Total earnings	1,374,100		2,155,000	

[a]From U.S. Water Resources Council (1974), Volume 2.

Table 1-11. Income characteristics of the Dalhart basin study area

County	Estimated per capita money income (dol)[b]				Family income, 1970[a]	
	1975	Percent change 1969 to 1975	Median	Mean	Families with incomes less than poverty level (%)	Families with incomes of $15,000 or more (%)
Dallam	4,323	80	7,053	8,401	15	13
Sherman	5,623	79	8,511	12,592	8	19
Hartley	5,415	76	9,472	10,558	16	24
Moore	4,588	59	8,906	10,034	7	16
Oldham	4,229	79	7,706	9,630	9	20
Average values						
All counties in study area[c]	4,836	75	8,330	10,243	11	18
State of Texas	4,641	66	8,490	9,955	15	17

[a]From USDC (1972), Tables 44, 57, and 124. (Note that 1970 figures are the most current official data.)

[b]From USDC (1979b), No. 782, Table 1.

[c]Average values for all counties in the study area are derived from simple arithmetic means of the values given for each county.

Table 1-12. Recreational and natural areas in the Dalhart basin study area[a]

Type and name (administration)	County	Size (acres)	Estimated acreage within basin
Rita Blanca National Grasslands (U.S. Forest Service)	Dallam	92,000	77,413
Rita Blanca Lake Park (county)	Dallam and Hartley	1,250	1,250
Cal Farley's Boys Ranch (commercial)	Oldham	4,100	4,100

[a]From Texas Parks and Wildlife Department (1979).

Table 1-13. Recorded Texas Historic Landmarks of the Dalhart basin study area[a]

Name	Town and county
St. James Episcopal Church	Dalhart, Dallam County
Channing Methodist Church	Channing, Hartley County
XIT Ranch Headquarters	Channing, Hartley County
First Hartley County Jail	Hartley, Hartley County
Old Tacosa Courthouse	Boy's Ranch, Oldham County

[a]From Texas Historical Commission (1979).

Table 1-14. Airports in the Dalhart basin area[a]

Name	County	Type
Dalhart	Hartley	Advisory service
Miller	Dallam	Advisory service
Conlen	Dallam	Private
Hi Plains	Dallam	Private

[a]From USDC (1979c,d,e).

Table 1-15. Low altitude training routes[a] in the Dalhart basin[b]

Reference name or number	Estimated land area within basin (acres)	Estimated percentage of basin area
IR-181	274,560	14
IR-177	164,480	8

[a]Originating from Barksdale Air Force Base.
[b]From U.S. Department of Defense (1979a,b).

Table 1-16. U.S., and state highways in the Dalhart basin study area[a]

Route type/number	Estimated total miles of route within basin	Orientation	Regional origin and terminus
	U.S. highways		
U.S. 287	13	NW-SSE	Oklahoma border to Amarillo
U.S. 385	55	N-S	Oklahoma border to Tacosa
U.S. 87	68	NW-E	New Mexico border to Dumas
U.S. 54	56	SW-NE	Straford to New Mexico border
	State highways		
354	3	E-W	Channing to Four Way

[a]From Texas State Department of Highways and Public Transportation (1978).

Table 1-17. Railroads and trackage in the Dalhart basin study area[a]

Railroads	Estimated miles of track within basin[b]
Atchison, Topeka & Santa Fe	11
Chicago, Rock Island & Pacific	66
Ft. Worth & Denver	77

[a]From USDT (1975).
[b]All tracks are single track and there are no shared trackage rights among railroad companies.

Table 1-18. Oil and gas statistics for counties in the Dalhart basin study area[a]

County	Year of first oil or gas discovery	Cumulative total for crude oil production to January 1, 1975 (42-gal barrels)	Value of oil produced in 1974 (dollars)	Value of gas produced in 1974 (dollars)	Wells completed in 1974		
					Oil	Gas	Dry holes
Dallam	1954			40,036			
Hartley	1937	754,633		4,648,550			5
Moore	1936	13,878,425	3,056,690	78,104,714	16	5	8
Oldham	1957	1,416,407	1,838,116	475,967			4
Sherman	1938	508,571	55,664	19,394,213			1

[a]From University of Texas at Austin (1976).

Table 1-19. Present water use[a] and projected water requirements by groundwater and surface water sources for the Canadian River basin (in thousands of acre-feet)[b]

Demand category	1974 Ground-water	1974 Surface water	1974 Total	2030 Ground-water	2030 Surface water	2030 Total
Zone 1	(Population 43,500)			(Population 32,800)		
Municipal	4.4	0	4.4	2.2	6.9	9.1
Manufacturing	0.1	0	0.1	(a)	0.3	0.3
Steam-electric	0	0	0	0	0	0
Irrigation	968.2	0.4	968.6	553.8	0.3	554.1
Mining	1.9	0	1.9	3.6	0	3.6
Livestock	4.9	1.9	6.8	8.1	3.1	11.2
Other	0	0	0	0	0	0
Subtotal	979.5	2.3	981.8	567.7	10.6	578.3
Zone 2	(Population 113,100)			(Population 153,700)		
Municipal	14.4	12.0	26.4	30.8	11.9	42.7
Manufacturing	30.4	3.7	34.1	103.0	10.3	113.3
Steam-electric	6.0	0	6.0	26.3	0	26.3
Irrigation	947.3	(a)	947.3	668.8	0.1	668.8
Mining	2.9	0.1	3.0	1.9	0	1.9
Livestock	5.4	3.3	8.7	9.4	5.1	14.5
Other	0	0	0	0	0	0
Subtotal	1,006.4	19.1	1,025.5	840.2	27.4	867.6
Basin summary	(Population 156,600)			(Population 186,500)		
Municipal	18.8	12.0	30.8	33.0	18.8	51.8
Manufacturing	30.5	3.7	34.2	103.0	10.6	113.6
Steam-electric	6.0	0	6.0	34.5	2.5	37.0
Irrigation	1,915.5	0.4	1,915.9	1,222.5	0.4	1,222.9
Mining	4.8	0.1	4.9	5.5	0	5.5
Livestock	10.3	5.1	15.4	17.6	8.2	25.8
Other	0	0	0	0	0	0
Total	1,985.9	21.3	2,007.2	1,416.1	40.5	1,456.6

[a]Uses are based on existing or locally available supplies.
[b]From TNRIS (1979).

Table 1-20. Groundwater pumpage for municipal and industrial use in the Dalhart basin for 1974, 1975, and 1976 (in acre-feet)[a]

County	Year	Use		
		Municipal	Industrial	Total
Dallam	1974	1,651.3	224.0	1,875.3
	1975	1,687.9	353.5	2,041.4
	1976	1,769.9	659.8	2,429.7
Hartley	1974	138.3	0.0	138.3
	1975	134.3	0.0	134.3
	1976	150.5	2,131.8	2,282.4
Moore	1974	3,275.3	12,361.0	15,636.4
	1975	2,912.1	10,276.9	13,189.0
	1976	4,018.6	11,769.1	15,787.7
Sherman	1974	663.8	12.0	675.8
	1975	556.7	11.2	567.9
	1976	602.3	11.3	613.6
Total	1974	5,728.7	12,597.0	18,325.8
	1975	5,291.0	10,641.6	15,932.6
	1976	6,541.3	14,572.0	21,113.4

[a]From TNRIS (1979).

Table 1-21. Irrigation in the Dalhart basin in 1974[a]

County	Acres	Acre-feet
Dallam	155,905	243,520
Hartley	140,000	187,972
Moore	230,136	327,908
Oldham	32,709	31,688
Sherman[b]	273,651	330,277

[a]From TWDB (1975).

[b]In Sherman County, 480 acres are irrigated using 420 acre-feet of water from combined supplies of surface and groundwater, and 84 acre-feet come from surface-water sources. All other counties used groundwater entirely.

Table 1-22. Irrigation water sources, modes, and acreages in Dalhart basin counties, 1974[a]

County	All irrigation (acres)	Surface-water irrigation only (acres)	Groundwater irrigation only (acres)	Irrigations using combined supplies (acres)	Irrigation wells (number)	Sprinkler systems (acres)
Dallam	155,905	0	155,905	0	900	93,120
Hartley	140,000	0	140,000	0	850	35,300
Moore	230,136	0	230,136	0	1,007	840
Oldham	32,709	0	32,709	0	242	1,330
Sherman	273,651	0	273,171	480	1,190	21,150

[a]From TWDB (1975).

Table 1-23. Dalhart basin county acreages of selected irrigated crops, 1974[a]

Crop	Dallam	Hartley	Moore	Oldham	Sherman
Cotton	0	0	0	0	0
Grain sorghum	46,320	78,000	79,500	12,100	120,300
Corn	44,240	15,000	73,000	1,458	23,000
Wheat	54,400	45,000	68,000	14,300	118,180
Other grain crops	8,000	1,000	3,000	1,995	3,000
Forage crops	500	2,000	3,500	3,000	1,500
Soybeans	0	15	300	0	7,900
Other oil crops	0	0	100	0	0
Alfalfa	4,800	3,000	500	200	1,600
Other permanent uses--hay, pasture	2,540	1,000	3,000	100	865
Sugar beets	100	3,300	2,000	0	306
Irish potatoes	0	0	0	0	0
Vegetables					
Shallow root	0	0	0	0	0
Deep root	0	60	350	0	0
All other crops	0	0	0	0	0
Total	160,900	148,375	233,250	33,153	276,651

[a]From TWDB (1975).

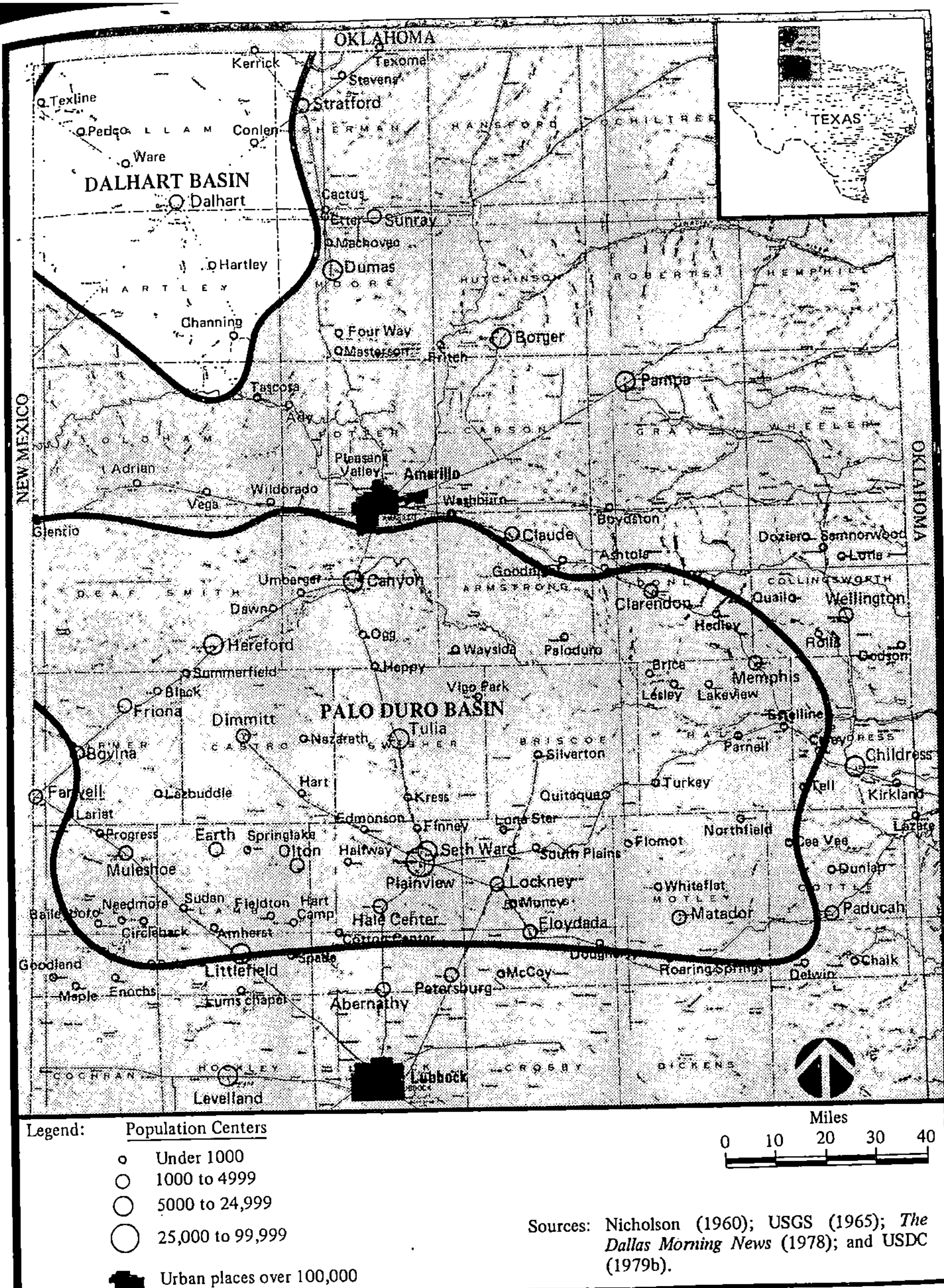


Figure 1-1. Population centers and urban places.

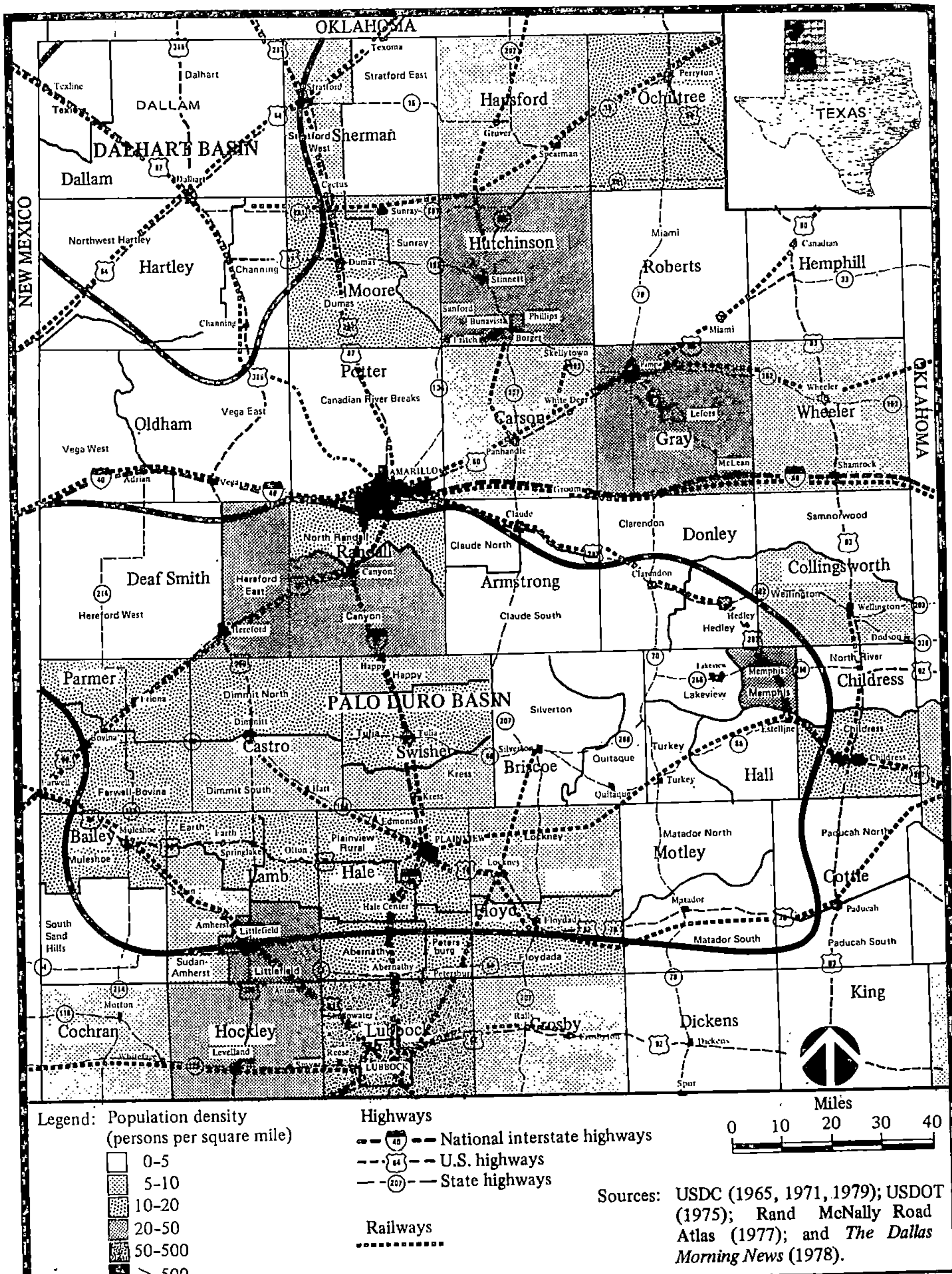


Figure 1-2. Population densities and major transportation routes.

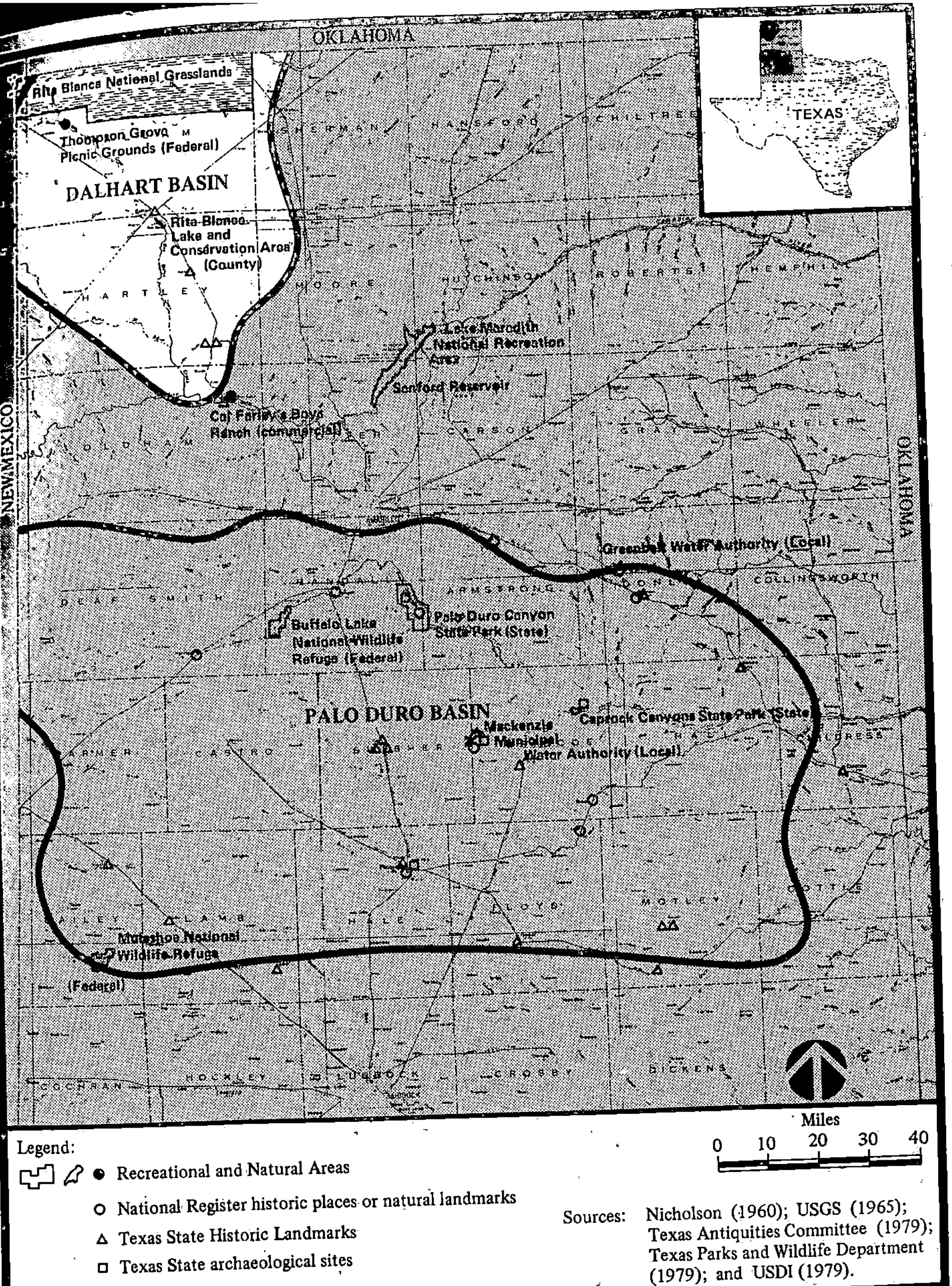
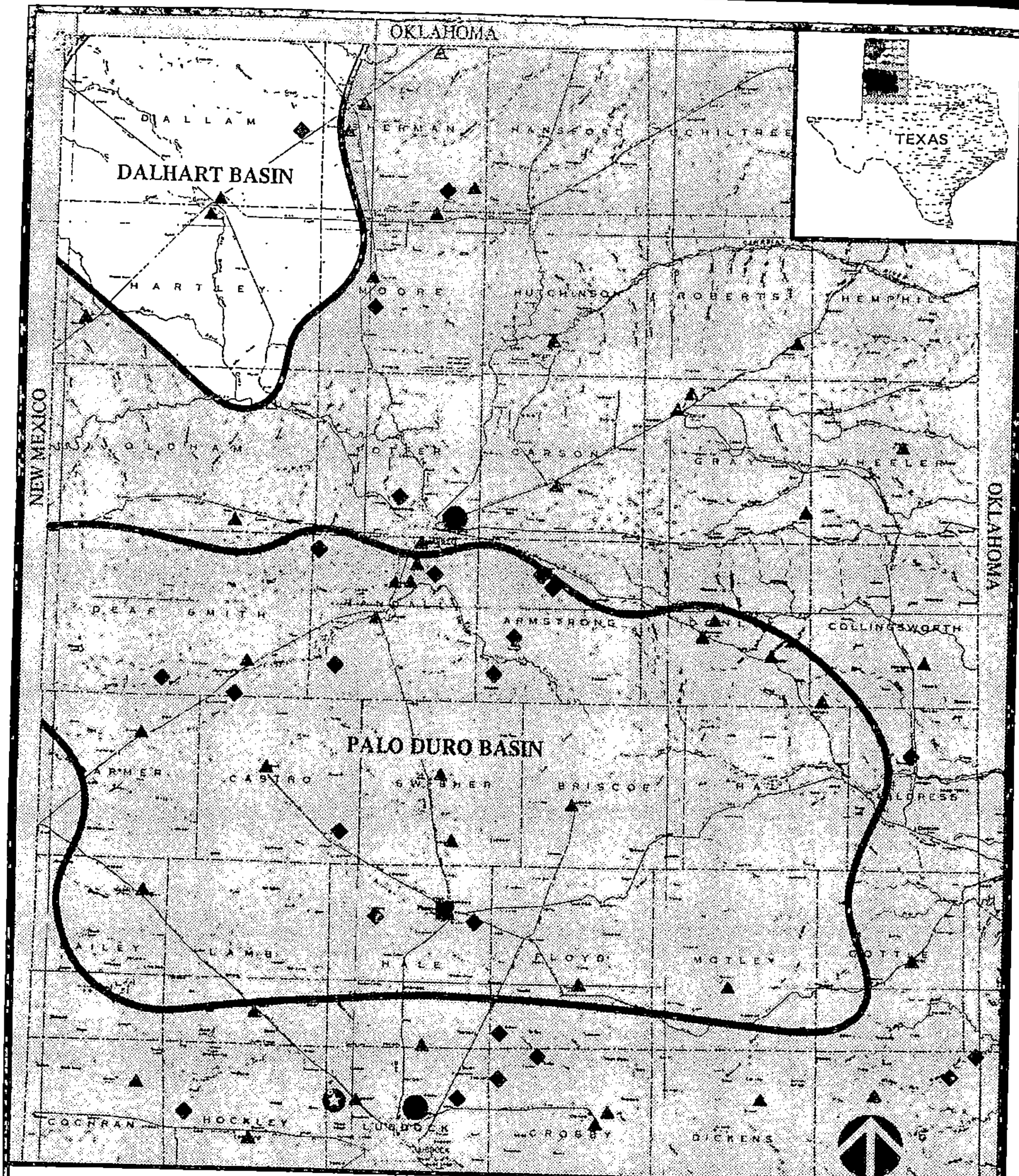


Figure 1–3. Recreational, natural, archaeological, and historic areas.



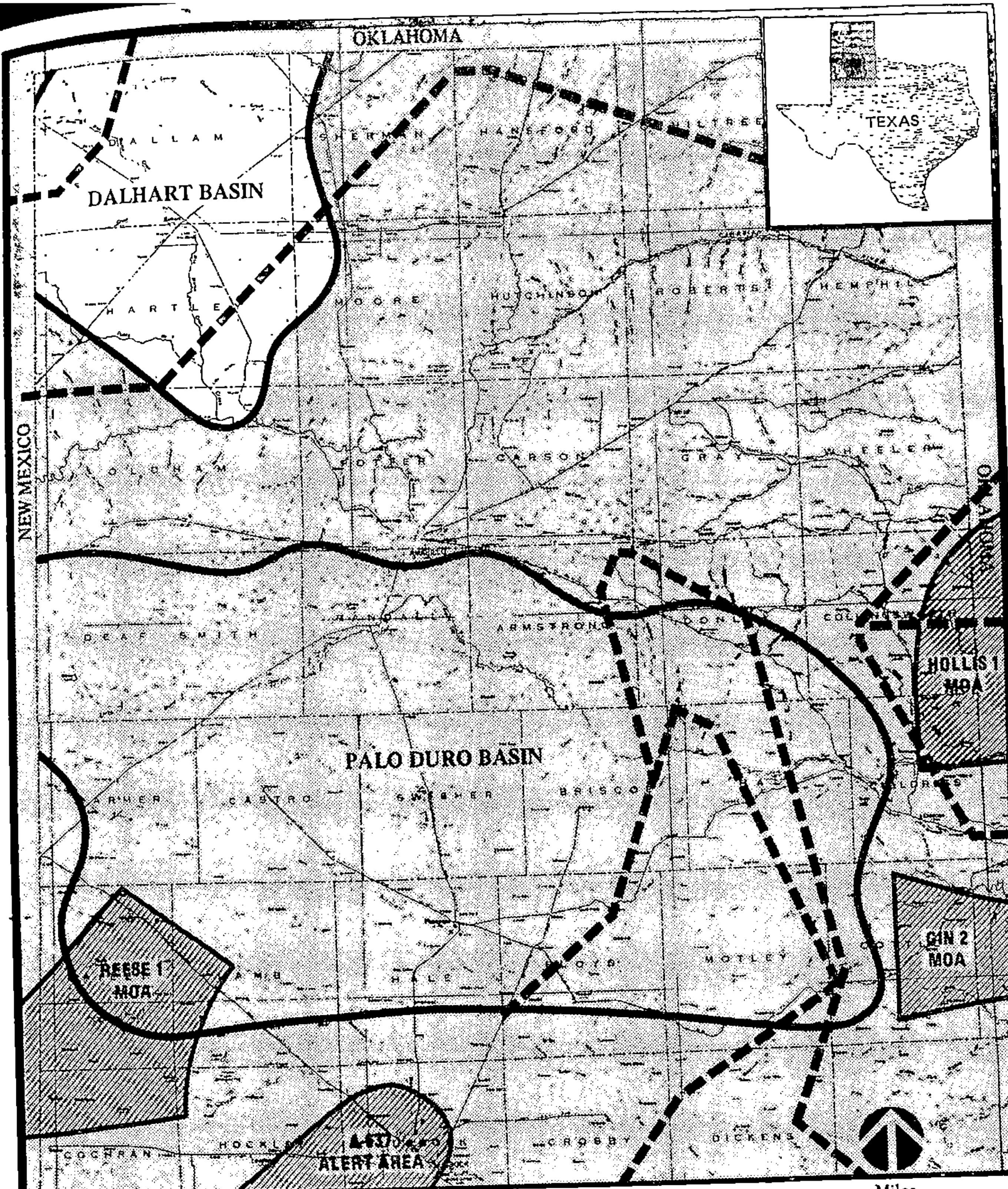
Legend:

- ▲ Advisory service
- ■ Tower controlled
- ◆ Private
- ● Small commercial hub
- ✪ Military

Miles
0 10 20 30 40

Sources: Nicholson (1960); USGS (1965); USGSA (1976); USDOT (1977); U.S. Department of Defense (1979a,b); and USDC (1979c,d,e).

Figure 1–4. Airports.



Legend:

Low-altitude training routes

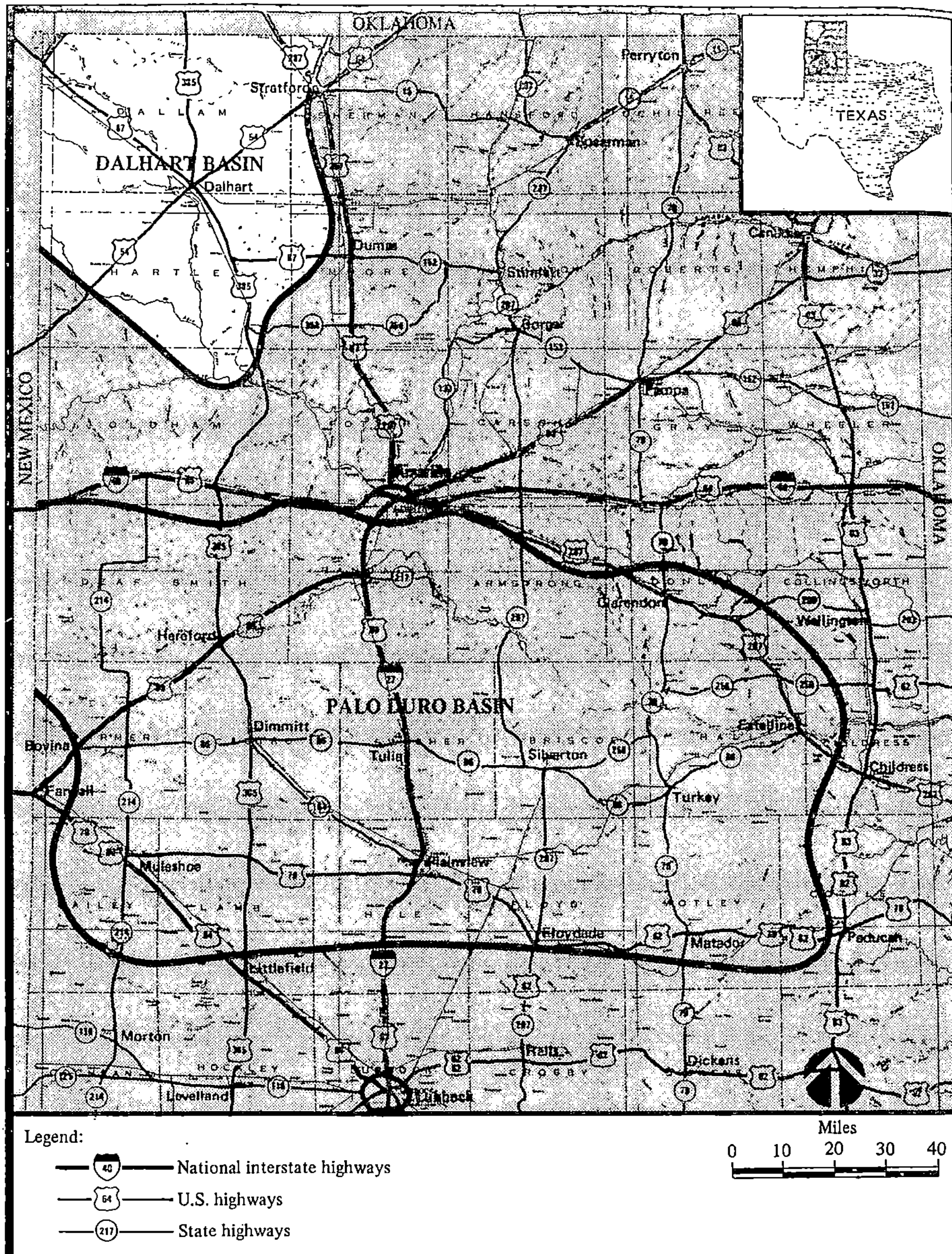
Military operations areas (MOAs)

Miles

0 10 20 30 40

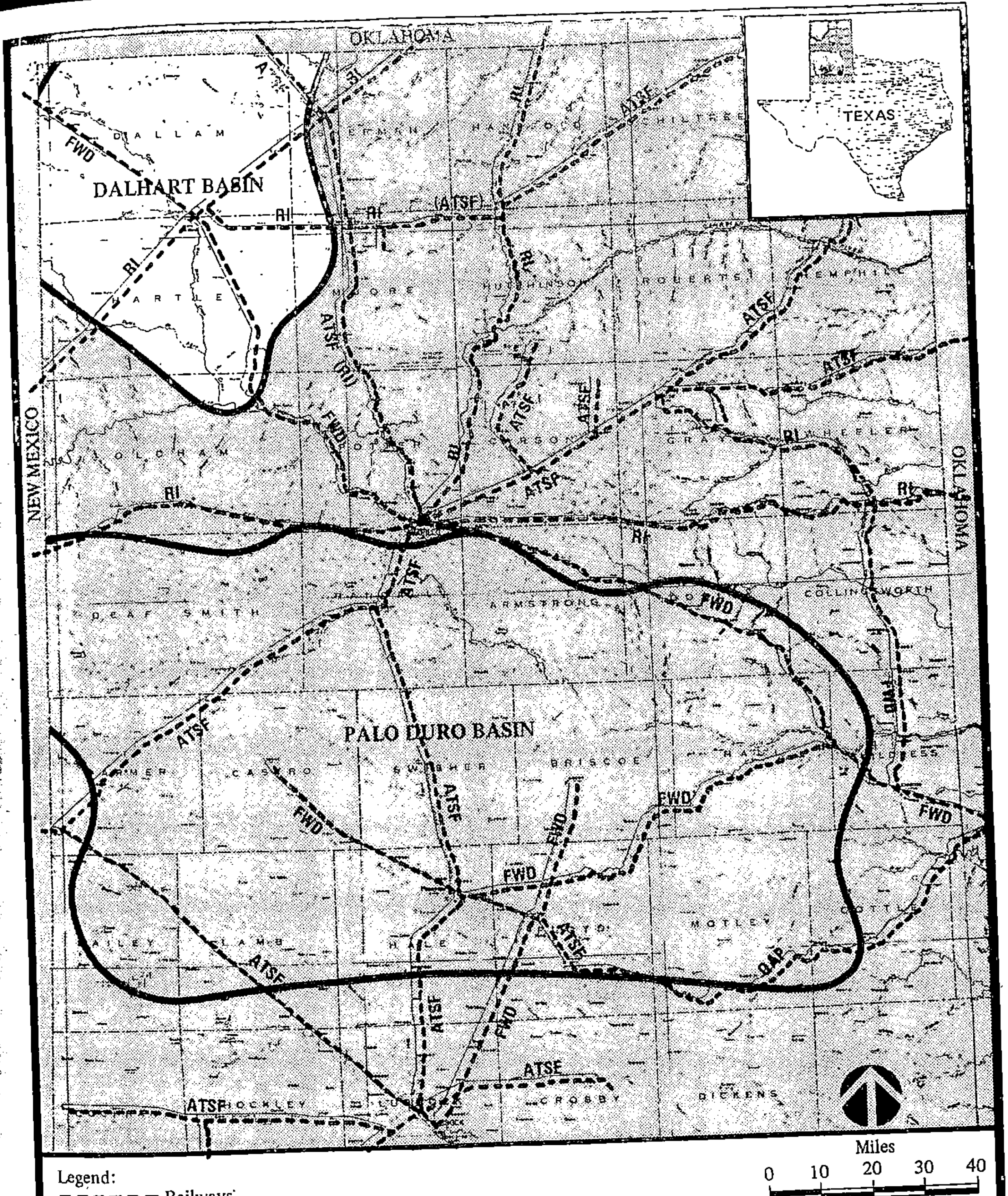
Sources: Nicholson (1960); USGS (1965); USDC (1979c,d,e); U.S. Department of Defense (1979a,b).

Figure 1–5. Restricted and military operations areas and military air training routes.



Sources: Nicholson (1960); USGS (1965); and Rand McNally Road Atlas (1977).

Figure 1–6. Highways.



Legend:
- - - - - Railways

ATSF – Atchison, Topeka, & Santa Fe
FWD – Fort Worth & Dallas
QAP – Quanah Acme & Pacific
RI – Chicago, Rock Island & Pacific

Sources: Nicholson (1960); USGS (1965); and USDT (1975).

Figure 1–7. Railroads.

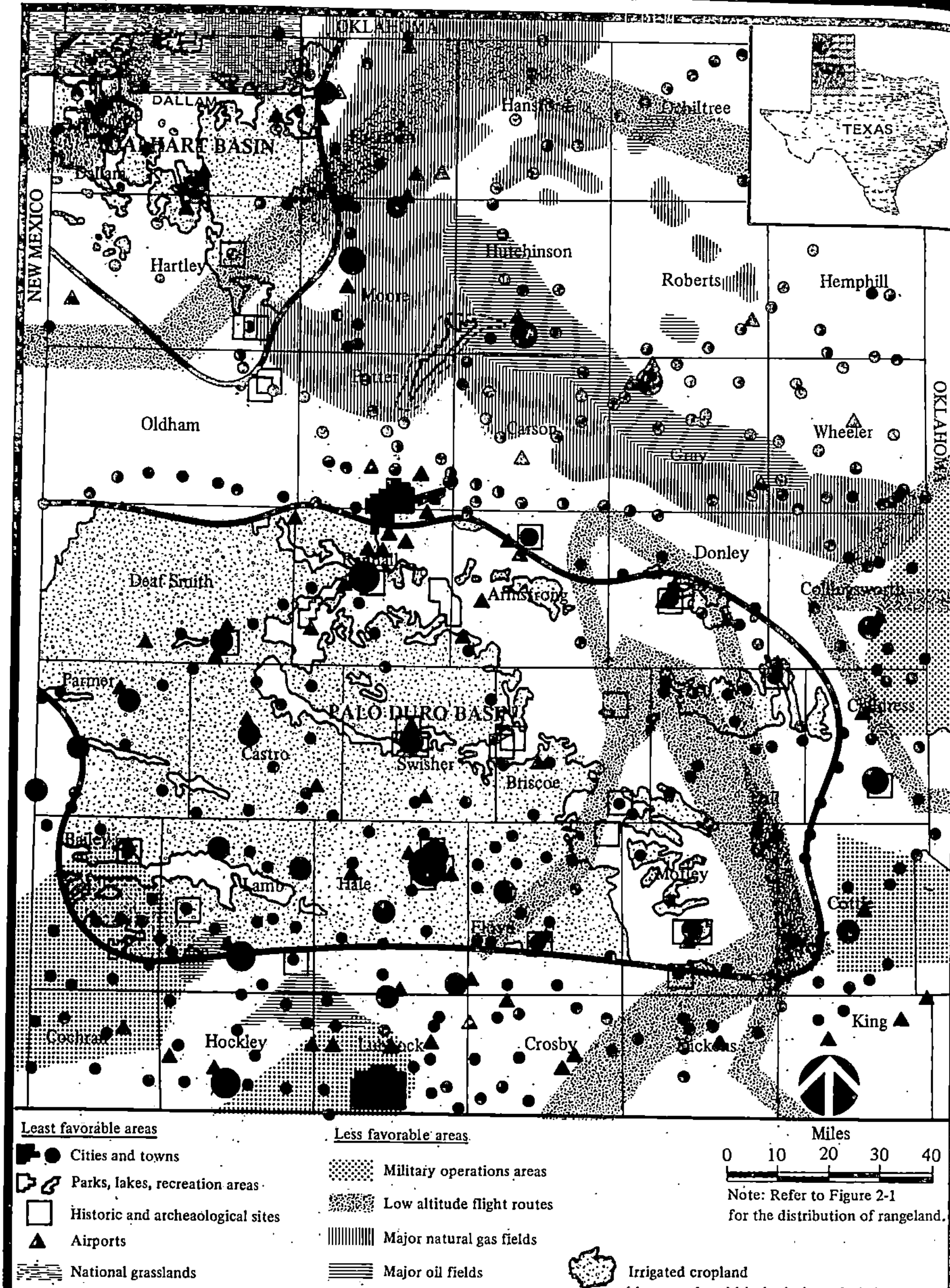
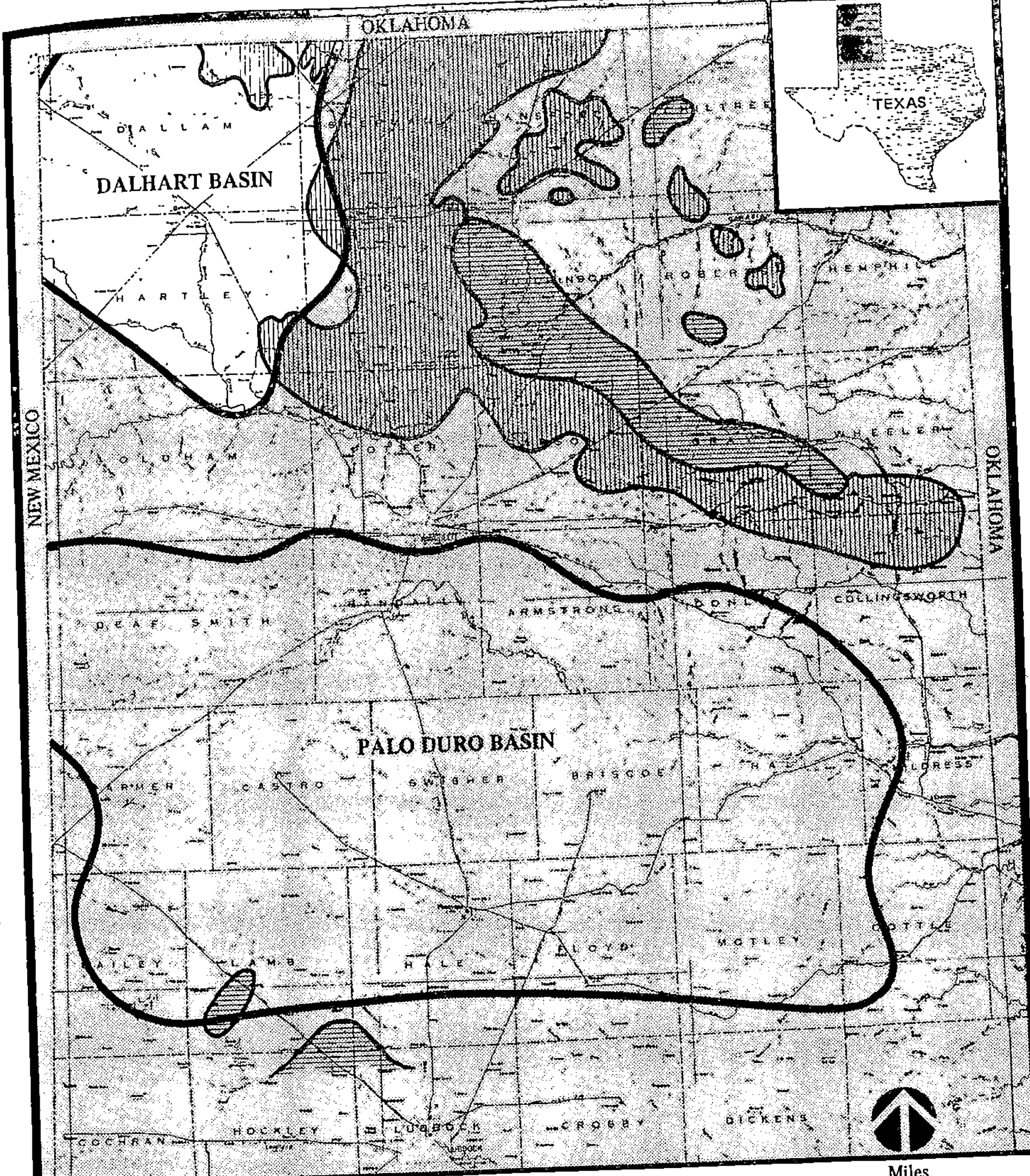


Figure 1-8. Land-use patterns.



Miles

0 10 20 30 40

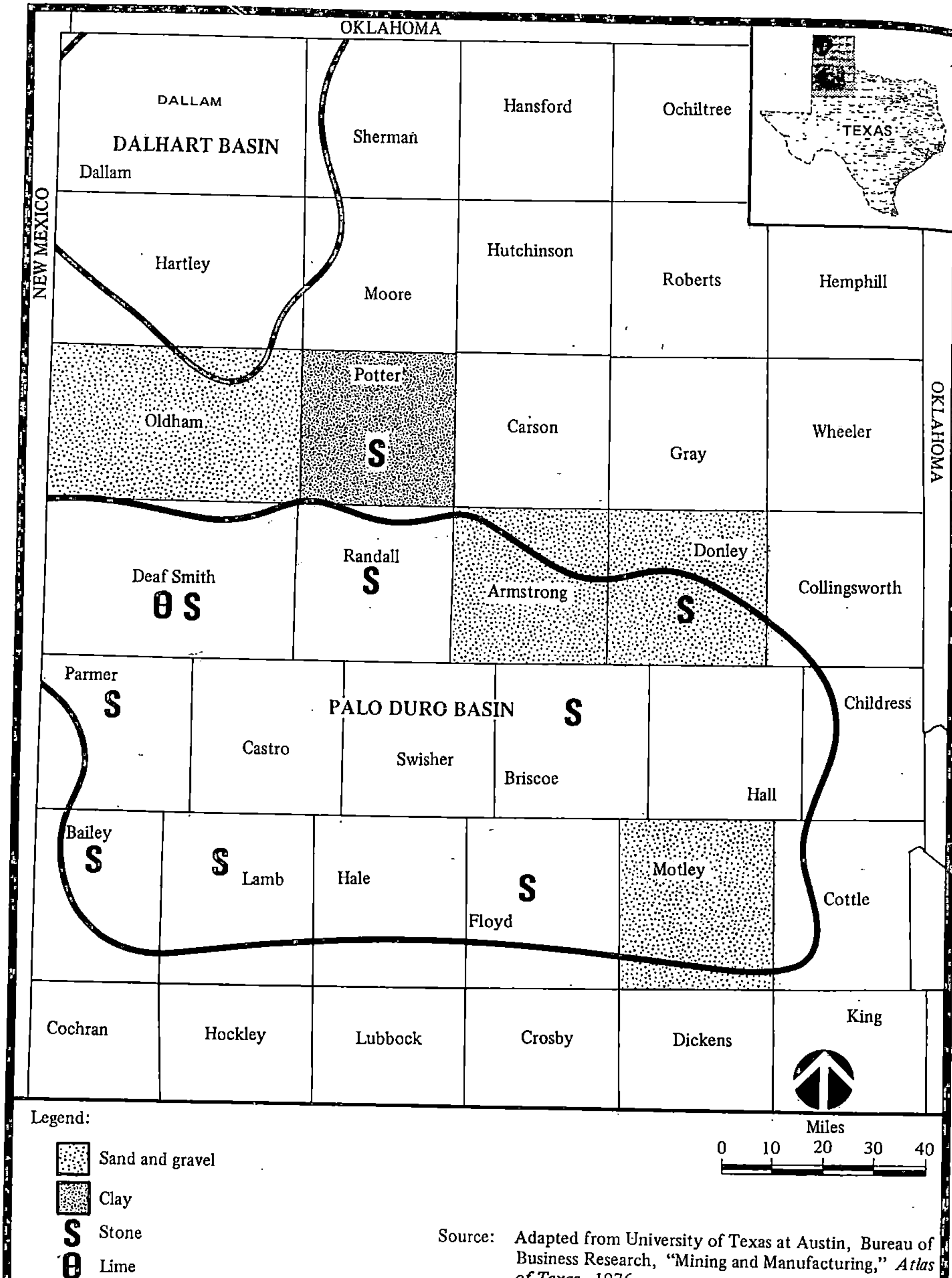
Legend:

Major oil fields

Major natural gas fields

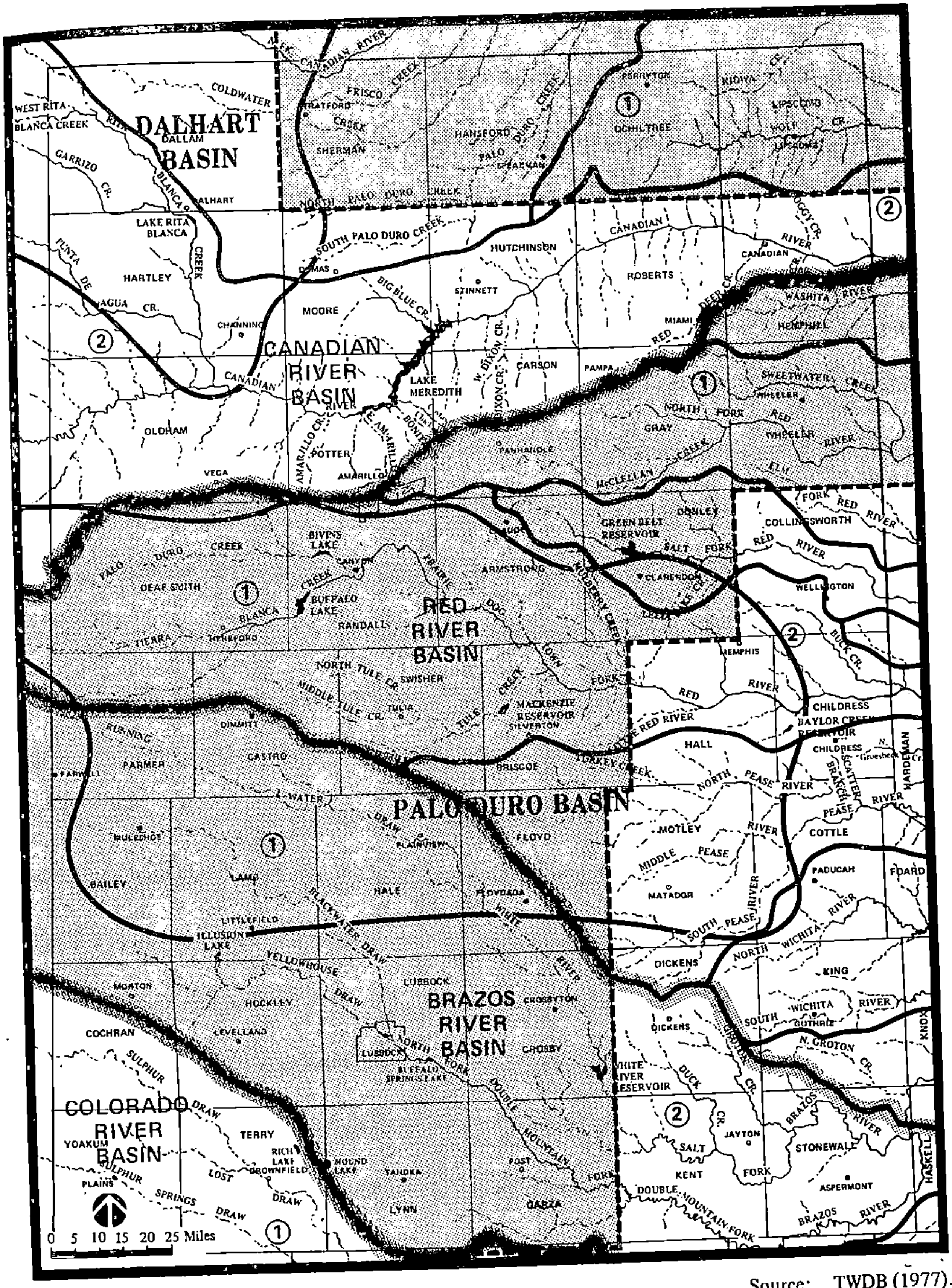
Sources: Adapted from University of Texas at Austin, Bureau of Business Research, "Mining and Manufacturing," *Atlas of Texas*, 1976.

Figure 1-9. Energy resources.



Source: Adapted from University of Texas at Austin, Bureau of Business Research, "Mining and Manufacturing," *Atlas of Texas*, 1976.

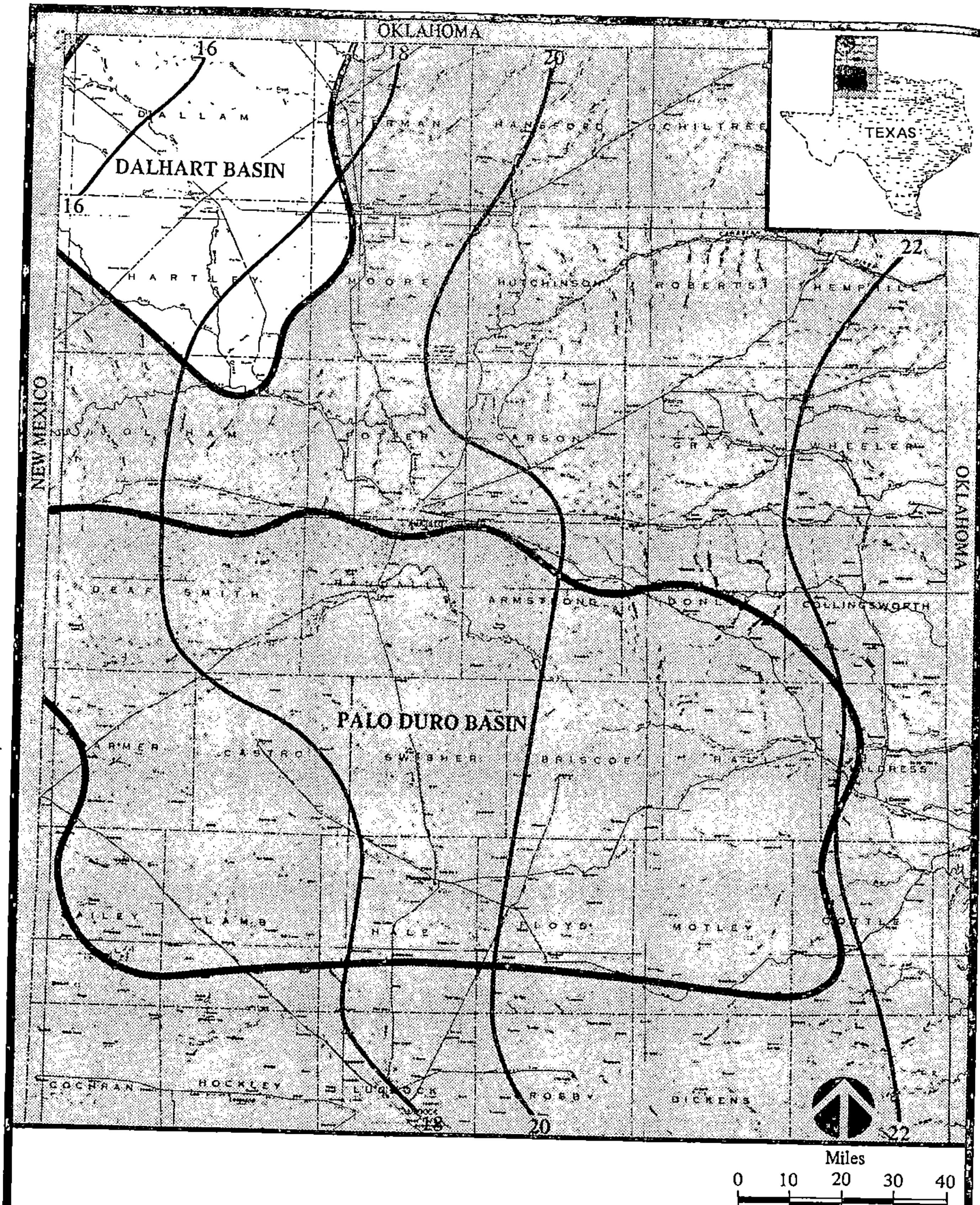
Figure 1-10. Mineral production for 1973.



Source: TWDB (1977).

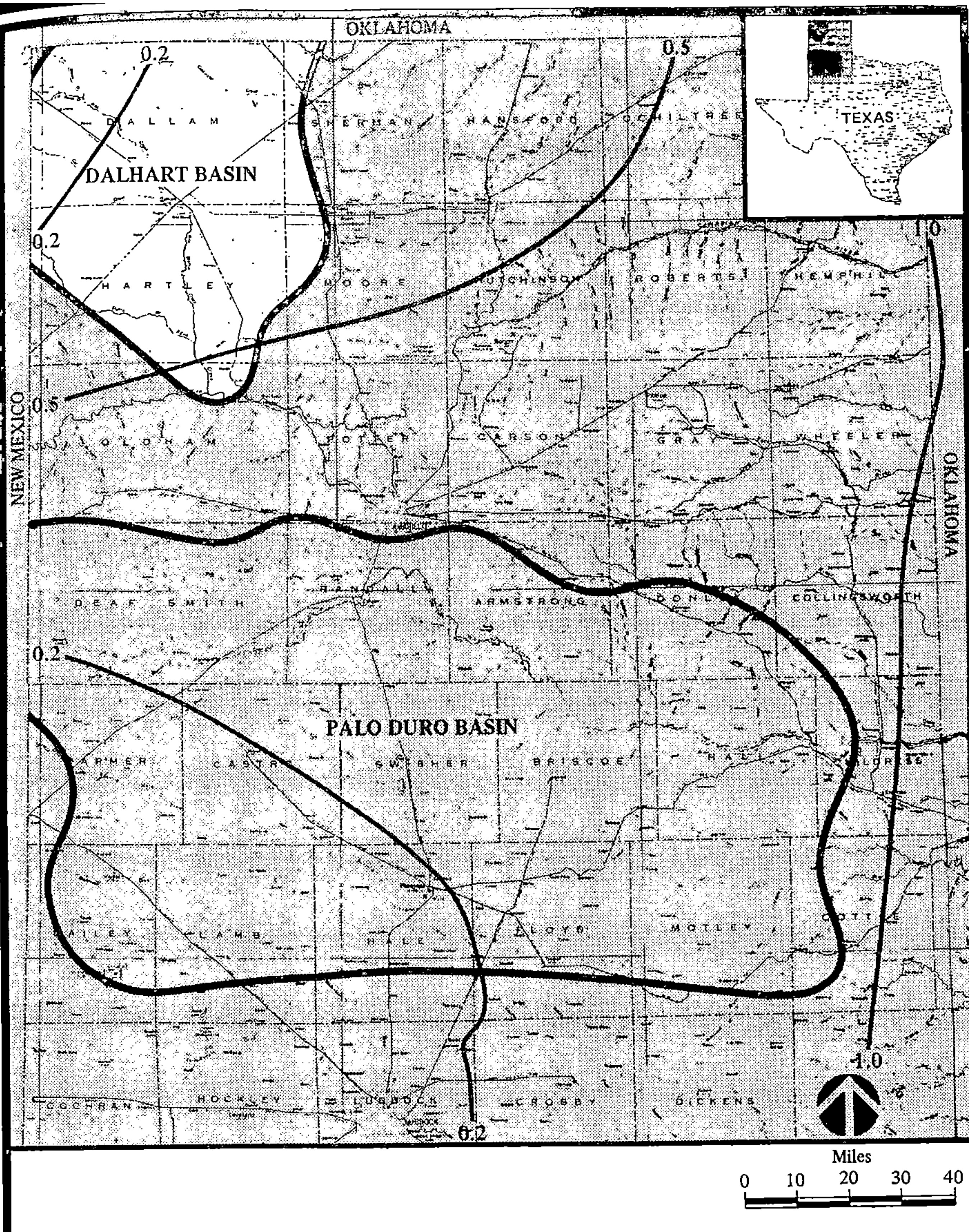
Major river basin boundaries
Other river basin boundaries
Zone boundaries
① Zone numbers
Zone 1

Figure 1-11. Planning zones.



Sources: Nicholson (1960); USGS (1965); TWDB (1966); and Carr (1967).

Figure 1-12. Annual precipitation



Sources: Nicholson (1960); USGS (1965); Busby (1966); TWDB (1975, 1977); and TNRIS (1979).

Figure 1-13. Annual runoff

2 Terrestrial Ecology

The Dalhart basin is part of the North American Great Plains, an area which once supported vast grasslands and large herds of buffalo. The terrestrial ecology of the region reflects the complex interactions between biotic and abiotic systems. One of the most influential factors affecting the region today is the agricultural activity; immense acreages are tilled for the production of crops, numerous cattle graze the rangelands, indigenous vegetation and wildlife habitat become increasingly less abundant, and irrigation continues to deplete subterranean aquifers.

The objectives of the following characterization report are to delineate areas of project compatibility, to define ecologically sensitive or incompatible environments, and to provide a comprehensive data base for future studies. Included are sections on vegetation, terrestrial vertebrate fauna, soils, agriculture, and areas of special interest. Because of the large area (3000 square miles) involved, much of the information presented here is, by necessity, general in nature. Emphasis was given to "important" flora and fauna, defined as species that (1) are threatened or endangered, (2) are commercially or recreationally valuable, (3) affect the well being of species within the preceding categories, or (4) are critical to the structure and function of the ecosystem.

Published literature, state and Federal agencies, interviews, and unpublished theses provided the basis for this report. The Texas Parks and Wildlife Department, the Texas Bureau of Economic Geology, Texas Tech University, and West Texas State University were of special assistance.

2.1 VEGETATION

The Dalhart basin lies in the southern portion of the Kansan Biotic Province (Blair, 1950). Two major plant zones (Figure 2-1) are recognized within this province: the Rolling Plains and High Plains (Blair, 1950; Penfound, 1967; Gould, 1969, 1975; Correll and Johnston, 1970). The Rolling Plains occurs at elevations of 800 to 3000 feet and is characterized in undisturbed areas by an abundance of tall grasses (greater than 1.2 meters) and mid grasses (0.7 to 1.1 meters) sparsely intermixed with short grasses (0.15 to 0.6 meter). Tall grass taxa listed by Gould (1975) include big bluestem (Andropogon gerardii var. gerardii), little bluestem (Schizachyrium scoparium), sand bluestem (Andropogon gerardii var. paucipilus), indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum). Mid grasses listed were sideoats grama (Bouteloua curtipendula) and Canada wildrye (Elymus canadensis). Short grass taxa diagnostic of this area included hairy grama (Bouteloua hirsuta) and blue gama (Bouteloua gracilis).

The High Plains ranges in elevation from 3000 to 4500 feet, and is interspersed with numerous temporary and permanent playa lakes. Characteristic short grass species include buffalograss (Buchloe dactyloides) and blue grama, both of which increase with grazing pressure. Mid and tall grasses of the area include sideoats grama, black grama (Bouteloua eriopoda), little bluestem, western wheatgrass (Agropyron smithii), indiangrass, and switchgrass. These plant associations are largely determined by edaphic and topographic factors, as demonstrated by the high frequency of sand burr

(Cenchrus) and sand dropseed (Sporobolus cryptandrus) on sandy soils in the southern portion of the High Plains. Mesquite (Prosopis) and yucca (Yucca) have invaded in some areas; sand sagebrush (Artemesia filifolia) and shin oak (Quercus mohriana) are common to deep sandy areas (Gould, 1975).

The principal factor affecting the region's vegetation has been grazing. Gould (1975) described two phases of community succession resulting from grazing pressure. The first phase involves the replacement of tall grass species with mid and short grasses such as buffalograss, common curly mesquite (Hilaria belangeri), tobosagrass (Hilaria mutica), three-awn (Aristida spp.), and sand dropseed. The second phase involves the decline of all aforementioned taxa and the establishment of sand burr, hairy tridens (Erioneuron), red grama (Bouteloua trifida), Texas grama (Bouteloua rigidiseta), gummy lovegrass (Eragrostis curtipedicellata), western ragweed, and Croton texensis.

Because the Dalhart basin is extensively farmed, most of the indigenous vegetation is restricted to areas unsuitable for crops (e.g., escarpments). Characteristic flora of the basin are listed in Table 2-1. All but the southern portion of the basin lies in the High Plains vegetation area. The Rolling Plains is almost entirely rangeland whereas over half the High Plains portion of the basin is devoted to agriculture, particularly east of Dalhart. Most of the cropland in the basin is irrigated although some areas near the Oklahoma state line do not require supplementary water.

This report follows the "range site" method of plant association description developed by the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) (adapted from Dyksterhuis, 1949). A "range site" is defined by its potential to produce indigenous species. Thus, with overgrazing of what was once virgin prairie, one can observe disclimax and postclimax associations in both the Rolling Plains and High Plains vegetational areas. These associations, because of local variations in soil, topography, climate, and other macro- and microenvironmental factors, are best delimited by specific range sites.

"Range condition" is the percentage to which the present community resembles that of the climax community for that specific site. The condition classes are classified as follows: excellent, where 76 to 100 percent of the taxa are members of the potential climax community; good, where 51 to 75 percent of the taxa are members of the potential climax; fair, where 26 to 50 percent of the taxa are as previously stated; and poor, where 25 percent or less of the taxa present would occur in the potential climax.

These range condition classes were determined by responses of the plant species to continual grazing. "Decreasers" are those plants that decrease in relative abundance when the community is subjected to grazing. "Increasers" are those plants expected to occur in the potential climax community that will increase in relative numbers and/or proportions as grazing continues. "Invaders" are those plants not expected to occur in the climax community, entering the site only due to grazing.

By using the range site method, one may gain a fairly accurate idea of what to expect on a particular site by simply consulting the SCS survey for the county involved. This procedure entails identifying the soils series from SCS maps, determining the range site type (Table 2-2), and consulting the associated species composition (Table 2-3).

In addition to grasslands, the second most important plant formation in the basin is wetlands. These are defined as follows:

> . . . a site where the water table is near, at, or above the surface of the ground for at least some portion of the year. Areas seasonally flooded, such as river flood plains, therefore qualify as wetlands. Lakes and ponds are included where they are ecologically related to specific wetland types. (Goodwin and Niering, 1975.)

Two wetland communities are distinguished: riparian vegetation and playa lake vegetation. Riparian vegetation includes those taxa likely to occur along streams, rivers, creeks, and in or on the periphery of lakes (other than playa lakes). Playa lake vegetation includes only those taxa occurring in or on the periphery of playa lakes. Rowell (1971) described the playas as follows:

> The playas are the result of leaching during wet periods and wind deflation during dry periods. Most of them contain water only following rains; however, some of the larger and deeper lakes retain permanent but usually highly saline water.

The 22 range sites of the Dalhart basin (Table 2-2) were taken from SCS reports from Dallam, Hartley, and Moore Counties (Ford and Fox, 1975; Fox, 1977; Geiger, 1975); no data were available for Sherman County. Of the 22 range sites listed, five are restricted to wetland habitats: Loamy, Sandy and Wet Bottomland, Bottomland, and High Lime. Four terrestrial range sites (Shallow Clay, Draw, Sand Hills, and Loamy Sand) occur in the Dalhart basin; three (Shallow Clay, Draw, and Loamy Sand) are restricted to Hartley County (Table 2-2). The flora associated with terrestrial range sites are presented in Table 2-3.

2.1.1 WETLANDS

The wetlands vegetation of the Dalhart basin is restricted to playa lakes and riparian areas. Riparian vegetation of the Dalhart basin has not been well documented, but it is typically associated with rivers and small streams. The riparian vegetation of the Dalhart basin is based on range site descriptions which accompany county soil surveys for Dallam (Ford and Fox, 1975), Moore (Geiger, 1975), and Hartley (Fox, 1977) Counties. There are four range sites (Bottomland and Wet, Loamy, and Sandy Bottomland) in riparian areas. Flora associated with these sites are provided in Table 2-3.

Rowell (1971) studied the vegetation of playa lakes in the Dalhart basin and listed the following flora as being characteristic: Najas guadalupensis (common water-nymph), Panicum obtusum (vine-mesquite), Nothoscordum bivalve (crow-poison), Salix nigra (Sauz), Polygonum aviculare (knotweed), Polygonum ramosissimum, Rumex altissimus (pale dock), Chenopodium leptophyllum, Ranunculus cymbalaria, Potentilla rivalis (brook cinquefoil), Lippia cuneifolia, Phyla cuneifolia (wedge-leaf frog-fruit), Verbena bracteata (prostraste vervain), Baccharis salicina, Bahia woodhousii Picradeniopsis woodhausii, and Croeopsis tinctoria.

2.1.2 THREATENED AND ENDANGERED FLORA

No federally listed endangered or threatened plants occur within the Dalhart basin (Ayensu and DeFilips, 1978; USDI, 1976, 1979). Although the State of Texas does not maintain a list of threatened and endangered flora, the Rare Plant Center lists Asclepias involucrata and Eriogonum correllii as endangered (University of Texas, 1974). The latter is endemic to the Texas Panhandle and both may occur within the Dalhart basin.

2.2 WILDLIFE

Wildlife of the Dalhart basin that are addressed in this report include amphibians, reptiles, birds, and mammals. Because of the intensive agricultural development in the basin, the abundance of wildlife habitat has declined; however, the basin's structure and habitat still reflect a wide array of vertebrate fauna. The following characterization is based entirely on published literature and contacts with the Texas Parks and Wildlife Department. Emphasis is given to species that are threatened, endangered, or commercially and recreationally valuable.

2.2.1 AMPHIBIANS AND REPTILES

The herpetofaunal composition of the Dalhart basin is strongly influenced by low habitat diversity and climate. The combination of low topographic relief, cold winters, and semiarid rainfall regime is unsuitable for several species that inhabit the Caprock Escarpment less than 100 miles to the southeast.

Grassland and sandy areas are the most widespread habitats within the basin (Hunsaker, 1957). With the exception of the Canadian River Valley at the southern edge of the basin, aquatic habitat is generally scarce. Rocky outcrops and woodlands habitat occur at scattered locations but are generally restricted to intermittent stream channels. Urban areas and irrigated cropland constitute small, relatively unimportant herptile (amphibian and reptile) habitats.

Nine amphibians and 31 reptiles may inhabit the Dalhart basin, all of which are widely distributed outside this area. No unique herptile habitats occur here, and there are no species endemic to the basin. Table 2-4 lists the common and scientific names of species that are known or are likely to inhabit the Dalhart basin area of the Texas Panhandle.

The grassland habitat, which predominates in the basin, supports relatively few herptile species, all of which are widely distributed outside of the basin. The racer, corn snake, western box turtle, and eastern fence lizard are typically found in this habitat (Hunsaker, 1957).

Sandy areas associated with intermittent stream channels and blowouts above flood plains support a more diverse assemblage of species than are found in grasslands. Sagebrush and clumps of sumac dominate. Herptiles characteristic of this habitat include the glossy snake, coachwhip, gopher snake, lesser earless lizard, and Texas horned lizard (Hunsaker, 1957; Fouquette and Lindsay, 1955). Most of the species associated with this habitat commonly occur in similar situations south and west of the Dalhart basin.

Permanent aquatic habitat occurs along the Canadian River Valley in stock ponds and in a few small lakes. Species inhabiting these bodies of water are the snapping turtle and plainbelly water snake. Several additional species that inhabit both permanent and temporary bodies of water (e.g., intermittent playa lakes) include the tiger salamander, plains spadefoot, western spadefoot, and all toad species. Toads and frogs frequently invade irrigated cropland and urban areas.

Rocky outcrops are especially important to fossorial species. Reptiles that are associated with this habitat type in the region are the Texas blind snake, ground snake, night snake, plains blackhead snake, and collared lizard (Fouquette and Lindsay, 1955). No amphibians are limited to this habitat, although the tiger salamander and several toads often inhabit rocky outcrops near water.

Habitat disturbances resulting from agricultural practices have created the greatest environmental stress on herptile populations. Intense grazing has altered the vegetative composition of grasslands and probably has had an adverse affect on the resident reptiles but there is no quantitative substantiation of impacts. Urban development and land clearing for cropland establishment have reduced available habitat in scattered locations.

The reptile species most susceptible to disturbance are the fossorial forms associated with rocky outcrops. Shelter, foraging area, and moisture relationships necessary for species such as the Texas blind snake and ground snake are easily disrupted as a result of land-clearing activities, and are not easily restored. This habitat is somewhat limited in the Texas portion of the Dalhart basin.

Permanent and intermittent bodies of surface water provide breeding habitat for all amphibians and a few reptiles. These areas are sensitive to disturbances and should be avoided.

2.2.2 BIRDS

Approximately 225 avian species are likely to occur in the Dalhart basin (Table 2-5). Most of these species inhabit grasslands, croplands, or less frequently, open, arid brushlands; very few species are restricted to aquatic or riparian habitats.

The principal wildlife habitat in the Dalhart basin is shortgrass prairie. The horned lark is the most common bird in grasslands; other common birds are the western meadowlark, grasshopper sparrow, and the lark bunting (Wiens, 1973). Common raptors include the American kestrel, marsh hawk, ferruginous hawk, and Mississippi kite. Comments on raptors that may occur in the Dalhart basin follow.

Turkey vulture - Seen in the basin during summer.

Cooper's hawk - Probably an uncommon visitor in the basin but recorded in summer and winter.

Red-tailed hawk - More common in migration and winter than in summer, but may breed in the basin.

Swainson's Hawk - An abundant migrant through rangelands between August and May; hundreds may be counted in a single day (September or October), with 641 recorded in a single day (Allan and Sime, 1943).

Rough-legged hawk - An uncommon winter visitor to the basin.

Ferruginous hawk - Generally distributed in summer and winter.

Prairie falcon - Most numerous in winter in rangeland and cropland.

Peregrine - Formerly rare, now virtually absent.

Merlin - Absent in most of the basin.

Barn owl and screech owl - Noted irregularly in the basin but a few documented instances of breeding.

2.2.3 MAMMALS

Approximately 56 species of mammals have geographic ranges that include all or parts of the Dalhart basin (Table 2-6). These include 1 marsupial, 2 shrews, 10 bats, 30 rodents, 9 carnivores, and 4 even-toed ungulates. The occurrence of 11 species (7 bats and 4 mice) is uncertain because the basin lies near the periphery of their geographic range. Of the remaining 45 species that may occur in the basin, some are not expected because of habitat limitations.

Many of the mammals occupying the basin are associated with nonagricultural areas. These habitats include rangelands and shrublands under various grazing pressures. Species characteristic of shortgrass prairie are the black-tailed jack rabbit, plains pocket gopher, plains pocket mouse, Ord's kangaroo rat, northern grasshopper mouse, badger, and pronghorn. Mammals inhabiting broken shrubland for denning and feeding include the Virginia opossum, several bats, eastern cottontail, white-footed mouse, brush mouse, southern plains woodrat, porcupine, ringtail, striped skunk, and white-tailed deer. Mammals indirectly associated with cropland include the Virginia opossum, eastern cottontail, deer mouse, hispid cotton rat, house mouse, coyote, striped skunk, and raccoon.

Associated with trees, particularly riparian cottonwoods, are the porcupine and several species of bats. Porcupines, however, also traverse open grassland or mixed brush habitats and bats may also inhabit residential areas.

The muskrat is the only truly aquatic mammal in the basin. Other species that require permanent or intermittent water sources include the opossum, hispid cotton rat, raccoon, striped skunk, mule deer, and white-tailed deer. Sources of water may be streams, rivers, playa lakes, or livestock tanks.

In general, mammalian diversity and abundance is lower in agricultural areas and slightly higher in shortgrass prairie habitats having moderate to low grazing intensity, broken shrubland, canyons, and riparian vegetation. Mammal diversity and abundance is greater in the Rolling Plains than in the High Plains vegetational area of Texas because of habitat diversity and agricultural practices.

Nongame Mammals

Thirty-seven species of small mammals have geographic ranges that include the Dalhart basin. These include shrews, bats, ground squirrels, gophers, pocket mice, kangaroo rats, harvest mice, Peromyscus spp., woodrats, voles, and pests (i.e., Norway rat, house mouse). Although these species have no recreational or commercial value, they are an important source of food for mammalian predators such as coyote, fox, skunk, and raccoon, and also for avian predators such as hawks, eagles, and owls.

Generally, small mammals are less common in agricultural areas than in shortgrass prairie or shrubland habitats in the High Plains or Rolling Plains. Undisturbed habitats (i.e., roadside ditches, wind breaks, canyons, ravines, woodlands, shrublands, playa lakes) would also support the highest predator population, both avian and mammalian, in the Dalhart basin.

2.2.4 COMMERCIALLY AND RECREATIONALLY VALUABLE WILDLIFE

2.2.4.1 Big Game

Mule deer, white-tailed deer, and pronghorn are the principal native big game mammals occurring in the Dalhart basin. A few aoudad (Barbary sheep) reportedly wander into southwest Dallam and northwest Hartley Counties from the New Mexico population but they are not considered an important hunting resource to the basin. The distribution of these animals is shown in Figure 2-2.

The pronghorn is the most important big game mammal of the Dalhart basin. It occurs in all five counties but its major range lies in Dallam, Hartley, and Oldham Counties. The Texas pronghorn population (estimated at 13,474 individuals in 1978) is monitored by the Texas Parks and Wildlife Department which subsequently sets permit limits within its Regulatory Districts.

Mule deer presently occur in Hartley, Moore, and Oldham Counties (Brownlee, 1979). However, the main population occurs in southern Hartley and northern Oldham Counties.

White-tailed deer, although common to abundant over much of southern and eastern Texas, are relatively uncommon over much of the High and Rolling Plains of Texas. The only substantial white-tailed deer population presently existing in the Dalhart basin occurs in Moore County, where there is an estimated 55,888 acres of suitable habitat.

The mouflon, or Barbados sheep, was introduced into Texas in 1951. About 22 Texas counties have populations with 50 or more individuals, and 32 counties have populations with less than 50 individuals (Ramsey, nd). In the Dalhart basin, only Moore and Oldham Counties contain mouflon, both of which support less than 50 individuals.

2.2.4.2 Small Game

Birds

Important small game birds of the Dalhart basin include the mourning dove, scaled quail, and ring-necked pheasant. Although the natural range of the lesser prairie chicken includes the entire Texas Panhandle, the present range of this species does not include the Dalhart basin.

Other Texas game birds are the turkey, common snipe, common gallinule, king, Virginia and sora rails, and sandhill crane. All of these species are uncommon to rare in the basin because of habitat limitations.

Waterfowl

Several species of waterfowl winter in the Dalhart basin, and many are harvested during game seasons (Table 2-7). The largest inland concentrations of wintering waterfowl in Texas occur south of the Dalhart basin, where more open water exists. Similarly, few waterfowl breed in the basin except in very wet years when temporary water bodies are abundant.

Two of the most common species of waterfowl in the Dalhart basin in summer and winter are the mallard and American coot. Both species occur throughout Texas. Numerous Canada geese winter in the basin, although the major wintering area is along the Gulf coast. Other species of waterfowl that are occasionally noted in or near the basin and similar habitats in northern Texas are the pintail, lesser scaup, common goldeneye, and common merganser.

Mammals

No small game mammals, as classified by the Texas Parks and Wildlife Hunting Regulations for 1979-1980, occur in the Dalhart basin. Some mammals such as the eastern cottontail, desert cottontail, and black-tailed jack rabbit are often hunted in various parts of the Texas Panhandle, including the Dalhart basin. All three species have ranges that include the Dalhart basin.

Furbearers

Eight mammals of the Dalhart basin are classified as furbearers by the Texas Parks and Wildlife Department (Table 2-6). In addition, the bobcat and coyote are not classified as furbearers but are taken for their pelts. Generally, the abundance of furbearers in the Dalhart basin is limited due to extensive agriculture and grazing. Optimum habitat for furbearers occurs along riparian areas, in canyons or other broken country, and in shrubland. The coyote and bobcat are the most widespread species in the basin. Raccoons are probably the most common furbearer in the basin because of their adaptability. Furbearers should be more common in the mixed brush areas of southwest Hartley and northern Oldham Counties than in the primary agricultural parts of the rest of the basin.

Based on estimates of the Texas Parks and Wildlife Department (Brownlee, 1979a), the number of furbearers harvested has nearly quadrupled from 1972 to 1978. Listed in order of decreasing annual harvest totals, raccoon, opossum, ringtail, and coyote were the most frequently captured furbearers. In terms of value, the bobcat ($55), red fox ($40), grey fox ($29), and coyote ($20) rank higher than all other mammals of the basin.

2.2.5 THREATENED AND ENDANGERED FAUNA

2.2.5.1 Amphibians and Reptiles

None of the herpetofauna inhabiting the Texas portion of the Dalhart basin are on the Federal list of endangered or threatened species, nor are any listed as endangered in Texas (Texas Parks and Wildlife Department, 1977a; USDI, 1979). Two species, the Texas horned lizard and milk snake, are designated as protected (i.e., threatened) in Texas (Texas Parks and Wildlife Department, 1977b).

The Texas horned lizard is common throughout northwestern Texas (Figure 2-3) and much of the surrounding region (Hunsaker, 1957). The species inhabits a variety of vegetation types on generally flat, open terrain (Conant, 1975). In the Dalhart basin, both grassland and sandy habitats are most frequently used (Hunsaker, 1957; Meriage, 1975). Neither habitat is limited in the basin, and critical areas for the Texas horned lizard cannot be identified. The status of this species has been questioned because it is common and is not limited to a particular habitat (Mecham, 1979).

Four subspecies of milk snake are protected in Texas. Only the central plains milk snake may occur in the Dalhart basin study area (Potter, 1979). This subspecies is widespread, though rarely encountered (Figure 2-4), and inhabits a variety of habitats including grasslands, sandy areas, and rocky hillsides (Meriage, 1975; Raun, 1965).

This reptile also appears on the TOES Watch List of Endangered, Threatened, and Peripheral Vertebrates of Texas (Texas Organization for Endangered Species, 1979).

Birds

The bald eagle, peregrine falcon, and least tern are endangered species which could occur in the Dalhart basin.

Bald eagles appear on both the Federal and state lists (USDI, 1979; Potter, 1979). This species has been documented in the Dalhart basin (Figure 2-5) but it is presently considered to be a migrant nonbreeder. Its current breeding range in Texas is along the Gulf Coast (Brownlee, 1979b).

Two subspecies of the peregrine falcon have protected status. The Arctic peregrine falcon, a subspecies on both the Federal and state lists of endangered species, breeds in the tundra region and is the most migratory of the peregrine subspecies. It may occur in the basin during migration, but this is unlikely. Similarly, it is now unlikely that the American peregrine falcon, another endangered subspecies, could occur in the basin.

The least tern is a coastal species that breeds along the Atlantic coast as well as the Mississippi River and its tributaries, including the Red River on the northern border of Texas (Oberholser, 1974). The northernmost subspecies of the least tern, the interior least tern, is currently on the state endangered species list. The more southern and coastal subspecies, the eastern least tern, is on the state list of threatened species. Although occasional sightings of least terns have been made in the Texas Panhandle, appropriate breeding habitat does not exist for either subspecies in the Dalhart basin, and neither has been recorded as a breeder in that region.

Ranges of several other endangered species on state and Federal lists occur in Texas but do not include the Dalhart basin at any season.

2.2.5.2 Mammals

Two species of mammals that could occur in the Dalhart basin have protected status. The black-footed ferret is on the U.S. Department of the Interior (USDI, 1979) Endangered Species List, the Texas Parks and Wildlife Endangered List (1979), and is also considered endangered by the Texas Organization for Endangered Species. The swift fox, although listed as a furbearer by the Texas Parks and Wildlife Department, is considered threatened by the Texas Organization for Endangered Species.

The black-footed ferret, although never reported to be common, historically occurred over much of the plains of the western United States. Its numbers have apparently declined in this century, primarily because of habitat destruction. The black-footed ferret is usually found in or near prairie dog towns. The elimination of many of these prairie dog populations over the years has been another major reason for the decline of the black-footed ferret population.

Since the ferret is usually associated with prairie dogs, the potential range of the ferret in Texas, and in the Dalhart basin, will generally be similar to that presently occupied by the black-tailed prairie dog (Cheatheam, 1977). The greatest number of prairie dog colonies (106) in the Dalhart basin, and in the state, occurs in Dallam County (Cheatheam, 1977). These colonies probably coincide with areas in and near the Rita Blanca National Grasslands in northern Dallam County. The population in Dallam County, and other Dalhart basin counties along the New Mexico boundary, decreases progressively in an easterly direction. Prairie dogs can occur in almost any grassland or shrubland habitat in the High Plains or Rolling Plains of the Texas Panhandle. However, because much of the High Plains is used for agriculture, the potential prairie dog habitat is greatly reduced. In many agricultural counties, the only prairie dog habitat is around playa lakes (Cheatheam, 1977).

The only known black-footed ferret records for the Dalhart basin were from Dallam County in 1953 and 1971 (Figure 2-6). No ferrets have been reported from the area in recent years.

The swift fox, once common throughout the grasslands of the western United States, has decreased in abundance due to habitat reduction and other man-related activities. Swift fox normally den in plains areas, usually in overgrazed pastures or other grassland habitats. They also den along fencerows or windbreaks and occasionally in agricultural fields. Two factors seem to be responsible for the decline in the swift fox population. Use of native shortgrass prairie habitats for agriculture may be the species' single greatest threat. This habitat reduction decreases denning sites and also reduces prey populations such as cottontails, jack rabbits, mice, rats, insects, and birds. Predator eradication programs aimed at coyotes and bobcats have also been detrimental to the swift fox and other smaller mammals.

Swift fox records exist for all Dalhart basin counties (Figure 2-7). Although some recent records of occurrence exist, the swift fox is considered uncommon regionally. Because it is still considered a furbearing species by the Texas Parks and Wildlife Department, almost 1000 furs were taken in the 1977 to 1978 trapping season. It is unlikely that the swift fox can continue to exist in Texas at present population levels because of its furbearer status, continued habitat reduction, and predator-control programs.

2.2.6 CRITICAL WILDLIFE HABITAT

2.2.6.1 Amphibians and Reptiles

No critical habitats for amphibians and reptiles have been identified within the basin. Rocky outcrops, although not critical for any particular species, tend to support a more diverse assemblage of species than exist in surrounding habitats. The two species listed as threatened in Texas that inhabit the basin occur in a wide range of habitats that are common in the region.

2.2.6.2 Birds

There are no critical habitats for birds within the Dalhart basin. Shelter belts may provide important roosting or nesting areas for some species, including raptors. Playa lakes may be important for wintering or migrating waterfowl, and during wet years may provide nesting areas for certain ducks. A variety of other species, including songbirds and upland game species such as the ring-necked pheasant, are also attracted to playa lakes.

2.2.6.3 Mammals

There are no known Federal or state designated critical habitats for mammals in the Dalhart basin. Important wildlife habitat in this region are (1) the playa lakes, especially those that provide a permanent water supply, (2) canyons or ravines formed by permanent or intermittent streams or rivers, (3) forested areas, (4) shortgrass prairies, (5) wetlands, and (6) shrublands that are lightly to moderately grazed. Relatively undisturbed High or Rolling Plains grassland or shrubland habitats provide the only significant wildlife habitat present in the Dalhart basin today. These areas occur mostly in northern Dallam, southwestern Hartley, northern Oldham, and northwest Sherman Counties.

2.3 AGRICULTURAL RESOURCES

The Dalhart basin covers approximately 3000 square miles (1,900,000 acres) and encompasses nearly all of Dalham County and portions of Sherman, Hartley, Moore, and Oldham Counties.

Agriculture is the most important land-use activity. Irrigated croplands comprise 46 percent of the basin whereas only 3 percent is nonirrigated or dry. The depletion of the Ogallala aquifer will eventually affect the agricultural practices of the area. An increase in the amount of acreage under dry-land farming can be expected (Wyatt et al., 1976). Approximately 50 percent of the Dalhart basin is rangeland.

Historically, variations in elevation, temperature, and rainfall have affected the distribution of soils in the region. Likewise, agricultural activity and regional specialization are reflected by the geologic setting and soil patterns. Within the

Dalhart basin two soil orders (Alfisols and Mollisols) are present (Figure 2-8). Alfisols have a light-colored surface layer over a developed, more clayey subsoil. They have moderate to high base saturation, and usually are fertile soils found in young landscapes.

Mollisols are soils with a very dark colored surface layer, relatively high organic matter content, and high base status throughout the profile. They are very fertile grassland soils of steppes and prairies. Rainfall is usually the limiting factor in their productivity.

In addition to spatial distribution and areal coverage of the major soils within the Dalhart basin, certain intrinsic characteristics, uses, limitations and special features of soils either enhance, or detract from, their value as resources. Table 2-8 gives a brief summary of the characteristics of the soil associations found within the Dalhart basin.

As a rule, soil resources are more valuable if they occur in relatively flat terrain, are fertile, have good drainage, and are found in areas of sufficient rainfall. These characteristics and others permit soil-mapping units to be designated as prime farmland soils, according to a national program of soil inventory (USDA, 1978).

Individual mapping units occurring under rain-fed conditions are further designated as "prime in native state," whereas others that are not prime under natural conditions may be upgraded to prime if they are irrigated or drained.

2.3.1 SOILS AND PRIME FARMLAND

Some 873,460 acres of Alfisols are represented by the Dallam-Sunray-Dumas association in Dallam and Hartley Counties. Mollisols occupy approximately 1,112,300 acres, extending to every county within the Dalhart basin.[1] The associations represented are: Sunray-Conlen-Gruver (535,510 acres); Sherm-Gruver-Sunray (380,950 acres); and Mansker-Berda-Potter (195,760 acres). The data are summarized in Table 2-9.

Table 2-10 lists the occurrence of prime farmland soils for each county in the Dalhart basin. Some counties are more richly endowed with a gentle terrain, adequate rainfall, etc., which may be reflected in a higher percentage of prime farmland soils. In some cases, the designation of prime farmland may be met if the land is irrigated or drained. Table 2-11 gives a comparative view of both prime farmland soils and additional potential prime soils.

2.3.2 CROPS

The Dalhart basin contributes significantly to the agricultural economy of the Northern High Plains. Due to differences in climate, soils, rainfall, etc., varied emphasis is placed on different crops. Major and minor crops are considered separately. In this report, major crops are defined as those produced in one or more of the counties that appear in the list of the 10 Texas counties leading in the production of that crop. That is to say, if one of the counties that constitute the Dalhart basin appears in the list of leading Texas counties producing a particular crop, that crop is considered a major crop in the Dalhart basin. Some crops that might otherwise be considered minor from an acreage or tonnage standpoint could be major crops if they are restricted to a particular geographic region.

Ten field crops, five small grain crops, several vegetable crops, and cotton are considered in the production statistics, based on their overall importance throughout Texas. The field crops are corn, guar, hay, peanuts, rice, sorghum, soybeans, sugar beets, sugar cane, and sunflowers (Texas Department of Agriculture, USDA, 1978a). Small grains include barley, flaxseed, oats, rye, and wheat (Texas Department of Agriculture, USDA, 1978b).

2.3.2.1 Field Crops

Of the 10 field crops named above, corn, hay, sorghum, and sunflowers are major crops; however, peanuts, rice, guar, and sugar cane are not produced in reportable amounts in any of the counties of the Dalhart basin. A few of the others represent minor crops in the Northern High Plains and in the Dalhart basin. Statistics on the production of field crops during 1978 are summarized in Table 2-12.

Major Crops

Sugar beet production in 1978 was restricted to five counties, all of which are within the Northern High Plains. Sherman County was the only county of the Dalhart basin reporting significant production of sugar beets, and ranked fifth in the state (Texas Department of Agriculture, USDA, 1978a).

Sunflower production is moderately important in the Dalhart basin. Hartley, Dallam, and Moore Counties are among the leading producers in the state, accounting for 19 percent of the state total. Virtually all of the sunflower production is found in either the Northern High Plains or Southern High Plains.

Corn is the second most important field crop grown in Dalhart basin counties from the standpoint of acres planted, acres harvested, yield per acre, and total production. Dallam, Moore, Sherman, and Hartley Counties ranked seventh through tenth, respectively, in bushels produced in Texas during 1978 (Texas Department of Agriculture, USDA, 1978a). They made up 10.5 percent of the state total corn production. Virtually all counties in the Dalhart basin produce yields of over 100 bushels per acre, an extremely high average compared to national averages and to other Texas counties outside the region.

Sorghum production is widespread throughout the Texas Panhandle and represents the most important crop in the region of the Northern High Plains. Sherman County ranked fifth among all Texas counties in total production in 1978 with 5,450,500 bushels harvested from 88,000 acres. Dallam County had the greatest number of acres planted to sorghum (108,400 acres) but had a relatively low yield of 39.9 bushels per acre (Texas Department of Agriculture, USDA, 1978a). Moore County had the highest yield per acre of any county in Texas (89.7 bushels per acre) but reported only 59,300 acres harvested, compared to 70,000 acres planted. All counties in the Dalhart basin devoted at least 40,000 acres to sorghum, a relatively high acreage for the state as a whole.

Minor Crops

Hay is produced in all counties of the study area, but regional production in the Dalhart basin is insignificant compared to counties in eastern and northeastern Texas. Dallam County led the basin in 1978 with 9100 acres in production and 4.5 tons per acre yield. Moore County had the lowest acreage harvested (1500 acres) and the lowest yield (2.6 tons per acre) of the Dalhart basin counties (Texas Department of Agriculture, USDA, 1978a).

Soybeans were produced in reportable amounts in Dallam, Sherman, Hartley, and Moore Counties. Moore County led the five-county study area with 1500 acres planted and 28.5 bushels per acre yield. Sherman County reported 900 acres planted and 26.7 bushels per harvested acre, for the lowest production reported. Some soybean acreage was planted in Oldham County but was not reported because the total was less than 500 acres, the minimum used by the Texas Crop and Livestock Reporting Service.

2.3.2.2 Small Grain Crops

Of the five grain crops reported statewide, only flaxseed is not grown in the Dalhart basin counties, and oats are a minor crop; barley, rye, and wheat are major crops. Statistics on production during 1978 are summarized in Table 2-13.

Major Crops

Rye is produced in reportable amounts only in Dallam County of the Dalhart basin counties; however, Dallam County ranked fifth overall in leading counties in production, with 13,900 bushels produced. Twenty-eight other counties statewide reported more or equal acreage planted to rye, but due to a superior yield per harvested acre (17.4 bushels per acre) and a high proportion of acreage harvested (75 percent), Dallam County was among the leaders.

Barley was a major crop in Sherman County, which ranked sixth (49,500 bushels) among the leading producers in 1978. Moore County ranked ninth (36,000 bushels) among all Texas counties. Hartley County produced 3000 bushels of barley from 800 acres. Barley was also planted in Dallam and Oldham Counties, but amounts were below reportable minima.

Wheat production is widespread in the High Plains. Sherman, Moore, and Hartley Counties ranked fifth, sixth, and tied for eighth, respectively, among leading Texas counties in production during 1978 (Texas Department of Agriculture, USDA, 1978b). Approximately 9 percent of the state production of wheat was produced in Sherman, Moore, and Hartley Counties.

Minor Crops

Small amounts of oats are grown in all counties within the Dalhart basin, but production is modest by state standards. Dallam County led in 1978 with 24,800 bushels from 3000 acres planted and 1200 acres harvested (Texas Department of Agriculture, USDA, 1978b). Sherman County was last with respect to acreage planted (1100), but Oldham County recorded only 400 acres harvested out of 1200 acres planted, for the lowest production of 10,500 bushels.

2.3.2.3 Vegetable Crops

Vegetable production does not attain commercial status in any Dalhart basin counties. Statistics on Texas vegetables for 1978 do not include even minimum acreage or production data for Dalhart basin counties except for a composite figure of 100 acres for Sherman County (Texas Department of Agriculture, USDA, 1978c). Acreage devoted to field crops, grain crops, and vegetables, ranked as a proportion of total county area is shown in Table 2-14.

2.3.2.4 Cotton

Although parts of the High Plains form one of the major producing and processing areas for cotton in Texas, none of the Dalhart basin counties are involved in producing or processing cotton.

2.3.3 LIVESTOCK

Texas leads the nation in the number of cattle and calves, beef cows that have calved, cattle on feed, and sheep and lambs (Texas Department of Agriculture, USDA, 1978d). West Texas is one of the more important livestock production areas in the state. Hartley and Moore Counties are 2 of the 10 leading counties in the state for producing cattle and calves. Approximately 14 percent (286,000 head) of the number of cattle on feed in Texas were found in the counties of the Dalhart basin. The other counties in the basin region are not among the leaders in the production of livestock; nevertheless, they may produce substantial numbers of cattle and hogs when compared to many Texas counties outside the basin region. Table 2-15 shows the number of livestock by county for the Dalhart basin. On the average, 111,000 cattle and calves were reported in Dalhart basin counties for 1978. The numbers are comparatively high on a regional basis.

2.3.4 IRRIGATION

The use of irrigation water is extremely important to the agriculture of the Dalhart basin. About 68 percent of the total irrigated acreage in the state occurs in the High Plains (Texas Water Development Board, 1975). Most of the irrigation water comes from the Ogallala aquifer which occurs in several western states. In the High Plains nearly 5.9 million acres were irrigated, but only 1250 acres were irrigated with surface water and 11,900 acres were irrigated with a combination of surface water and groundwater supplies.

Irrigation wells and various sprinkler systems are important modes of applying water to crops. Table 2-16 summarizes the 1974 data with respect to source of irrigation water and modes of application on land in Dalhart basin counties.

Irrigated acreage relative to county size is important in the Dalhart basin. The county average exceeds 166,000 acres; only Oldham County has less than 100,000 acres devoted to irrigation. Sprinkler systems are also quite important in the Dalhart basin counties. Dallam County led all others in 1974 with 93,120 acres. Hartley County was second with 35,300 acres (Table 2-16).

Crops that are irrigated vary from county to county. In general, however, corn, grain sorghum, and wheat are the most important regional crops in terms of acreage under irrigation (see Table 1-23).

2.3.5 ECONOMIC ASPECTS OF AGRICULTURE

Based on the kind of crops grown and the acreage devoted to each field crop, it is possible to assign relative importance values to those aspects of the counties' agricultural milieu. Relative ranking may change from year to year, and not all aspects of agriculture have been considered here. Nevertheless, the ranking of counties in the respective basins by the amount of land devoted to agriculture may be taken as an index of the importance of agriculture to the county. Table 2-12 summarizes Dalhart basin county acreage devoted to important field crops of Texas (Texas Department of Agriculture, USDA, 1978a). Table 2-17 ranks the counties with respect to total acreage devoted to important field crops in relation to county area. Sherman County ranks highest in terms of percentage of acres tilled. An overall summary of total acreage devoted to all crops and relative ranking by counties is given in Table 2-14.

2.3.6 FARM CENSUS INFORMATION

Data on crop production and animal husbandry can be considered as either the number and size of farms, or the relative amount of land in farms. In many cases the value of livestock far exceeds that of crops, even in such agriculturally diverse counties like Dallam and Moore. For 1974, the value of livestock and poultry products in Oldham County was 12.2 times that of crops; it was 4.0 times as great in Hartley, and 1.9 times higher in Dallam County (Pass, 1977). An overall view of farm size, land in farms, and crop and livestock values is given in Table 2-18. Average production figures vary from year to year and county to county. Sherman County ranked first ($103.1 million) in relation to total average dollar value of agricultural products. Moore, Hartley, Dallam, and Oldham Counties followed with values of $101.8, $81.8, $63.1, and $33.4 million dollars, respectively. These rankings correspond closely to the number of irrigated acres.

2.4 AREAS OF SPECIAL INTEREST

The acquisition of land by Federal and State governments has been accomplished with two summary goals in mind: the creation of recreational areas and the preservation of scenic and natural areas for future generations. Considered here as areas of special interest, these include natural areas, national wildlife refuges, national grasslands, wetlands, and state parks and wildlife-management areas. Collectively, these areas cover approximately 77,443 acres of the Dalhart basin and consist of the Rita Blanca National Grasslands and XIT Springs. No state or national forests are present.

The Rita Blanca National Grasslands is located in Dallam County. Currently, 87 permit holders lease 10-year grazing rights on the 77,413-acre grasslands which are administered by U.S. Forest Service (Hamilton, 1979).

One proposed National Register Natural Landmark is located within the Dalhart basin. The 30-acre XIT Springs (Buffalo Springs) is the basin's only fresh meadow. Located in Dallam County, the site consists of live springs near the headwaters of Coldwater Creek.

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Table 2-1. Characteristic flora of the Dalhart basin[a]

Scientific name	Common name
CUPRESSACEAE	
Juniperus pinchotii Sudw.[b]	Redberry juniper
FAGACEAE	
Quercus harvardii Rydb.	Harvard oak, Shin oak
Quercus mohriana Buckl.	Shin oak, Scrub oak
CACTACEAE	
Opuntia sp.	Prickly pear
CHENOPODIACEAE	
Cycloloma atriplicifolium (Spreng.) Coult.	Tumble ringwing
ROSACEAE	
Prunus sp.	Sand plum
FABACEAE	
Acacia sp.	Acacia
Mimosa sp.	Catclaw
Prosopis glandulosa var. *torreyana* (L. Benson) M. C. Johnst.	Mesquite
Cercocarpus montanus Ref.	Mountain mahogany
EUPHORBIACEAE	
Croton texensis (Klotzch) Muell. Arg.	Texas croton
ANACARDIACEAE	
Rhus aromatica Ait.	Skunkbush sumac
SOLANACEAE	
Solanum eleaeagnifolium Cav.	Silverleaf nightshade
VERBENACEAE	
Verbena bipinnatifida Nutt.	Dakota vervain
ASTERACEAE	
Ambrosia psilostachya DC.	Western ragweed
Artemisia filifolia Torr.	Sand sagebrush
Evax sp.	Evax
Xanthocephalum sp.	Common broomweed
POACEAE	
Agropyron smithii Rydb.	Western wheatgrass
Andropogon gerardii Vitman var. *gerardii*	Big bluestem
Andropogon gerardii var. *paucipilus* (Nash) Fern.	Sand bluestem
Aristida wrightii Nash *in* Small.	Wright three-awn
Aristida sp.	Three-awn
Bothriochloa saccharoides (Swartz) Rydb. var. *torreyana* (Steud.) Gould	Silver bluestem
Bouteloua curtipendula (Michx.) Torrey *in* Emery	Sideoats grama
Bouteloua eriopoda (Torr.) Torr.	Black grama
Bouteloua gracilis (H.B.K.) Lag. *ex* Steud.	Blue grama
Bouteloua hirsuta Lag.	Hairy grama
Bouteloua rigidiseta (Steud.) Hitchc.	Texas grama
Bouteloua trifida Thurb. *in* Wats.	Red grama
Brachiaria ciliatissima (Buckl.) Chase *in* Hitchc.	Fringed signalgrass

Note: See footnotes at end of table.

Table 2-1. Characteristic flora of the Dalhart basin[a] (continued)

Scientific name	Common name
POACEAE (continued)	
Buchloe dactyloides (Nutt.) Engelm.	Buffalograss
Calamovilfa gigantea (Nutt.) Scribn. & Merr.	Big sandreed
Cenchrus sp.	Sand burr
Elymus canadensis L. var. *canadensis*	Canada wildrye
Eragrostis curtipedicellata Buckl.	Gummy lovegrass
Eragrostis secundiflora Presl.	Red lovegrass
Eragrostis sessilispica Buckl.	Tumble lovegrass
Erioneuron pilosum (Buckl.) Nash *in* Small	Hairy tridens
Hilaria belangeri (Steud.) Nash	Common curly mesquite
Hilaria jamesii (Torr.) Bentham	Galleta
Hilaria mutica (Buckl.) Bentham	Tobosagrass
Hordeum pusillum Nutt.	Little barley
Panicum obtusum H. B. K.	Vine-mesquite
Panicum virgatum L.	Switchgrass
Schizachyrium scoparium (Michx.) Nash *in* Small	Little bluestem
Sorghastrum nutans (L.) Nash *in* Small	Indiangrass
Sporobolus aroides (Torr.) Torr.	Alkali sacaton
Sporobolus cryptandrus (Torr.) A. Gray	Sand dropseed
Stipa commata (Trin. et Rupr.)	Needle-and-thread
LILIACEAE	
Yucca sp.	Yucca, beargrass
Yucca elata Engelm.	Soapweed

[a]From Ford and Fox (1975), Fox (1977), Geiger (1975), and Correll and Johnston (1970).

[b]Probably *Juniperus monosperma* (Engelm.) Sarg. var. *monosperma* (Adams and Zanoni, 1979).

Table 2-2. Range sites and associated soils for counties of the Dalhart basin[a]

Range site type	Soil series		Counties	
Clay flat	1. Mangum		1. Hartley	
Clay loam	1. Dumas 2. Gruver 3. San Jon	4. Sherm 5. Sunray	1. Hartley 2. Hartley 3. Hartley	4. Hartley 5. Hartley
Shallow clay	1. Glenrio		1. Hartley	
Draw	1. Bippus	2. Spur	1. Hartley	2. Hartley
Bottomland	1. Dalupe	2. Humbarger	1. Dallam	2. Dallam
Wet bottomland	1. Gracemore		1. Hartley	
Loamy bottomland	1. Colorado 2. Guadalupe	3. Cass 4. Humbarger	1. Hartley 2. Hartley	3. Moore 4. Moore
Sandy bottomland	1. Lincoln	2. Corlena	1. Hartley, Moore	2. Dallam
Deep hardland	1. Cappus 2. Dumas 3. Harney 4. Manzano 5. Sherm	6. Sunray 7. Ulysses-Sunray 8. Gruver 9. Texline	1. Moore 2. Moore, Dallam 3. Moore 4. Moore 5. Moore	6. Moore 7. Moore 8. Dallam 9. Dallam
Hardland slopes	1. Berda 2. Conlen	3. Sunray 4. Berthond	1. Hartley 2. Hartley, Moore, Dallam	3. Dallam 4. Dallam
Mixedland	1. Enterprise		1. Moore	
Mixedland slopes	1. Berda-Veal 2. Mobeetie 3. Perico	4. Spurlock 5. Veal	1. Hartley 2. Hartley, Moore 3. Hartley, Dallam	4. Hartley, Dallam 5. Moore

Note: See footnote at end of table.

Table 2-2. Range sites and associated soils for counties of the Dalhart basin[a] (continued)

Range site type	Soil series	Counties
Deep sand	1. Valentine	1. Dallam
	2. Valentine-Spurlock	2. Dallam
	3. Tivoli	3. Moore
Gravelly	1. Tascosa	1. Hartley, Moore
High lime	1. Karde	1. Hartley
	2. Church	2. Dallam
	3. Ness	3. Hartley, Dallam, Moore
Rough breaks	1. Berda-Potter	1. Hartley
	2. Rough broken	2. Moore
Sand hills	1. Springer	1. Moore
	2. Likes	2. Moore
	3. Dallam	3. Dallam
	4. Rickmore	4. Dallam
	5. Vingo-Dallam	5. Dallam
	6. Perico	6. Dallam
Sandy land	1. Springer	1. Moore
	2. Likes	2. Moore
	3. Dallam	3. Dallam
	4. Rickmore	4. Dallam
	5. Vingo-Dallam	5. Dallam
	6. Perico	6. Dallam
Sandy loam	1. Dallam	1. Dallam, Hartley
	2. Rickmore	2. Dallam
	3. Dalhart	3. Hartley
	4. Springer	4. Moore
Loamy sand	1. Vingo-Dallam	1. Hartley
	2. Dallam	2. Hartley
	3. Likes	3. Hartley
	4. Perico	4. Hartley
	5. Rickmore	5. Hartley
Very shallow	1. Kerrick-Plack	1. Dallam
	2. Plack	2. Dallam
	3. Ector	3. Moore
	4. Pastura	4. Moore
	5. Potter	5. Hartley
Shallow redland	1. Vernon	1. Moore

[a]From Ford and Fox (1975); Fox (1977); and Geiger (1975).

Table 2-3. Species composition for the terrestrial and wetland range sites of the Dalhart basin[a]

Species	Terrestrial range sites[b]																	Wetland range sites[c]				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Blue grama	15-	50-	15-	20-	D-	D+	25	D	D-	I	20-			10	D-	5+		I			+	20-
Buffalograss	15+	20+	10	15+	I+	I+	5+	I+	D+		5+				I			D+		+		15+
Sideoats grama	10-	5-	20-	10-	D-	I-	35-	D-	D-	D	20-	3.3+	20-	25-	D-	20-	10	D	+	10+	5-	30-
Alkali sacaton	5+		+	5														I	+	5+	10	
Galleta	45																					
Galleta or tobosagrass		5																				
Vine-mesquite	2.5-	5-		15-		I	5-				10-				I				+	5+	+	
Little bluestem		5	5-		D-		5-	D-	I	D-	10-	10-	15-	10	I	15-	15-	D	5	10-	5-	5-
Three-awn		+		+	+			+	+	I	+	+			I	+	5+					+
Sand dropseed		+			I+		5+	+	I+	I	+	3.3+	+	+		+	5+	D			+	+
Yucca					+		+			+												
Hairy grama			10		I+			I+		I+		+	10	+	I	10+	5+					
Black grama			5-		D-				I													
Silver bluestem			5+	+	I+	I	5+		I	I+	+	5	+	+	I			I		+		
Wright three-awn			+		I		5+		I				+	+								
Redberry juniper													+									
Western wheatgrass	2.5-	5-		10-		I												I	10	10	+	
Arizona cottontop					I-				I	+	10-											
Texas wintergrass					I+				I													
Shin oak					I+							+				+						
Fall witchgrass											+											
Sand sagebrush										+						+	+					
White tridens						I																
Tobosagrass						+									I							
Indiangrass								I		D-		20-	2.5-	5-		5-	5-		10-	15-	5-	
Switchgrass										D-		5-	2.5-	5-		10-	5-		15-	15-	20-	5-
Plains bristlegrass					I				I	+	10-	3.3						D			5	
Dotted gayfeather															I							
Sand bluestem					D			D-		D-		20-	2.5-	15-		15-	10	D	10-	15-	20-	
Canada wildrye										I			2.5-					D				
Hooded windmillgrass											5											
Needle-and-thread																5	5					
Giant dropseed										+		10-										
Sand lovegrass										I-		5										
Sand plum												+										
Skunkbush												+										
Catclaw					+																	
Catclaw sensitivebrier													+								-	
Engelmann daisy															I						-	
Heath aster															I						-	
Big sandreed												-					10-					
Inland saltgrass																		I			+	
Prairie cordgrass																			5-			
Eastern gramagrass																			5-			
Willow																			+			
Western ironweed																			+			

Note: See footnotes at end of table.

Table 2-3. Species composition for the terrestrial and wetland range sites of the Dalhart basin[a] (continued)

Species	Terrestrial range sites[b]																	Wetland range sites[c]				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Wild plum																				+		
Tall dropseed																					+	
American licorice																						
Perennial forbs	5	5	5	10			5	I	I				5	5		5	10		5	5	10	10
Annual forbs	+	+	+					+		+		+		+			+			+		+
Forbs					I						5	5			I							
Other grasses			15	5				I					20	25		5			15	5		5
Sedges and rushes																			15			
Woody plants			10	10	I		5	I	I	+	5	10+	20	10	I	5	15		5	5	15	10

Key: Numbers = percentage of composition by weight (weights represent means of a particular county and may vary by locality); D = dominant species; I = other important species; + = increaser (plants that increase as the site deteriorates due mainly to heavy grazing); and – = decreaser (plants that decrease as the site deteriorates due mainly to heavy grazing).

[a]From Blakley and Mohle (1963); Blakley (1967); Richardson et al. (1974, 1977); Ford and Fox (1975); Fox (1977); Geiger and Mitchell (1977); and Neitsch and Blackstock (1978).

[b]Terrestrial Range Sites: 1 = Clay Flats; 2 = Clay Loam; 3 = Shallow Clay; 4 = Draw; 5 = Gravelly; 6 = Deep Hardland; 7 = Hardland Slopes; 8 = Mixedland Slopes; 9 = Mixedland; 10 = Sandyland; 11 = Sandy Loam; 12 = Deep Sand; 13 = Rough Breaks; 14 = Very Shallow; 15 = Shallow Redland; 16 = Loamy Sand; and 17 = Sand Hills.

[c]Wetland Range Sites: 18 = Bottomland; 19 = Wet Bottomland; 20 = Loamy Bottomland; 21 = Sandy Bottomland; and 22 = High Lime

Table 2-4. Amphibians and reptiles of the Dalhart basin, Texas[a]

Common name[b]	Scientific name[b]
AMPHIBIANS	
Tiger salamander	*Ambystoma tigrinum*
Plains spadefoot	*Scaphiopus bombifrons*
Western spadefoot	*Scaphiopus hammondi*
Great plains toad	*Bufo cognatus*
Green toad	*Bufo debilis*
Red-spotted toad	*Bufo punctatus*
Woodhouse's toad	*Bufo woodhousei*
Plains leopard frog	*Rana blairi*
Bullfrog	*Rana catesbeiana*
REPTILES	
Snapping turtle	*Chelydra serpentina*
Yellow mud turtle	*Kinosternon flavescens*
Western box turtle	*Terrapene ornata*
Spiny softshell	*Trionyx spiniferus*
Collared lizard	*Crotaphytus collaris*
Texas horned lizard[c]	*Phrynosoma cornutum*
Lesser earless lizard	*Holbrookia maculata*
Eastern fence lizard	*Sceloporus undulatus*
Great plains skink	*Eumeces obsoletus*
Six-line race runner	*Cnemidophorus sexlineatus*
Colorado checkered whiptail	*Cnemidophorus tesselatus*
Texas blind snake	*Leptotyphlops dulcis*
Glossy snake	*Arizona elegans*
Racer	*Coluber constrictor*
Ringneck snake	*Diadophis punctatus*
Corn snake	*Elaphe guttata*
Western hognose snake	*Heterodon nasicus*
Night snake	*Hypsiglena torguata*
Central plains milk snake[c]	*Lampropeltis triangulum gentilis*
Coachwhip	*Masticophis flagellum*
Plainbelly water snake	*Nerodia erythrogaster*
Gopher snake	*Pituophis melanolecus*
Longnose snake	*Rhinocheilus lecontei*
Ground snake	*Sonora episcopa*
Plains blackhead snake	*Tantilia nigriceps*

Note: See footnotes at end of table.

Table 2-4. Amphibians and reptiles of the Dalhart basin, Texas[a] (continued)

Common name[b]	Scientific name[b]
Checkered garter snake	*Thamnophis marcianus*
Western ribbon snake	*Thamnophis proximus*
Plains garter snake	*Thamnophis radix*
Lined snake	*Tropidoclonion lineatum*
Massasauga	*Sistrurus catenatus*
Western rattlesnake	*Crotalus viridis*

[a]Distributions are based on Bernard and Brown (1977); Brown (1950); Raun and Gehlbach (1972); Smith (1978); Stebbins (1966); Tinkle and Knoff (1964); and Werler (1964).

[b]Common and scientific names follow those used by the Society for the Study of Amphibians and Reptiles (1978).

[c]Species or subspecies listed as protected (threatened) in Texas (Potter, 1979).

Table 2-5. Avian species that may occur in the Dalhart basin[a]

Common name	Scientific name
Eared grebe	*Podiceps migricollis*
Western grebe	*Aechmophorus occidentalis*
Pied-billed grebe	*Podilymbus odiceps*
Great blue heron	*Ardea herodias*
Green heron	*Butorides striatus*
Little blue heron	*Florida caerulea*
Cattle egret	*Bubulcus ibis*
Snowy egret	*Egretta thula*
Black-crowned night heron	*Nycticorax nycticorax*
Yellow-crowned night heron	*Nyctanassa violacea*
American bittern	*Botaurus lentiginosus*
Whistling swan	*Olor columbianus*
Canada goose	*Branta canadensis*[b]
White-fronted goose	*Anaser albifrons*[b]
Snow goose	*Chen caerulescens*[b]
Mallard	*Anas platyrhynchos*[b]
Gadwall	*Anas strepera*[b]
Pintail	*Anas acuta*[b]
Green-winged teal	*Anas crecca*[b]
Blue-winged teal	*Anas discors*[b]
Cinnamon teal	*Anas cyanoptera*[b]
American wigeon	*Anas americana*[b]
Northern shoveler	*Anas clypeata*[b]
Redhead	*Aythya americana*[b]
Ring-necked duck	*Aythya collaris*[b]
Canvasback	*Aythya valisineria*[b]
Lesser scaup	*Aythya affinis*[b]
Common goldeneye	*Bucephala clangula*[b]
Bufflehead	*Bucephala albeola*[b]
Oldsquaw	*Clangula hyemalis*[b]
Surf scoter	*Melanitta perspicillata*[b]
Common merganser	*Mergus merganser*[b]
Turkey vulture	*Cathartes aura*
Black vulture	*Coragyps atratus*
Mississippi kite	*Ictinia mississippiensis*
Goshawk	*Accipiter gentilis*
Sharp-shinned hawk	*Accipiter striatus*
Cooper's hawk	*Accipiter cooperii*
Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*Buteo lineatus*
Broad-winged hawk	*Buteo platypterus*
Swainson's hawk	*Buteo swainsoni*
Rough-legged hawk	*Buteo lagopus*
Ferruginous hawk	*Buteo regalis*
Harris' hawk	*Parabuteo unicinctus*
Golden eagle	*Aquila chrysaetos*
Bald eagle	*Haliaeetus leucocephalus*[c]

Note: See footnotes at end of table.

Table 2-5. Avian species that may occur in the Dalhart basin[a] (continued)

Common name	Scientific name
Marsh hawk	*Circus cyaneus*
Prairie falcon	*Falco mexicanus*
Peregrine falcon	*Falco peregrinus*[c]
Merlin	*Falco columbarius*
American kestrel	*Falco sparverius*
Lesser prairie chicken	*Tympanuchus palladicinctus*[b]
Bobwhite	*Colinus virginianus*[b]
Scaled quail	*Callipepla squamata*[b]
Ring-necked pheasant	*Phasianus colchicus*[b]
Turkey	*Meleagris gallopavo*[b]
Sandhill crane	*Grus canadensis*[b]
Virginia rail	*Rallus limicola*[b]
Sora	*Porzana carolina*[b]
American coot	*Fulica americana*[b]
Semipalmated plover	*Charadrius semipalmatus*
Snowy plover	*Charadrius alexandrinus*
Killdeer	*Charadrius vociferus*
Mountain plover	*Charadrius montanus*
Blackbellied plover	*Pluvialis squatarola*
Common snipe	*Capella gallinago*[b]
Long-billed curlew	*Numenius americanus*
Upland sandpiper	*Bartramia americana*
Spotted sandpiper	*Actitis macularia*
Solitary sandpiper	*Tringa solitaria*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Pectoral sandpiper	*Calidris melanotos*
White-rumped sandpiper	*Calidris fuscicollis*
Baird's sandpiper	*Calidris bairdii*
Least sandpiper	*Calidris minutilla*
Dunlin	*Calidris alpina*
Semipalmated sandpiper	*Calidris pusilla*
Stilt sandpiper	*Micropalama himantopus*
Buff-breasted sandpiper	*Tryngites subruficollis*
American avocet	*Recurvirostra americana*
Black-necked stilt	*Himantopus mexicanus*
Forester's tern	*Sterna foresteri*
Least tern	*Sterna albifrons*[c]
Black tern	*Chlidonias niger*
Rock dove	*Columba livia*
White-winged dove	*Zenaida asiatica*[b]
Mourning dove	*Zenaida macroura*[b]
Yellow-billed cuckoo	*Coccyzus americanus*
Roadrunner	*Geococcyx californianus*
Barn owl	*Tyto alba*
Screech owl	*Otus asio*

Note: See footnotes at end of table.

Table 2-5. Avian species that may occur in the Dalhart basin[a] (continued)

Common name	Scientific name
Great horned owl	Bubo virginianus
Burrowing owl	Athene cunicularia
Barred owl	Strix varia
Long-eared owl	Asio otus
Short-eared owl	Asio flammeus
Poor-will	Phalaenoptilus nuttallii
Common nighthawk	Chordeiles minor
Black swift	Cypseloides niger
Chimney swift	Chaetura pelagica
Broad-tailed hummingbird	Selasphorus platycercus
Belted kingfisher	Megaceryle alcyon
Common flicker	Colaptes auratus
Red-bellied woodpecker	Melanerpes carolinus
Golden-fronted woodpecker	Melanerpes aurifrons
Red-headed woodpecker	Melanerpes erythrocephalus
Acorn woodpecker	Melanerpes formicivorus
Yellow-bellied sapsucker	Sphyrapicus varius
Williamson's sapsucker	Sphyrapicus thyroideus
Hairy woodpecker	Picoides villosus
Downy woodpecker	Picoides pubescens
Ladder-backed woodpecker	Picoides scalaris
Eastern kingbird	Tyrannus tyrannus
Western kingbird	Tyrannus verticalis
Scissor-tailed flycatcher	Muscivora forficata
Ash-throated flycatcher	Myiarchus cinerascens
Say's phoebe	Sayornis saya
Eastern wood pewee	Contopus virens
Western wood pewee	Contopus sordidulus
Olive-sided flycatcher	Nuttallornis borealis
Vermilion flycatcher	Pyrocephalus rubinus
Horned lark	Eremophila alpestris
Tree swallow	Iridoprocne bicolor
Bank swallow	Riparia riparia
Barn swallow	Hirundo rustica
Cliff swallow	Petrochelidon pyrrhonota
Purple martin	Progne subis
Blue jay	Cyanocitta cristata
Steller's jay	Cyanocitta stelleri
Scrub jay	Aphelocoma coerulescens
White-necked raven	Corvus cryptoleucus
Common crow	Corvus brachyrhynchos
Pinon jay	Gymnorhinus cyanocephalus
Clark's nutcracker	Nucifraga columbiana
White-breasted nuthatch	Sitta carolinensis
Red-breasted nuthatch	Sitta canadensis
House wren	Troglodytes aedon

Note: See footnotes at end of table.

Table 2-5. Avian species that may occur in the Dalhart basin[a] (continued)

Common name	Scientific name
Bewick's wren	*Thryomanes bewickii*
Canyon wren	*Catherpes mexicanus*
Rock wren	*Salpinctes obsoletus*
Mockingbird	*Mimus polyglottos*
Gray catbird	*Dumetella carolinensis*
Curve-billed thrasher	*Toxostoma curvirostre*
Sage thrasher	*Oreoscoptes montanus*
American robin	*Turdus migratorius*
Hermit thrush	*Catharus guttatus*
Swainson's thrush	*Catharus ustulatus*
Gray-cheeked thrush	*Catharus minimus*
Veery	*Catharus fuscescens*
Eastern bluebird	*Sialia sialis*
Western bluebird	*Sialia mexicana*
Mountain bluebird	*Sialia currucoides*
Blue-gray gnatcatcher	*Polioptila caerulea*
Ruby-crowned kinglet	*Regulus calendula*
Water pipit	*Anthus spinoletta*
Sprague's pipit	*Anthus spraygueii*
Bohemian waxwing	*Bombycilla garrulus*
Cedar waxwing	*Bombycilla cedrorum*
Northern shrike	*Lanius excubitor*
Loggerhead shrike	*Lanius ludovicianus*
Starling	*Sturnus vulgaris*
Warbling vireo	*Vireo gilvus*
Black-and-white warbler	*Mniotilta varia*
Yellow warbler	*Dendroica petechia*
Bay-breasted warbler	*Dendroica castanea*
Palm warbler	*Dendroica palmarum*
Ovenbird	*Seiurus aurocapillus*
Northern waterthrush	*Seiurus noveboracensis*
Kentucky warbler	*Oporornis formosus*
MacGillivray's warbler	*Oporornis tolmiei*
Common yellowthroat	*Geothlypis trichas*
Yellow-breasted chat	*Icteria virens*
Hooded warbler	*Wilsonia citrina*
Wilson's warbler	*Wilsonia pusilla*
American redstart	*Setophaga ruticilla*
House sparrow	*Passer domesticus*
Eastern meadowlark	*Sturnella magna*
Western meadowlark	*Sturnella neglecta*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Red-winged blackbird	*Agelaius phoeniceus*
Orchard oriole	*Icterus spurius*
Northern oriole	*Icterus galbula*
Rusty blackbird	*Euphagus carolinus*

Note: See footnotes at end of table.

Table 2-5. Avian species that may occur in the Dalhart basin[a] (continued)

Common name	Scientific name
Brewer's blackbird	*Euphagus cyanocephalus*
Common grackle	*Quiscalus quiscula*
Brown-headed cowbird	*Molothrus ater*
Western tanager	*Piranga ludoviciana*
Summer tanager	*Piranga rubra*
Cardinal	*Cardinalis cardinalis*
Black-headed grosbeak	*Pheucticus melanocephalus*
Blue grosbeak	*Guiraca caerulea*
Luzzuli bunting	*Passerina amoena*
Painted bunting	*Passerina ciris*
Evening grosbeak	*Hesperiphona vespertina*
Purple finch	*Carpodacus purpureus*
House finch	*Carpodacus mexicanus*
Pine siskin	*Carduelis pinus*
American goldfinch	*Carduelis tristis*
Lesser goldfinch	*Carduelis psaltria*
Red crossbill	*Loxia curvirostra*
Green-tailed towhee	*Pipilo chlorurus*
Brown towhee	*Pipilo fuscus*
Lark bunting	*Calamospiza melanocorys*
Savannah sparrow	*Passerculus sandwichensis*
Grasshopper sparrow	*Ammodramus savannarum*
Vesper sparrow	*Pooecetes gramineus*
Lark sparrow	*Chondestes grammacus*
Rufous-crowned sparrow	*Aimophila ruficeps*
Cassin's sparrow	*Aimophila cassinii*
Dark-eyed junco	*Junco hyemalis*
Tree sparrow	*Spizella arborea*
Chipping sparrow	*Spizella passerina*
Clay-colored sparrow	*Spizella pallida*
White-crowned sparrow	*Zonotrichia leucophrys*
White-throated sparrow	*Zonotrichia albicollis*
Fox sparrow	*Passerella iliaca*
Lincoln's sparrow	*Melospiza lincolnii*
Song sparrow	*Melospiza melodia*
Chestnut-collared longspur	*Calcarius ornatus*

[a]Ranges include one or more counties of the basin, as determined from Oberholser (1974).

[b]Game species.

[c]Endangered.

Table 2-6. Mammals whose geographic ranges[a] include all or part of the Dalhart basin

Common name	Scientific name	Range[c]	Occurrence by county[b] Dallam	Hartley	Oldham	Moore	Sherman	Total counties	Special status[d]
Virginia opossum	Didelphis virginiana	Entire			x			1	Furbearer
Least shrew	Cryptotis parva	Sherman and Moore						0	
Desert shrew	Notiosorex crawfordi	Entire						0	
*Yuma myotis	Myotis yumanensis	Northwestern Dallam						0	
*Cave myotis	Myotis velifer	Mostly south of basin						0	
*Small-footed myotis	Myotis leibii	Northwestern Dallam						0	
*Silver-haired bat	Lassionycteris notivagans	Northwestern Dallam						0	
*Western pipistrelle	Pipistrellus hesperus	Mostly southeast of basin			x			1	
Big brown bat	Eptesicus fuscus	Entire						0	
*Red bat	Lasiurus borealis	Mostly southeast of basin						0	
Hoary bat	Lasiurus cinereus	Entire						0	
*Townsend's big-eared bat	Plecotus townsendii	Northwestern Dallam and southeast of basin						0	
Pallid bat	Antrozous pallidus	Western part of basin			x			1	
Eastern cottontail	Sylvilagus floridanus	Entire						0	
Desert cottontail	Sylvilagus audubonii	Entire	x	x	x			3	
Black-tailed jack rabbit	Lepus californicus	Entire	x		x			2	
Thirteen-lined ground squirrel	Spermophilus Tridecemineatus	Entire	x		x	x	x	4	
Spotted ground squirrel	Spermophilus spilosoma	Entire						0	
Black-tailed prairie dog	Cynomys ludovicianus	Entire	x			x		2	
Plains pocket gopher	Geomys bursarius	Entire	x					1	
Yellow-faced pocket gopher	Pappogeomys castanops	Entire			x			1	
Plains pocket mouse	Perognathus flavescens	Entire						0	
Silky pocket mouse	Perognathus flavus	Entire			x	x		2	
Hispid pocket mouse	Perognathus hispidus	Entire			x			1	
Ord's kangaroo rat	Dipodomys ordii	Entire	x		x			2	
Plains harvest mouse	Reithrodontomys montanus	Entire						0	

Note: See footnotes at end of table.

Table 2-6. Mammals whose geographic ranges[a] include all or part of the Dalhart basin (continued)

Common name	Scientific name	Range[c]	Occurrence by county[b] Dallam	Hartley	Oldham	Moore	Sherman	Total counties	Special status[d]
Western harvest mouse	Reithrodontomys megalotis	Entire						0	
Deer mouse	Peromyscus maniculatis	Entire			x			1	
White-footed mouse	Peromyscus leucopus	Entire						0	
Brush mouse	Peromyscus boylii	All of basin but Sherman						0	
Pinon mouse	Peromyscus truei	Entire						0	
*Rock mouse	Peromyscus difficilis	Extreme western edge						0	
Northern grasshopper mouse	Onychomys leucogaster	Entire	x	x	x			3	
Hispid cotton rat	Sigmodon hispidus	Entire						0	
Southern plains woodrat	Neotoma micropus	Entire		x				1	
*White-throated woodrat	Neotoma albigula	Northwestern half of Oldham			x			1	
*Mexican woodrat	Neotoma mexicana	Northwestern Dallam						0	
*Prairie vole	Microtus ochrogaster	Northern Dallam and Sherman						0	
Muskrat	Ondatra zibethica	All but southwestern Hartley and Oldham						0	Furbearer
Black rat	Rattus rattus	Residential, entire						0	
Norway rat	Rattus noryegicus	Residential, entire						0	
House mouse	Mus musculus	Entire						0	
Porcupine	Erethizon dorsatum	Entire						0	
Coyote	Canis latrans	Entire			x			1	
Swift fox	Vulpes velox	Entire	x	x	x	x	x	5	TOES, Furbearer
Ringtail	Bassariscus astutus	Entire						0	Furbearer
Raccoon	Procyon lotor	Entire			x			1	Furbearer
Black-footed ferret	Mustela nigripes	Entire	x					1	USDI, TOES, TPWD
Badger	Taxidea taxus	Entire			x	x		2	Furbearer
Eastern spotted skunk	Spilogale putorius	Entire				x		1	Furbearer
Striped skunk	Mephitis mephitis	Entire						0	Furbearer
Bobcat	Felis rufus	Entire	x	x	x	x	x	5	
Mule deer	Odocoileus hemionus	Southwestern part of basin		x	x	x		3	Game

Note: See footnotes at end of table.

Table 2-6. Mammals whose geographic ranges[a] include all or part of the Dalhart basin (continued)

Common name	Scientific name	Range[c]	Occurrence by county[b] Dallam	Hartley	Oldham	Moore	Sherman	Total counties	Special status[d]
White-tailed deer	Odocoileus virginianus	Eastern part of basin				x	x	2	Game
Pronghorn	Antilocapra americana	Mostly Dallam, Hartley and Oldham	x	x	x	x	x	5	Game
Mouflon	Ovis sp.	Moore and Oldham			x	x		2	Exotic, game
Total species	55		11	7	21	11	5		

*The Dalhart basin is near the periphery of the known range of the species.

[a]Ranges from Burt and Grossenheider (1976), Barbour and Davis (1969), and Davis (1974); nomenclature from Jones et al. (1975).

[b]County records from Davis (1974), the museum collection from Texas Tech University, and various journal reports.

[c]Range within Dalhart basin.

[d]Game = game status; Furbearer = furbearer status; USDI, TOES, TPWD = listed as threatened or endangered by the USDI (U.S. Department of the Interior), by the TOES (Texas Organization for Endangered Species), or by the TPWD (Texas Parks Wildlife Department).

Table 2-7. Waterfowl harvest[a] in the Dalhart basin,[b] 1961-1970

Species	Number
Mallard	1,440
Gadwall	77
Green-winged teal	848
Northern shoveler	19
Teal[c]	33
Pintail	49
Redhead	34
Canvasback	17
American wigeon	197
Bufflehead	16
Canada goose	585

[a]Adapted from Carney et al. (1975).

[b]Dallam, Sherman, Hartley, Oldham, and Moore Counties.

[c]Blue-winged and cinnamon teal.

Table 2-8. Dominant characteristics, uses, and limitations of soil associations found in the Dalhart basin[a]

Soil association name	Annual rainfall (in.)	Setting: Regolith	Setting: Relief	Mineralogical and chemical properties	Vegetation	Limitations and special features	Major land uses and potentials
				Alfisols			
Dallam-Sunray-Dumas	14-20	Calcareous loamy outwash and wind-laid deposits	Level to gently undulating	Mixed; carbonatic (Conlen, Mansker)	Short and mid grasses; small mesquite trees; thorny shrubs; cacti	Wind erosion; high corrosion potential	Crops (irrigated); range; crops; residences; wildlife
				Mollisols			
Mansker-Berda-Potter	19-25	Calcareous, loamy and clayey red beds or limestone; loamy and clayey outwash	Rolling to level	Mixed; montmorillonite (Tarrant); carbonatic (Mansker); moderately alkaline; calcareous	Short and mid grasses; tall grasses; mesquite trees; live oak trees (Tarrant)	Limestone, cemented caliche, or compact red beds at 10 to 40 inches, except for deeper soils (Rowena, Berda); high corrosion potential	Range; wildlife; crops (irrigated-Rowena)
Sherm-Gruver-Sunray	14-20	Clayey and loamy outwash and wind-laid deposits, some over cemented	Level to gently undulating	Mixed (appreciable montmorillonite); carbonatic (Mansker)	Short grasses; some mesquite trees; cacti	High shrink-swell potential (Pullman-Sherm); high corrosion potential; wind erosion	Crops; crops (irrigated); range; wildlife
Sunray-Conlen-Gruver	14-20	Calcareous, loamy outwash and wind-laid deposits	Level to gently undulating	Mixed; carbonatic (Conlen, Mansker)	Short and mid grasses; small mesquite trees; thorny shrubs; cacti	Wind erosion; high corrosion potential	Crops (irrigated); range; crops, residences; wildlife

[a]Godfrey et al. (1973).

Table 2-9. Distribution of the principal soil Orders and associations for the Dalhart basin[a]

County	Soil Order	County area within association	Estimated acreage
Dallam	Mollisol	Sunray-Conlen-Gruver	492,310
	Mollisol	Sherm-Gruver-Sunray	54,070
	Alfisol	Dallam-Sunray-Dumas	409,780
Sherman	Mollisol	Sunray-Conlen-Gruver	43,200
	Mollisol	Sherm-Gruver-Sunray	79,200
Moore	Mollisol	Sherm-Gruver-Sunray	86,400
Hartley	Alfisol	Dallam-Sunray-Dumas	463,680
	Mollisol	Sherm-Gruver-Sunray	161,280
	Mollisol	Mansker-Berda-Potter	142,560
Oldham	Mollisol	Mansker-Berda-Potter	53,200
Total			1,985,680

[a]From USDA (1979).

Table 2-10. Prime farmland soils in the Dalhart basin[a]

County	Mapping unit name	Prime in native state	Prime if Irrigated	Acres
Dallam	Gruver L 0-1% slopes	Yes	-	80,000
	Gruver L 1-3% slopes	Yes	-	4,300
	Humbarger L	Yes	-	5,230
	Sherm CL	Yes	-	32,800
	Total			122,330
Hartley	Bippus CL 0-1% slopes	Yes	-	1,800
	Bippus CL 1-3% slopes	Yes	-	2,200
	Gruver L 0-1% slopes	Yes	-	45,600
	Gruver L 1-3% slopes	Yes	-	1,600
	Sherm CL 0-1% slopes	Yes	-	71,000
	Spur L	Yes	-	1,700
	Total			124,000
Moore	Capps CL 0-1% slopes	Yes	-	3,705
	Capps CL 1-3% slopes	Yes	-	829
	Harney (Gruver) CL 0-1% slopes	Yes	-	15,375
	Harney (Gruver) CL 1-3% slopes	Yes	-	3,455
	Manzano CL 1-3% slopes	Yes	-	983
	Sherm SICL 0-1% slopes	Yes	-	266,578
	Sherm SICL 1-3% slopes	Yes	-	9,960
	Total			300,885
Oldham	Bippus CL 0-2% slopes	Yes	-	5,040
	Lofton CL 0-1% slopes	Yes	-	980
	Olton CL 0-1% slopes	Yes	-	16,080
	Olton CL 1-3% slopes	Yes	-	11,300
	Pullman CL 0-1% slopes	No	Yes	115,430
	Pullman CL 1-3% slopes	No	Yes	13,390
	Total			162,220
Sherman	Gruver CL 0-1% slopes	Yes	-	75,863
	Manzano CL	Yes	-	2,942
	Sherm CL 0-1% slopes	Yes	-	182,565
	Total			261,370

Abbreviations: CL = clay loam
L = loam
SICL = silty clay loam.

[a]From USDA (1979).

Table 2-11. Prime and additional potential prime farmland soils in the Dalhart basin counties[a]

County	Land area (acres)	Prime[b] (acres)	Percent	Additional potential prime[c] (acres)	Percent
Dallam	956,160	122,330	12.8	0	0
Hartley	952,320	124,000	13.0	0	0
Moore	581,760	300,885	52.0	0	0
Oldham	945,920	33,400	3.5	128,820	13.6
Sherman	586,240	261,370	44.6	0	0

[a]From USDA (1979).
[b]Meets criteria for prime farmland in native state.
[c]Irrigated or drained.

Table 2-12. Acreage devoted to important field crops in the Dalhart basin, 1978[a]

County	Corn		Hay		Sorghum		Soybeans		Sugar beets		Sunflowers		Total	
	PL	HA	PL	HA	PL	HA	PL	HA	PL	HA	PL	HA	PL	HA
Dallam	53,000	35,500	--	9,100	108,400	93,000	1,000	900	--	--	1,800	1,600	164,600	140,100
Hartley	29,600	27,700	--	3,900	58,100	35,000	1,000	900	(b)	--	1,900	1,700	90,600	69,200
Moore	39,800	32,700	--	1,500	70,000	59,300	1,500	1,300	(b)	--	1,300	1,000	112,600	95,800
Oldham	2,600	2,100	--	2,000	43,000	36,700	--	--	(b)	--	500	400	46,100	41,200
Sherman	33,500	26,800	--	4,000	88,000	78,200	900	900	600	500	(b)	--	123,000	110,400

Abbreviations: PL = planted; HA = harvested.

[a]From Texas Department of Agriculture, USDA (1978a).
[b]Item reported but estimated at less than 500 acres.

Table 2-13. Acreage devoted to small grain crops in the Dalhart basin counties, 1978[a]

	Barley		Oats		Rye		Wheat		Totals	
	PL	HA	PL	HA	PL	HA	PL	HA	PL	HA
Dallam	(b)	--	3,000	1,200	1,200	800	129,000	70,300	133,200	72,300
Hartley	800	200	1,600	600	(b)	--	97,000	63,400	99,400	63,600
Moore	3,600	2,000	1,500	500	--	--	100,000	59,800	105,100	62,300
Oldham	(b)	--	1,200	400	(b)	--	67,000	18,000	68,200	18,400
Sherman	4,400	3,300	1,300	900	(b)	--	143,000	66,200	148,700	70,400

Abbreviations: PL = planted; HA = harvested.

[a]From Texas Department of Agriculture, USDA (1978b).
[b]Reported but estimated at less than 500 acres.

Table 2-14. Acreage devoted to selected field crops, grain crops, and vegetables in the Dalhart basin counties, 1978

County	Field crops[a]	Grain crops[b]	Vegetables[c]	Total acreage in crops	Acreage in county	Proportion of county in crops	Rank by percentage in crops
Dallam	164,600	133,200	--	297,800	956,160	31.1	3
Hartley	90,600	99,400	--	190,000	952,192	19.9	4
Moore	112,600	105,100	--	217,700	578,953	37.6	2
Oldham	46,100	68,200	--	114,300	945,600	12.1	5
Sherman	123,000	148,700	100	271,800	586,240	46.4	1

[a]From Texas Department of Agriculture, USDA (1978a).
[b]From Texas Department of Agriculture, USDA (1978b).
[c]From Texas Department of Agriculture, USDA (1978c).

Table 2-15. Number of cattle and hogs by county for the Dalhart basin[a]

County	Cattle and calves	Hogs
Dallam	93,000	--
Hartley	151,000	1,100
Moore	128,000	13,600
Oldham	64,000	1,200
Sherman	120,000	1,100

[a]From Texas Department of Agriculture, USDA (1978d).

Table 2-16. Irrigation water sources, modes, and acreages in the Dalhart basin counties, 1974[a]

	County				
	Dallam	Hartley	Moore	Oldham	Sherman
All irrigation (acres)	155,905	140,000	230,136	32,709	273,651
Surface-water irrigation only (acres)	0	0	0	0	0
Groundwater irrigation only (acres)	155,905	140,000	230,136	32,709	273,171
Irrigations using continued supplies (acres)	0	0	0	0	480
Irrigation wells (number)	900	850	1,007	242	1,190
Sprinkler systems (acres)	93,120	35,300	840	1,330	21,150

[a]From Texas Water Development Board (1975).

Table 2-17. Acreages of the Dalhart basin counties relative to acreages planted with important field crops, 1978[a]

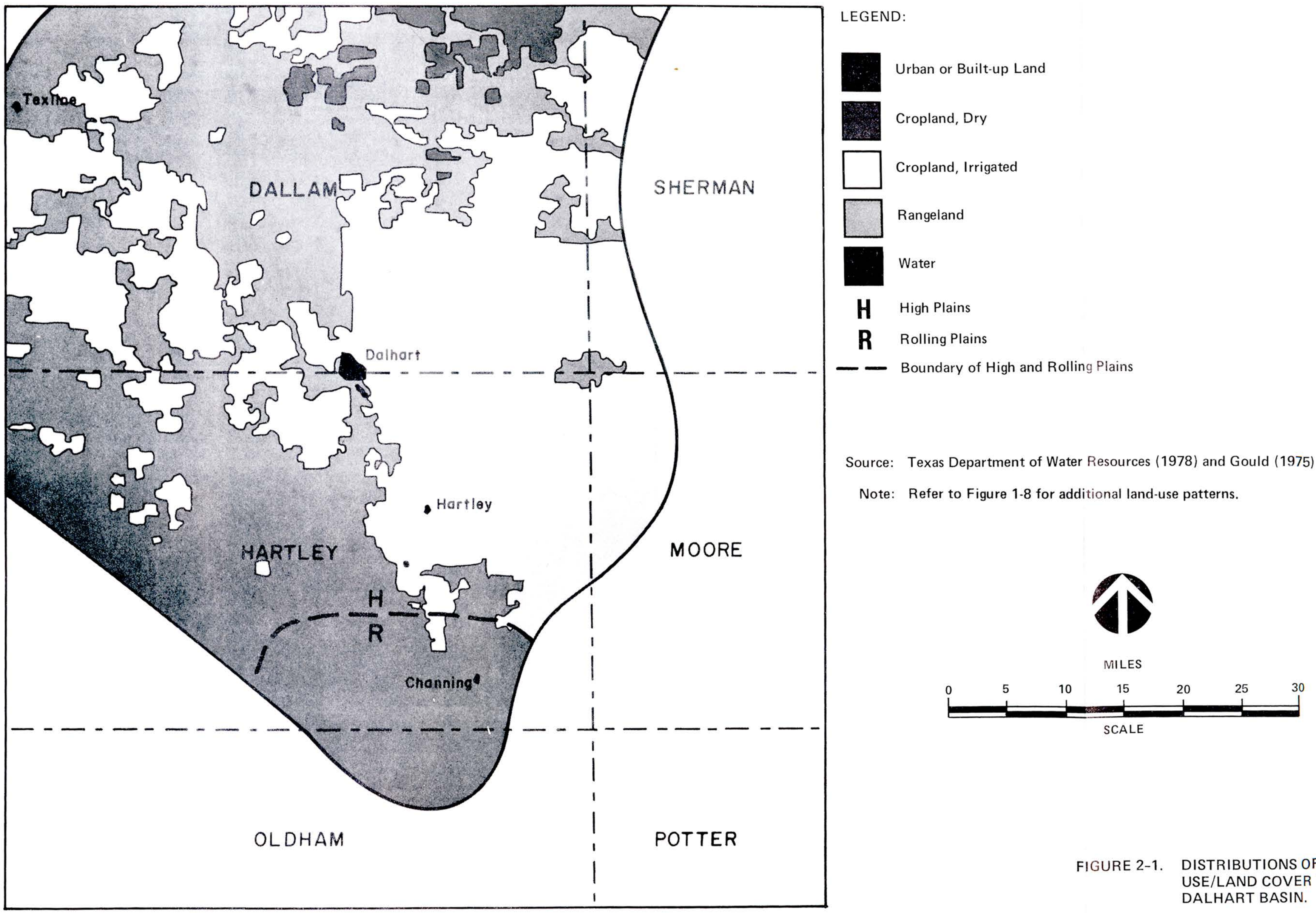
County	Total acres	Acres tilled	Percent	Rank
Dallam	956,160	164,200	17	3
Hartley	952,192	90,600	10	4
Moore	578,953	112,600	19	2
Oldham	945,600	46,100	5	5
Sherman	586,240	123,000	21	1

[a]From Texas Department of Agriculture, USDA (1978a).

Table 2-18. Farm census data of the Dalhart basin counties, 1974[a]

County	Number of farms	Land in farms (acres)	Average size of farms	Value of crops sold ($1000)	Value of livestock and poultry products sold ($1000)	Value of crops and livestock ($1000)
Hartley	204	957,830	4,695	16,318	65,462	81,780
Moore	291	520,304	1,788	23,769	78,114	101,883
Oldham	165	820,888	4,975	2,550	31,122	33,672
Sherman	298	558,673	1,875	28,668	74,435	103,103
Dallam	362	973,869	2,690	21,691	41,442	63,113

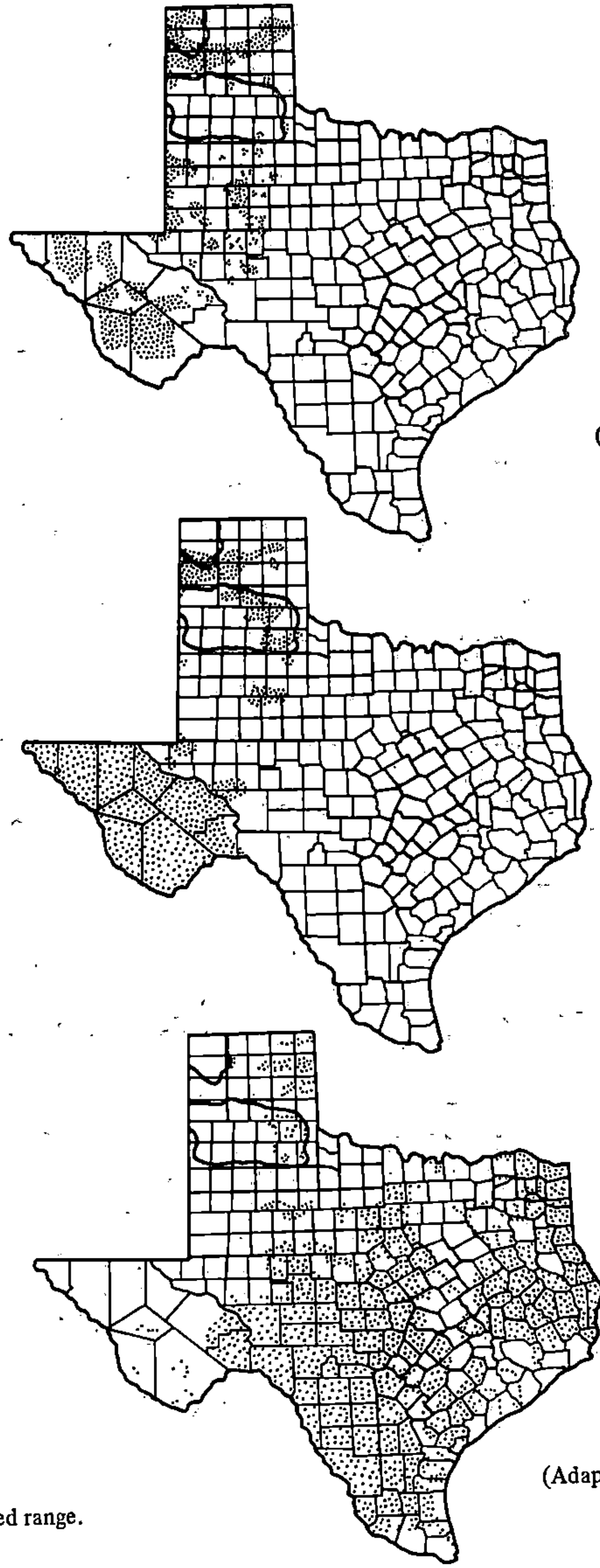
[a]From Pass (1977).



Source: Texas Department of Water Resources (1978) and Gould (1975)

Note: Refer to Figure 1-8 for additional land-use patterns.

FIGURE 2-1. DISTRIBUTIONS OF MAJOR LAND USE/LAND COVER TYPES FOR THE DALHART BASIN.



Pronghorn
(Kothman, 1979)

Mule deer
(Brownlee, 1979)

White-tailed deer
(Adapted from Cook and Harwell, 1979)

Legend:

Documented range.

Figure 2-2. Distribution of big game mammals in Texas.

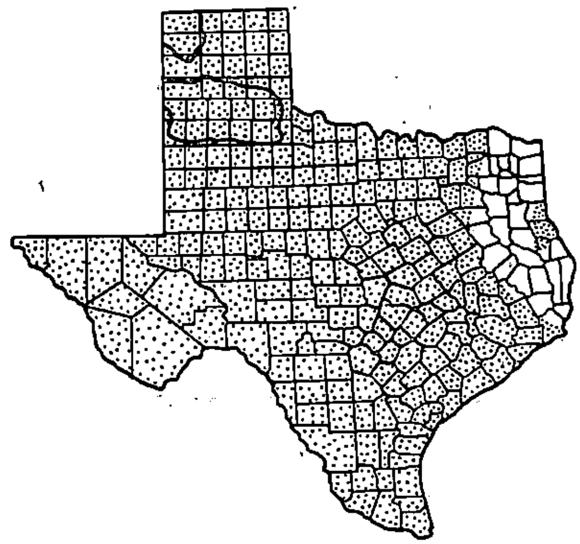


Figure 2–3. Distribution of the Texas horned lizard (Conant, 1975).

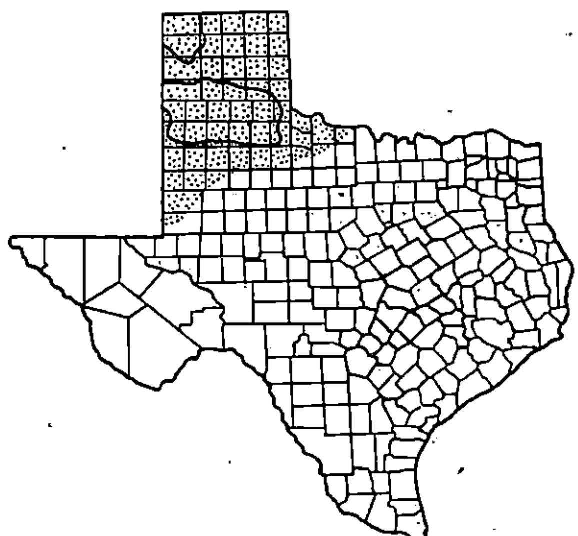
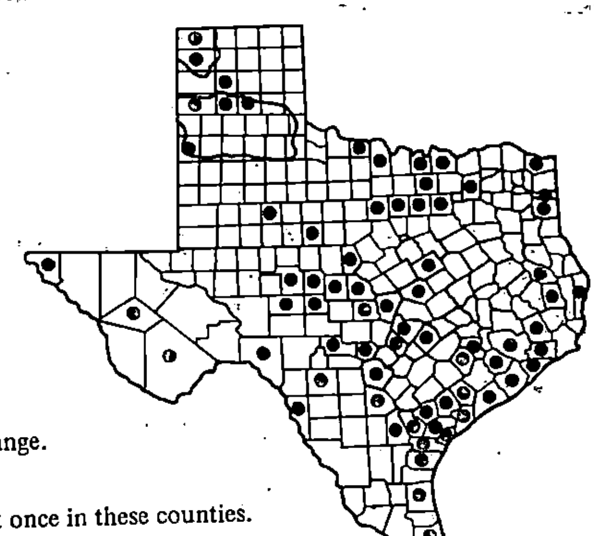


Figure 2–4. Distribution of the central plains milk snake in Texas (Conant, 1975).



Legend:

Documented range.

● Sighted at least once in these counties.

Figure 2–5. Occurrence of the southern bald eagle in Texas by county (Oberholser, 1974).

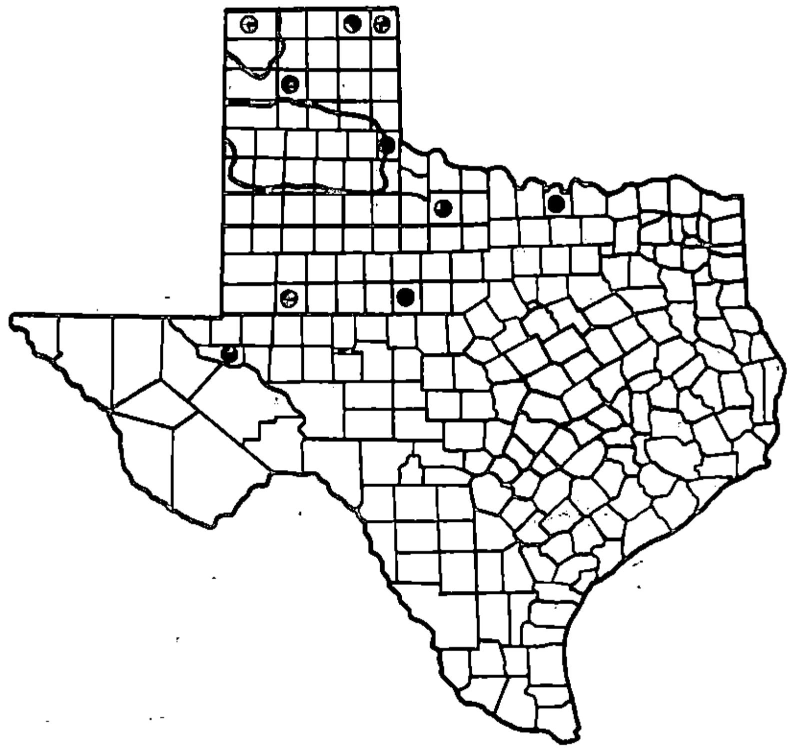


Figure 2–6. Occurrence of the black-footed ferret in Texas by county (Brownlee, 1977).

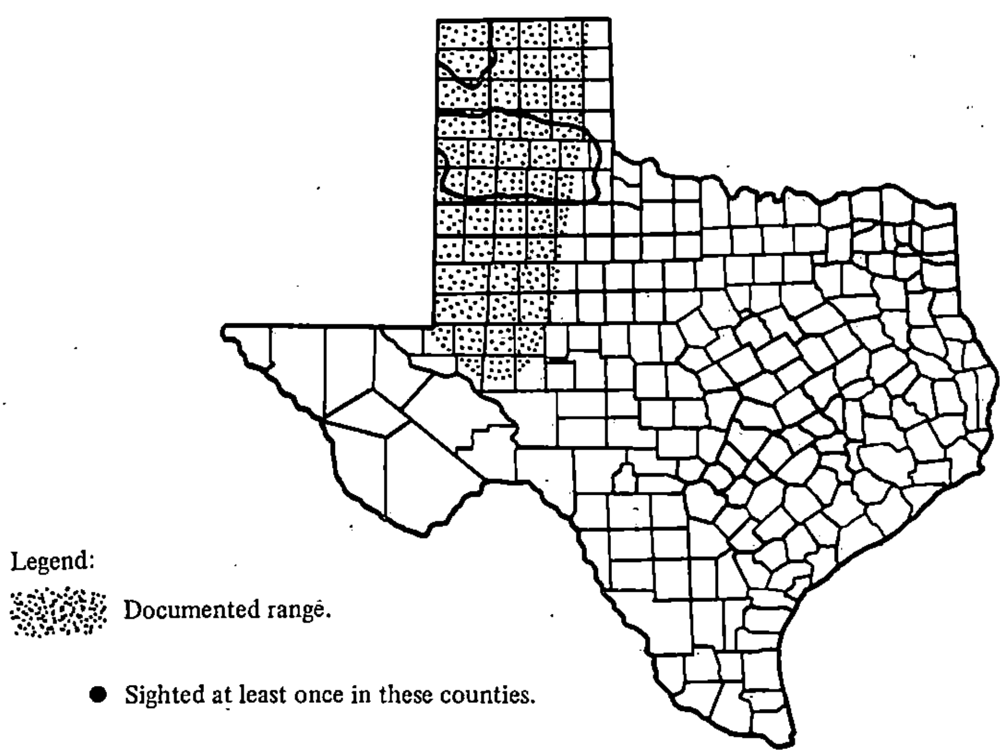
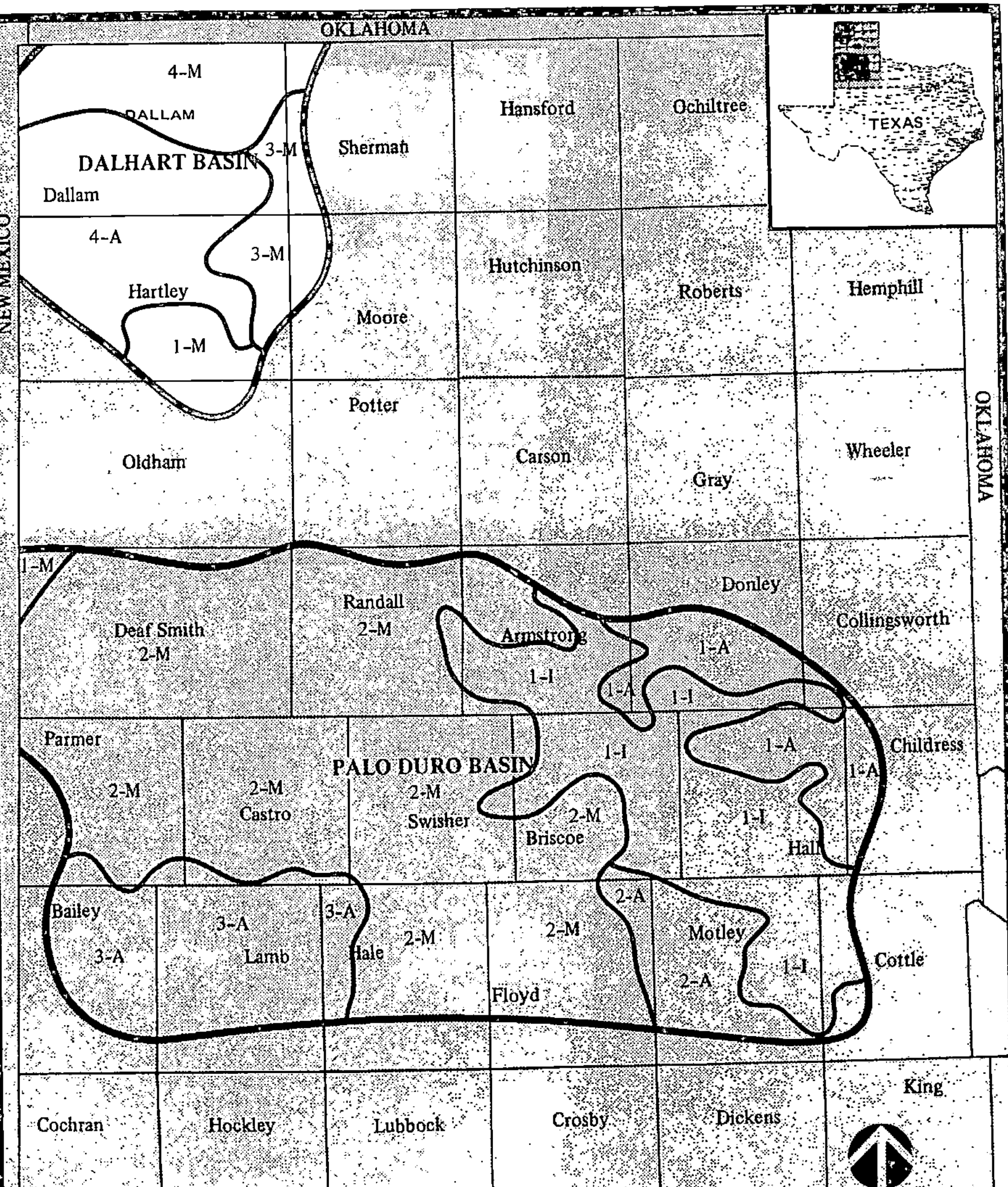


Figure 2–7. Distribution of the swift fox in Texas (Davis, 1974).



Legend:

1-A	Miles-Springer-Woodward	1-M	Mansker-Berda-Potter	A =	Alfisols
2-A	Miles-Brownfield-Olton	2-M	Pullman-Olton-Mansker	M =	Molisols
3-A	Amarillo-Acuff-Mansker	3-M	Sherm-Gruver-Sunray	I =	Inceptisols
4-A	Dallam-Sunray-Dumas	4-M	Sunray-Conlen-Gruver		
1-I	Woodward-Quinlan-Vernon				

Source: Godfrey et al. (1973).

Figure 2-8. Soil associations of the Dalhart basin.

3 Aquatic Ecology

The aquatic resources of the Texas Panhandle are limited. Region I of the Comprehensive Planning Division of the Texas Parks and Wildlife Department (TPWD), which includes the Dalhart basin, contains 8.9 percent of the Texas population but only 2.2 percent of the total outdoor recreation acreage (Welden, 1972). This includes a sport fishery, primarily associated with reservoirs rather than streams. Fisheries problems in the major public waters of the region are associated with poor water quality and limited food production or with an over-abundance of rough species. In addition to a recreational fishery, there are considerable demands on the water for agricultural, municipal/domestic, and industrial needs. Development of surface water supplies to meet these demands has included reservoir construction and, in some areas, modification of natural playa lakes to impound runoff following precipitation. Many of these water projects, particularly the larger reservoirs, are managed for multiple uses, including maintenance of recreational fisheries.

This chapter addresses the pertinent aspects of the aquatic environments and associated biota of the Dalhart basin. Included is a description of the major drainage features, natural water bodies and impoundments, and water quality as well as discussions of important aquatic species and existing environmental stresses on the resident biota. Data on surface-water characteristics (quantity and quality) are provided as important background information relative to understanding subsequent discussions on aquatic species and existing environmental stresses.

3.1 DESCRIPTION OF SURFACE-WATER BODIES

3.1.1 PHYSIOGRAPHY

The High Plains section (Figure 3-1) is a remnant of a gigantic alluvial apron that formerly extended uninterrupted from the foot of the Rockies and the mountains to the south in New Mexico to an unknown terminus, probably some hundreds of miles to the east of its present edge (McGuiness, 1963). The alluvium was deposited on the eroded, gently undulating, eastward-sloping surface of a thick body of stratified sandstone, shale, and limestone. The alluvium of this vast plain, most of which is uniform enough to be classified as a single stratigraphic unit, the Ogallala Formation, covers the eroded, older rocks with a layer that may be thicker than 500 feet in places. In large areas the original depositional surface is intact, forming a flat, imperceptibly eastward-sloping tableland that is modified only by shallow depressions (playas) and sand dunes. Around the edges of the High Plains, however, the alluvial apron has been stripped away by erosion, and the High Plains are now isolated from the Rockies.

The eastern margin of the High Plains is marked by a prominent escarpment, known as the Caprock Escarpment. In Texas, the Canadian River has cut to bedrock in its entire course, dividing the Texas portion of the High Plains into the northern and the southern High Plains.

Flanking the Canadian River on both sides are the Canadian River "Breaks." This strip of land, varying in width from 15 to 30 miles, is strongly undulating and deeply dissected by the tributaries of the Canadian River, few of which are more than 20 miles long. The river is entrenched in a deep gorge 500 to 800 feet below the plateau and flows in a wide channel over alluvial fill of great depth.

3.1.2 GEOLOGY

Underlying most of the Canadian River basin, and exposed principally along the central and western reaches of the Canadian River, is the westerly-dipping Quartermaster Formation of Permian age. It is overlain by the Dockum Group of Triassic age.

Throughout most of the basin, the Permian and the Triassic sediments are covered with river-deposited sand, clay, silt, and gravel of the Tertiary age Ogallala Formation. The caprock is covered with wind-blown sand and sand dunes of Quaternary age. Throughout the basin, alluvium of Recent age occurs along streams and caps some of the highlands (Kunze and Lee, 1968).

Permian rocks, the oldest rocks exposed in the Canadian River basin, crop out in the canyon of the Canadian River in western Oldham County, Potter County, southeastern Moore County, and Hutchinson County. Rocks of Cretaceous age, overlain by the Ogallala Formation, extend over an area of about 150 square miles in the northwestern corner of Dallam County. Water in these permeable Cretaceous beds occurs under artesian conditions (TWDB, 1977).

The geology of the Canadian River basin is shown in Figure 3-2.

3.1.3 RIVER BASINS

The Dalhart basin is drained by the tributaries of the Canadian and the North Canadian Rivers. The drainage basins of these rivers are shown in Figure 3-3.

The Canadian River starts in northeastern New Mexico, flows easterly across the Texas Panhandle, and merges with the Arkansas River in Oklahoma. It has an overall length in Texas of about 180 miles. The total basin drainage in Texas is about 12,700 square miles, of which about 8200 square miles is considered to be contributing and about 4500 square miles probably noncontributing to the flows of the Canadian and the North Canadian Rivers (TWDB, 1977).

The Dalhart basin is drained by the headwaters of Coldwater, Garrizo, Perico, Punta de Agua, and Rita Blanca Creeks (Gould, 1907).

Coldwater Creek flows from New Mexico into Texas, passing across the northern part of Dallam and Sherman Counties in a meandering valley 50 feet deep and 0.25 mile wide. For the greater part of its course, it is merely a dry sand bed. In two places Coldwater Creek has cut through the Tertiary deposits into the Cretaceous rocks below. It is here that the springs known as Buffalo and Agua Fria Springs emerge. Coldwater Creek drains into the North Canadian River.

Perico and Garrizo Creeks rise among volcanic peaks on the High Plains of northeastern New Mexico, flow southeastward across Dallam County, and unite near the town of Dalhart to form Rita Blanca Creek, a tributary of the Canadian River.

Both Perico and Garrizo Creeks are shallow sand draws and rarely contain water. (Perico Creek becomes West Rita Blanca at the New Mexico/Texas border.)

Rita Blanca Creek flows southward across Hartley County into the Canadian River. Its valley averages 75 feet in depth and a mile in width. For the greater part of its course, it is merely a dry sand bed, but 15 miles above its mouth the stream cuts through the Tertiary rocks and exposes the underlying red beds. The springs that emerge here furnish sufficient water to produce a running stream below this point for most of the year.

Punta De Agua Creek flows eastward from New Mexico and empties into Rita Blanca Creek in the southern part of Hartley County. It is a dry sand bed for most of the year.

3.1.4 SPRINGS

The springs in the western part of the Texas Panhandle may be classed under three general headings according to the geologic formation from which they are derived: Red-bed springs, Cretaceous springs, and Tertiary springs.

Red-bed springs are generally found in the valleys of the larger streams. Springs from both Permian and Triassic red beds are found in the valley of the Canadian River. Some of the springs are strong; some are only seeps. Their water quality depends on the amount of mineral salts contained in the rocks from which the springs issue.

Cretaceous springs occur only in a limited area in the extreme northwest corner of Texas. There are only two springs worthy of note: Buffalo and Agua Fria Springs.

Buffalo Springs are located in Dallam County at the point where the two branches of Coldwater Creek unite. The stream has cut through the Tertiary deposits, exposing the Cretaceous rocks. The water from the springs forms a stream that flows at approximately 5 feet per second (Gould, 1907; Brune, 1975).

Agua Fria Springs are located in Dallam County, 10 miles west of the Sherman County line, in the valley of Coldwater Creek. The creek has cut into the Cretaceous sandstone and clays to a depth of 35 feet (Gould, 1907).

Tertiary springs occur throughout the Texas Panhandle in stream valleys and at the edge of the High Plains. Practically every stream that enters the Canadian River in the Texas portion of the basin is fed by Tertiary springs. In the Dalhart basin, Rita Blanca Creek is fed by a number of strong Tertiary springs (Gould, 1907; Brune, 1975).

3.1.5 DRAINAGE

The Canadian River basin has two very different drainage patterns. In the Plains area, where there is no well-developed drainage, surface runoff collects in numerous circular depressions called playas. Almost all of this water evaporates, but some infiltrates into the soil and reaches the water table. These depressions vary in depth from a few feet to as much as 70 feet and range from several hundred feet to several miles in diameter. Many of the larger ones have drainage basins, some of which are several square miles in area (Gould, 1907; U.S. Congress, 1950).

A few meandering shallow draws, such as those that form the upper reaches of Coldwater and Rita Blanca Creeks, traverse the Plains. Most of the area, however, is devoid of stream channels (Gould, 1907; U.S. Congress, 1950).

In the area of the Canadian River "Breaks," tributary streams have dissected the Ogallala Formation to form deep and narrow canyons. The slope of most of the tributaries of the Canadian and the North Canadian Rivers is usually very steep, and surface runoff is quite rapid.

3.1.6 STREAMFLOW

In their upper reaches across the northern High Plains, the headwaters of the streams draining the Dalhart basin are little more than dry channels that often flow only during periods of heavy precipitation. Streamflow in general is characterized by very short periods of high to extremely high flow followed by long periods of very low or no flow (Kunze and Lee, 1968).

The locations of streamflow-gaging and water-quality stations are shown in Figure 3-4, and gaging data are presented in Table 3-1. The average, maximum, and minimum discharges are shown in Table 3-2. The mean monthly discharges are given in Table 3-3. The data show that the flow is low, the streams are often dry or near dry, and the discharge varies over a wide range (USGS, 1978, 1979a).

Large floods are rare in the Canadian River basin. The low frequency of large-scale flooding is attributable mainly to two factors: (1) the low annual precipitation and (2) the generally flat terrain and the numerous playa lakes, which prevent drainage to stream channels. The floods that do occur are generally characterized by rapid rise and fall and high flow velocities. Some flooding may result from the ponding of water in the playa lakes. Precipitation occurs most often in the form of severe thunderstorms that produce rapid runoff. These storms normally come during the summer or early fall (TWDB, 1977).

Three major floods were experienced in the Canadian River in Texas during the period of record. They occurred in 1904, 1914, and 1941. They were caused by intense precipitation in the New Mexico portion of the basin, with minor to moderate rains in the balance of the drainage area in 1904 and 1941. In 1914, the area of intense precipitation extended into the western Panhandle (TWDB, 1966, 1977).

The maximum discharges in the Canadian River during the 26-year period 1939-1964 were 135,000 cubic feet per second, recorded on July 25, 1941, at the gaging station near Amarillo, and 122,000 cubic feet per second, recorded on September 23, 1941, at the gaging station at Canadian (TWDB, 1966).

The U.S. Geological Survey has prepared maps of flood-prone areas for selected portions of the Texas Panhandle. These maps show the area subject to flooding by the 100-year storm. As would be expected, most of the playa lakes are flooded under these conditions. The major stream channels that are subject to flooding are shown in Figure 3-5 (USGS, 1979b).

Because of the limited urbanization of the Canadian River basin, flood damage in urban areas has not been significant. Lake Meredith is the only major flood-control reservoir in the basin, with 543,200 acre-feet of flood-control storage.

3.1.7 RESERVOIRS AND LAKES

Groundwater is the principal source of water in the Canadian River basin. There are only two major reservoirs with storage capacities of more than 5000 acre-feet in the Texas portion of the Canadian River basin (TNRIS, 1979). (See Figure 3-4.) The larger of these is Lake Meredith, constructed by the U.S. Bureau of Reclamation on the Canadian River about 8 miles northwest of Borger in Hutchinson County. It has a total capacity of 1,407,600 acre-feet and a surface area of 21,693 acres. The drainage area for Lake Meredith is about 20,220 square miles, of which 4172 square miles are probably noncontributing. The reservoir, owned and operated by the Canadian River Municipal Authority, is used for flood control, recreation, and to supplement the groundwater supplies of a number of cities in the general area of the reservoir.

Lake Rita Blanca, the other large reservoir, is on Rita Blanca Creek in Hartley County. The reservoir, completed in 1939, is operated by Dallam and Hartley Counties for recreational purposes. It has a capacity of 12,100 acre-feet and a surface area of 524 acres (Dowell and Breeding, 1967; TWDB, 1974).

Several minor dams are located in or near the Dalhart basin.

The Dalhart basin contains numerous playa lakes (Figure 3-6). The majority of these are temporary water bodies depending on seasonal rainfall for annual filling. Permanent playa lakes are shown in Figure 3-6. Most playa lakes were formed by wind action and are round to oval in shape (Bell and Sechrist, 1972). They are very shallow when filled; those 1 foot deep are usually 3 to 5 acres in size; those that are 2 feet deep cover 10 to 15 acres; those that are 3 feet deep cover 20 to 30 acres; and those that are 4 feet deep cover up to 160 acres (Ward and Huddleston, 1972). In the natural state, playa lakes represent important "watering holes" for wildlife. Currently, many are under cultivation; the farmers gamble on a relatively dry year that will allow a harvest without flooding. Playa lake waters are also being used and under further consideration for irrigation and for injection into the underlying water table. They also are important for watering stock and some have been modified for multiple use or mosquito control.

Since playa lakes have no drainage and little percolation potential, most of the water loss is due to evaporation. They are typically filled by May and June rainfall, and dry again by October or November. Waters tend to be turbid and hard, becoming progressively more mineralized as evaporation decreases levels until the lakes approach dryness, at which time soluble concentrations decrease (Sublette and Sublette, 1967).

3.2 WATER QUALITY

The quality of water in the Canadian River basin is generally poor because of the natural characteristics of the basin. Silt and salt are the two pollutants that create the basin's most critical water problems and prevent or hinder many beneficial uses (USDI, 1967).

As it enters Texas from New Mexico, the Canadian River is moderately saline during periods of low flow. During periods of low flow, water in the main stem of the river generally has dissolved-solids concentrations ranging from 2000 to 3000 milligrams per liter. In contrast, runoff from storms generally has a dissolved-solids content of less than 300 milligrams per liter. The discharge-weighted average dissolved-solids concentration in the river at the New Mexico-Texas state line generally ranges from 500 to 1000 milligrams per liter.

Overall, the quality of water improves somewhat as the Canadian River traverses Texas; however, the discharge-weighted average dissolved-solids concentrations remain between 500 and 1000 milligrams per liter west of Potter County. The influx into tributary streams of good-quality water from Ogallala and Dockum rocks is not sufficient to dilute natural saline inflows from Permian rocks, inflows of oil-field brines, and manufacturing and municipal return flows, all of which locally degrade the quality of water. During extreme low flow, most of the surface water derived from the Ogallala Formation and the Dockum Group is lost to evaporation, and the streamflow is probably sustained almost entirely by water from Permian rocks. At such times, the dissolved-solids concentration is greatly increased, and the water has higher equivalent amounts of sodium, chloride, and sulfate than of other constituents (TWDB, 1966, 1977; Kunze and Lee, 1968).

In recent years, water stored in Lake Meredith has contained, per liter, 300 to 340 milligrams of chloride, 280 to 320 milligrams of sulfate, and 1000 to 1150 milligrams of total dissolved solids.

In contrast, many of the tributaries of the Canadian River, including the Rita Blanca and Punta de Agua creeks, have excellent water quality, with dissolved-solids concentrations commonly below 500 milligrams per liter (TWDB, 1977).

The locations of water-quality stations are shown in Figure 3-4. Gage data are shown in Table 3-2, and important water-quality parameters are presented in Table 3-4 (USGS, 1979c). These water quality data can be compared with the Texas Water Quality Standards for the Canadian River basin, shown in Table 3-5.

3.3 IMPORTANT SPECIES AND THEIR HABITATS

The important species that will be emphasized in the following sections will be those that fit the following categories (adapted from USNRC, 1979; USEPA, 1977):

- Species that are of commercial or recreational value
- Species that are threatened or endangered

- Species that can affect the well-being of species in the above two categories
- Species that are critical to the structure and function of the ecological system
- Species that are capable of becoming localized nuisance species.

The important species considered in the following discussion of aquatic ecology are mostly fish (Table 3-6). There are no other aquatic species that are considered to be threatened or endangered. Mosquitoes are also considered due to their importance as disease vectors. The major aquatic habitats that support a fishery in the Dalhart basin are shown in Figure 3-7.

In the following sections, native stream fishery resources of the Dalhart basin study area are described in relation to the Stream Evaluation Maps for the State of Texas (USDI, 1978). These maps provide an appraisal of the relative value of stream fishery resources in Texas based on data and "professional opinions" available as of fall 1978. A standard rating system was used to evaluate fishery habitat of permanent streams, streams considered necessary for the continued maintenance of a highly valued fishery, and those streams or stream segments protected under the Wild and Scenic Rivers Act (Appendix A). Four criteria were evaluated: (1) the occurrence of endangered species; (2) the occurrence of threatened species; (3) stream use by species of high interest in the state; and (4) restoration, mitigation, or reclamation potential.

The principal drainage features of the basin providing aquatic habitats are a short reach of the Canadian River and a tributary, Punta de Agua Creek, near Boys Ranch, Oldham County (Figure 3-7). Punta de Agua Creek, which is confluent with the Canadian River west of Boys Ranch, receives drainage from Garrizo and Rita Blanca Creeks of Dallam and Hartley Counties. Lake Rita Blanca in Hartley County near Dalhart, Texas, is the only water body of the study area capable of sustaining a significant recreational fishery (J. Kraai, personal communication, 1979). Playa lakes, which are found throughout the basin but are concentrated in the eastern portion, provide seasonal habitats for aquatic invertebrates, plants, and amphibians (Figure 3-6).

The Canadian River above Lake Meredith, including the reach located within the Dalhart basin, has been classified by the U.S. Fish and Wildlife Service (USDI, 1978) as a "highest-valued fishery resource" that supports self-sustaining populations of native fish species. Additionally, the river is valued principally for the unique aesthetic qualities and scenic beauty of the Canadian River Breaks. No identifiable alternative resources or acceptable options for reclamation or mitigation activities are presently available to compensate for any loss of this habitat. Where the Canadian River crosses through the Dalhart basin in Oldham County there are a few deep areas where bank fishing for blue catfish and channel catfish is possible. An abundance of baitfish has been reported by Crabtree (1969).

Two streams of the Dalhart basin, Punta de Agua Creek and the Beaver River, are classified as "high-priority fishery resources." Both streams support stream fishes such as carp, river carpsucker, bullhead, sunfish, minnows, and some largemouth bass and channel catfish. Both streams are valued locally for their aesthetic qualities. Because of their intermittent flow characteristics, Garrizo and Rita Blanca Creeks provide a limited fishery resource, although native species found in Punta de Agua Creek occasionally use these tributary streams. Stream fishing apparently has little importance in the basin; the streams of Dallam and Hartley Counties were not mentioned by the Texas Parks and Wildlife Department in a survey of public stream access and facilities (Crabtree, 1969).

Lake Rita Blanca is owned and operated jointly by Dallam and Hartley counties (Kraai and Prentice, 1974a). Constructed in 1939 for flood-control purposes, the lake drains a watershed of 690 square miles along Rita Blanca and Garrizo creeks. The lake covers 524 acres at maximum pool elevation, but normally occupies 200 to 300 acres (Clarke 1973). Water depth, approximately 7 feet on the average, does not exceed 11 feet and the lake is heavily silted and nearly devoid of aquatic vegetation or other cover. Presently the lake is used for recreational activities such as fishing, boating, waterskiing, picnics, and family outings (J. Kraai, personal communication, 1979).

Before 1973, Lake Rita Blanca had exhibited a long history of recurring water-quality problems as a result of runoff from feedlot operations, and extensive fish kills were frequent (Kraai and Prentice, 1974a). Although runoff has since been controlled, the lake's sediments and water quality reflect an accumulation of animal wastes, and the fish population is characterized by resistant species such as goldfish, carp, and bullheads.

Due to its significance as the only locally available recreational fishery resource near Dalhart (Lake Meredith, located in neighboring Moore, Potter, and Hutchinson counties, is approximately 60 miles away), TPWD fisheries biologists and the sponsoring counties have maintained an experimental fisheries management program on Lake Rita Blanca since the mid-fifties. Management practices during this period have included the stocking of predatory gamefish such as largemouth bass, crappie, and flathead and channel catfish; water-level stabilization using groundwater resources; and habitat enhancement through emplacement of brush covers and artificial spawning structures (Peters, 1963). Total-kill renovation with rotenone was attempted in 1972 to rid Lake Rita Blanca of problematic goldfish, carp, black bullhead, golden shiner, and stunted white crappie populations. After the moderately successful chemical renovation in 1972, the lake was stocked with channel and blue catfish, rainbow and brown trout (an experimental program, since discontinued), and with largemouth bass and several forage species (Kraai and Prentice, 1974b). Recent surveys conducted by TPWD personnel indicate, however, that the lake is again over-populated by goldfish, black bullhead, gizzard shad, and golden shiner. A list of fish species present in Lake Rita Blanca is given in Table 3-7.

Lake Meredith, located outside the Dalhart basin in neighboring Moore, Hutchinson, and Potter counties, is the principal recreational fishery resource in the Texas Panhandle (J. Kraai, personal communication, 1979). This impoundment is a multi-purpose reservoir owned by the Canadian River Municipal and Industrial Water Authority and administered by the National Park Service. The lake is impounded in a deep canyon of the Canadian River near Borger and Fritch, Texas, and exhibits an irregular shoreline with many side canyons. At maximum pool elevation the reservoir covers over 16,500 acres and has a depth of more than 120 feet (Crabtree and Winkley, 1968).

Walleye were introduced in Lake Meredith in 1965 and have since become the most popular game species in the lake (Crabtree, 1968). Currently, Lake Meredith walleye are being used as brood stock for stocking programs in other Texas impoundments, some of which occur in the study area. Other important recreational species include largemouth bass, channel catfish, blue catfish, flathead catfish, white bass, and white crappie. The walleye, channel catfish, white bass, and white crappie populations have increased in recent years and currently provide good fishing (J. Kraai, personal communication, 1979). Brown trout and rainbow trout were stocked in the lake in May 1973 but did not become established; further stocking efforts were discontinued (Kraai and Prentice, 1974a). A list of species found in Lake Meredith is presented in Table 3-8.

In the playa lakes of eastern New Mexico and Texas, midge larvae and oligochaetes dominate the benthic fauna during periods of water retention (Sublette and Sublette, 1967). Other fauna typical of the temporary playa waters include fairy shrimp (Anostraca), tadpole shrimp (Notostraca), clam shrimp (Conchostraca), and tadpoles of various amphibians. The authors infer the phenology, or seasonal succession of Texas playa lake fauna, to be phyllopods/amphibians-phyllopods/amphibians/insects-restricted insects (midges)/oligochaetes; or restricted insects (midges)/oligochaetes/leeches.

Of the aquatic Insecta, the Chironomidae, Culicidae, and Ceratopogonidae are the three most conspicuous dipteran families in the playa lakes (Sublette and Sublette, 1967). The authors recorded 17 species or subspecies of mosquitoes (Culicidae) from the Llano Estacado. Of these, Culex tarsalis is known to be the major vector of "encephalitides." Western encephalitis and St. Louis encephalitis viruses are the only two arthropod-borne viruses known to cause human illness in the High Plains (Grubb et al., 1968).

One successful means of controlling the vector species, Culex tarsalis, is by physically modifying the playa lake. Ward and Huddleston (1972) describe modifications that resulted in excellent control of playa-lake mosquito populations.

3.4 IMPORTANT SPECIES

Except for limited bait-minnow seining operations concentrated near Lake Rita Blanca, there is no commercial fishery in the Dalhart basin. Minnows commonly taken in the bait-fishery include fathead minnow, killifishes, and several native shiners (J. Kraai, personal communication, 1979). As part of the undesirable-species management program in Lake Rita Blanca during the early 1960s, commercial bait dealers were permitted to exploit an overpopulation of golden shiners (Dodgen, 1960).

Gamefish species sought by recreational fishermen in public waters of the Dalhart basin include channel, blue, and flathead catfish, largemouth bass, crappie, and sunfishes, and, to a lesser extent, black bullheads. Walleye, white bass, crappie, blue, channel and flathead catfish, and largemouth bass are the principal gamefish sought by Lake Meredith fishermen. Gamefish species stocked in area impoundments were selected on the basis of their ability to exert predator pressure on undesirable fish populations as well as for their relative merits as desirable and catchable sportfish.

Native stream fishes of the Dalhart basin include largemouth bass, sunfishes, channel catfish, black bullhead, carpsucker, plains minnow, speckled and flathead chubs, golden, red, and Arkansas River shiners, fathead minnow, plains killifish, and mosquitofish.

3.5 SPECIAL STATUS SPECIES

The Endangered Species Act of 1973 has engendered a great deal of research, and as a result, numerous publications concerning special status species are now available. In one of the earliest studies, R. R. Miller (1972) categorized special status fish species as endangered, rare, depleted, or indeterminate. He listed 15 species from Texas as rare and 2 of these as rare and endangered. However, none of these species are recorded from the Plains area (Panhandle) of Texas (Hubbs, 1976). Hubbs, in his checklist of Texas Freshwater Fishes, divides the State of Texas into eight game areas. He recorded 57 fish species from Area 7 (which includes the Dalhart basin). These species (Table 3-6) were used to compare with recent special status species publications including TPWD (1977a, b); Longley et al. (1979); Miller (1972); Deacon et al. (1979); and USDI (1979).

The shovelnose sturgeon, Scaphirhynchus platorynchus, listed as depleted by Hubbs (1976) is considered endangered, by the TPWD (1977a) and threatened, by Longley et al. (1979). It does not, however, occur within the Dalhart basin and its known range in Texas is limited to the Red River below Lake Texoma. Reservoir construction and water diversion have contributed to the demise of this species.

Based on available literature and personal communications with local experts (C. Hubbs and F. Potter, in particular), there are no known endangered or threatened fish or non-fish aquatic species in the Dalhart basin.

3.6 EXISTING STRESSES AND SENSITIVITY

Environmental conditions resulting in stress to aquatic communities of the Dalhart basin study area derive principally from a lack of stabilized flow in area streams. Although area streams carry much water and are subject to flooding following heavy rains, for much of the year many exhibit braided channels with shallow pools connected by rivulets of flowing water. Streamflow in some areas is frequently reduced to underground flow. Consequently, fish can occur only in the most permanent channels and pools.

In the past, contaminated runoff from cattle feedlot operations has contributed to degradation of aquatic habitats in the Dalhart basin and, before 1973, was the principal cause of fish kills in Lake Rita Blanca. Although the runoff problem has been corrected, the lake continues to exhibit water-quality characteristics influenced by a long-term buildup of animal wastes.

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Table 3-1. Streamflow gaging and water-quality stations in the Canadian River basin

Station number	River	Location	River (mi)	Drainage area (mi^2)	Period of record: Discharge	Period of record: Water quality
07-2268-00	Ute Reservoir (Canadian River)	Near Logan, New Mexico Quay County Lat. 35° 20' 35" Long. 103° 26' 37"	673.1	11,140[a] (1,110)	1963-1977[b]	1963-1977
07-2270-00	Canadian River	At Logan, New Mexico Quay County Lat. 35° 21' 25" Long. 103° 25' 03"	672.0	11,141 (1,140)	1904-1905, 1912-1913, 1927-1977[c]	
07-2271-00	Revuelto Creek	Near Logan, New Mexico Quay County Lat. 35° 20' 28" Long. 103° 23' 40"	2.3	786	1959-1977	1959-1977
07-2271-40	Canadian River	At New Mexico-Texas State line Quay County Lat. 35° 23' 35" Long. 103° 02' 30"		12,616	1969-1973, 1975-1977[d]	1969-1973, 1975-1977
07-2274-70	Canadian River	At Tascosa, Texas Oldham County Lat. 35° 31' 08" Long. 102° 15' 35"		18,536 (3,823)	1968-1977[e]	1968-1977
07-2275-00	Canadian River	Near Amarillo, Texas Potter County Lat. 35° 28' 13" Long. 101° 52' 45"	537.7	19,445 (4,069)	1924-1925, 1938-1977	1949-1977

Note: See footnotes at end of table.

Table 3-1. Streamflow gaging and water-quality stations in the Canadian River basin (continued)

Station number	River	Location	River (mi)	Drainage area (mi^2)	Period of record: Discharge	Period of record: Water quality
07-2279-00	Lake Meredith (Canadian River)	Near Sanford, Texas Hutchinson County Lat. 35° 42' 38" Long. 101° 33' 03"	508.5	20,220 (4,172)	1964-1977[b]	1968-1977
07-2279-20	Dixon Creek	Near Borger, Texas Hutchinson County Lat. 35° 39' 53" Long. 101° 21' 02"	7.6	134	1974-1977	
07-2280-00	Canadian River	Near Canadian, Texas Hemphill County Lat. 35° 56' 06" Long. 100° 22' 13"	433.9	22,866 (4,688)	1924-1925, 1938-1977	1968-1977
07-2325-00	Beaver River (Headwater of North Canadian River)	Near Guymon, Oklahoma Texas County Lat. 36° 43' 24" Long. 101° 29' 30"	650.7	2,139 (96.4)	1937-1977	1952-1963, 1968-1977
07-2335-00	Palo Duro Creek	Near Spearman, Texas Hansford County Lat. 36° 12' 08" Long. 101° 18' 20"		960	1945-1977	1967-1977

[a]Drainage area in parentheses is noncontributing.
[b]Reservoir contents.
[c]Flow regulated by Conchas Dam (1938) and Ute Dam (1962).
[d]Water-discharge measurements made when water-quality samples collected.
[e]Discontinued.

Table 3-2. Discharge data for streams in the Canadian River basin

Station number	River	Location	Period of record	Discharge (cfs)		
				Average	Maximum	Minimum
07-2270-00	Canadian River	At Logan, New Mexico	1909, 1912-1913, 1937-1938[a] 1939-1962[b] 1963-1977	392 257 32.4	219,000 (Sept. 22, 1941)	No flow at times prior to completion of Ute Dam
07-2271-00	Revuelto Creek	Near Logan, New Mexico	1959-1977	48.2	26,700 (July 9, 1960)	No flow at times most years
07-2274-70	Canadian River	At Tascosa, Texas	1968-1977	168	27,500 (July 27, 1971)	No flow at times each year
07-2275-00	Canadian River	Near Amarillo, Texas	1925, 1939-1977	354	135,000 (July 25, 1941)	No flow 1/24 - 12/25 and on Aug. 7, 18, 1940
07-2279-20	Dixon Creek	Near Borger, Texas	1974-1977		3,640 (May 26, 1977)	No flow for many days each year
07-2280-00	Canadian River	Near Canadian, Texas	1939-1964[c] 1965-1977	549 90.9	122,000 (Sept. 23, 1941)	No flow at times most years
07-2325-00	Beaver River (headwater of North Canadian River	Near Guymon, Oklahoma	1937-1977	25.4	55,400 (June 15, 1964)	No flow at times most years
07-2335-00	Palo Duro Creek	Near Spearman, Texas	1945-1977	19.2	21,200 (Oct. 7, 1946)	No flow at times most years

[a]Prior to completion of Conchas Dam.
[b]Prior to completion of Ute Dam.
[c]Prior to completion of Lake Meredith.

Table 3-3. Mean monthly discharge[a]

Station number	Canadian River	Mean discharge (cfs)											
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
07-2274-70	At Tascosa, Texas	108	51.7	20.4	23.0	18.9	14.7	84.4	124	264	295	477	537
07-2275-00	Amarillo, Texas	419	74.9	55.4	58.9	50.3	46.6	235	550	626	782	629	728
07-2270-00	At Logan, New Mexico	273	37.4	24.0	31.5	26.6	21.4	164	380	583	328	362	496

[a]From USGS (1979).

Table 3-4. Water quality of the streams in the Dalhart basin[a]

	Instantaneous discharge (cfs)	Dissolved silica (mg/ℓ)	Dissolved iron (mg/ℓ)	Dissolved calcium (mg/ℓ)	Dissolved magnesium (mg/ℓ)	Dissolved sodium (mg/ℓ)	Dissolved potassium (mg/ℓ)	Bicarbonate as HCO_3 (mg/ℓ)	Carbonate as $CaCO_3$ (mg/ℓ)	Dissolved sulfate (mg/ℓ)	Dissolved chloride (mg/ℓ)	Hardness as $CaCO_3$: Calcium/magnesium (mg/ℓ)	Hardness as $CaCO_3$: Noncarbonate (mg/ℓ)	Specific conductance (micromhos)	pH	Turbidity (JTU)	Temperature (°C)	Dissolved oxygen (mg/ℓ)	BOD (5-day) (mg/ℓ)
07-2271-40 Revuelto Creek near Logan, New Mexico																			
Maximum	3,000	14	450	168	920	2,400	18	404	8	780	3,800	4,100	3,900	12,500	8.9	22,000	32.0	14.8	9.8
Minimum	1.6	3.5	0	12	4.5	83	0.5	130	0	45	36	50	0	580	7.1	2	0	5.9	0.2
Mean	75	9.3	33	101	66	1,143	7.9	269	0	386	1,711	524	315	5,792	8.1	1,045	16.9	9.4	1.4
07-2274-70 Canadian River at Toscosa, Texas																			
Maximum	1,160	32	140	150	80	949	10	452	28	720	1,800	670	450	2,332	8.1	277	33.0	13.7	16
Minimum	0.12	1.0	0	9.2	3.3	65	2.6	20	0	35	16	37	0	260	8.0	10	0	6.0	0.2
Mean	128	12	26	59	32	423	6.0	220	0	283	475	286	107	2,332	8.1	277	15.4	9.1	2.3
07-2275-00 Canadian River near Amarillo, Texas																			
Maximum	56,200	87	720	360	98	990	76	530	31	1,500	1,500	1,300	1,100	6,250	8.9	11,000	32.5	18.3	46
Minimum	0.38	.4	0	9.8	2.8	21	1.8	20	0	9.6	5.8	36	0	14	6.3	1	0	0.3	0.2
Mean	1,305	24	79	79	30	257	9.9	233	0	256	29	320	135	1,776	7.5	773	16.4	9.9	8.7

Abbreviations: JTU = Jackson turbidity unit; BOD = biological oxygen demand.

[a]USGS (1978a,b).

Table 3-5. Texas water-quality standards for the Canadian River basin, fresh and tidal waters[a]

Segment Number	Segment Description	Water uses deemed desirable: Contact recreation	Noncontact recreation	Propagation of fish and wildlife	Domestic raw water supply	Criteria: Chloride (mg/liter), average not to exceed	Sulfate (mg/liter), average not to exceed	Total dissolved solids (mg/liter), average not to exceed	Dissolved oxygen (mg/liter), not less than	pH range	Coliform: Fecal (100 ml), log. avg. not more than	Temperature (^oF)
0101	Canadian River - Oklahoma to Lake Meredith (Sanford Dam)		X	X		1,000	600	3,500	5.0	6.5-8.5	2,000	90
0102	Lake Meredith	X	X	X	X	350	350	1,250	5.0	7.0-9.0	200	85
0103	Canadian River - Lake Meredith to New Mexico		X	X		900	500	2,500	5.0	6.5-8.5	1,000	90
0104	Wolf Creek	X	X	X		300	100	1,000	5.0	6.5-8.5	200	93
0105	Rita Blanca Lake	X	X	X	X	50	40	300	5.0	6.5-9.0	200	85

[a]Bureau of National Affairs (1976).

Table 3-6. Fishes of the Texas plains (Panhandle) and their status[a]

Common name	Scientific name	Status
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	D,[a] E,[b] T[c]
Shortnose gar	*Lepisosteus platostomus*	+
Spotted gar	*Lepisosteus oculatus*	+
Longnose gar	*Lepisosteus osseus*	+
Gizzard shad	*Dorosoma cepedianum*	+
Brown trout	*Salmo trutta*	I[e]
Rainbow trout	*Salmo gairdneri*	I[e]
Northern pike	*Esox lucius*	I
Goldeye	*Hiodon alosoides*	P
Mexican tetra	*Astyanax mexicanus*	I
Carp	*Cyprinus carpio*	I
Goldfish	*Cyprinus auratus*	I
Golden shiner	*Notemigonus crysoleucas*	+
Flathead chub	*Hybopsis gracilis*	P
Speckled chub	*Hybopsis aestivalis*	+
Plains shiner	*Notropis percobromus*	+
Sharpnose shiner	*Notropis oxyrhynchus*	+
Silverband shiner	*Notropis shumardi*	+
River shiner	*Notropis blennius*	+
Chub shiner	*Notropis potteri*	+
Red River shiner	*Notropis bairdi*	+
Smalleye shiner	*Notropis buccula*	+
Arkansas River shiner	*Notropis girardi*	P
Blacktail shiner	*Notropis venustus*	+
Red shiner	*Notropis lutrensis*	+
Mimic shiner	*Notropis volucellus*	+
Ghost shiner	*Notropis buchanani*	+
Plains minnow	*Hybognathus placitus*	+
Bullhead minnow	*Pimephales vigilax*	+
Fathead minnow	*Pimephales promelas*	+
Stoneroller	*Campostoma anomalum*	+
Bigmouth buffalo	*Ictiobus cyprinellus*	+
Smallmouth buffalo	*Ictiobus bubalus*	+
River carpsucker	*Carpiodes carpio*	+
Gray redhorse	*Moxostoma congestrum*	L
Channel catfish	*Ictalurus punctatus*	+
Blue catfish	*Ictalurus furcatus*	+
Black bullhead	*Ictalurus melas*	+
Yellow bullhead	*Ictalurus natalis*	+
Flathead catfish	*Pylodictis olivaris*	+
Tadpole madtom	*Noturus gyrinus*	+
Plains killifish	*Fundulus kansae*	+
Red River pupfish	*Cyprinodon rubrofluviatilis*	+
Mosquitofish	*Gambusia affinis*	+
Mississippi silverside	*Menidia audens*	I[e]
White bass	*Morone chrysops*	+
Spotted bass	*Micropterus punctulatus*	+
Largemouth bass	*Micropterus salmoides*	+

Note: See footnotes at end of table.

Table 3-6. Fishes of the Texas plains (Panhandle) and their status[a] (continued)

Common name	Scientific name	Status
Warmouth	*Lepomis gulosus*	+
Green sunfish	*Lepomis cyanellus*	+
Spotted sunfish	*Lepomis punctatus*	+
Redear sunfish	*Lepomis microlophus*	+
Bluegill	*Lepomis macrochirus*	+
Orangespotted sunfish	*Lepomis humilis*	+
Longear sunfish	*Lepomis megalotis*	+
White crappie	*Pomoxis annularis*	+
Walleye	*Stizostedion vitreum*	I
Logperch	*Percina caprodes*	+
Orangethroat darter	*Etheostoma spectabile*	+
Freshwater drum	*Aplodinotus grunniens*	+

Abbreviations:

D = Depleted.

I = Introduced (i.e., not native to project study boundaries).

P = Peripheral (i.e., species with limited Texas distribution but may be abundant elsewhere).

L = Limited (i.e., species with reasonably broad distribution but limited to a few areas).

+ = Present in the plains (Panhandle) of Texas.

Note: According to TPWD (1977b), there are no Protected non-game species (Threatened) reported within the project study boundaries.

[a]From Hubbs (1976).

[b]From TPWD (1977a), E = Endangered. One was listed in the Plains (Panhandle) area but does not occur within the project study boundaries.

[c]From Longley et al. (1979).

[e]Not reported in Hubbs (1976), but reported in TPWD reports.

Table 3-7. Fish species occurring in Lake Rita Blanca, Texas[a]

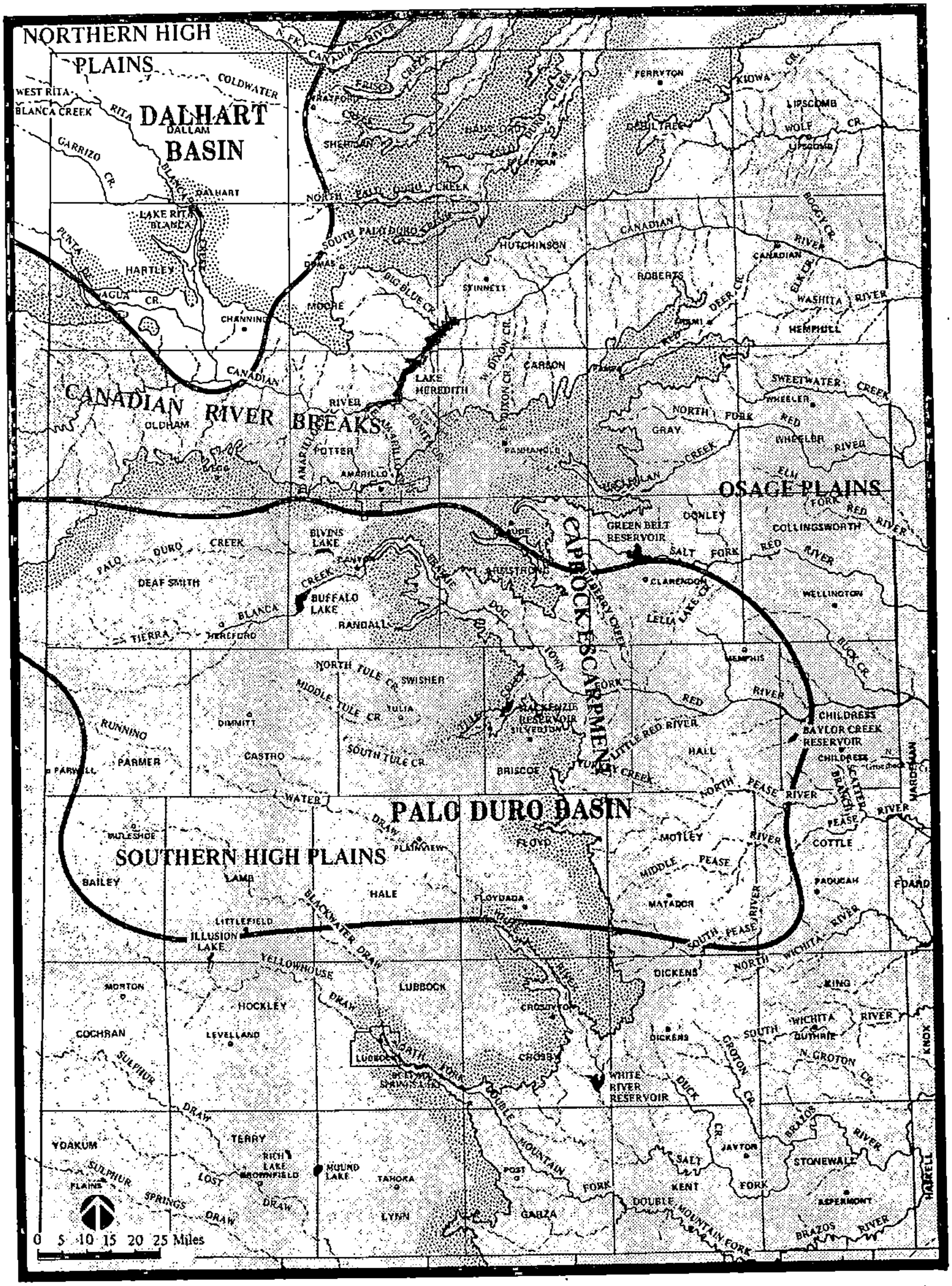
Common name	Scientific name
Goldfish	*Carassius auratus*
Golden shiner	*Notemigonus crysoleucas*
Fathead minnow	*Pimephales promelas*
Mississippi silversides	*Menidia audens*
Bullhead minnow	*Pimephales vigilax*
Carp	*Cyprinus carpio*
Orangespotted sunfish	*Lepomis humilis*
Largemouth bass	*Micropterus salmoides*
Channel catfish	*Ictalurus punctatus*
Blue catfish	*Ictalurus furcatus*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Rainbow trout	*Salmo gairdneri*
White crappie	*Pomoxis annularis*
White bass	*Morone chrysops*

[a]From Clarke (1973), and Kraai and Prentice (1974a,b).

Table 3-8. Fish species occurring in Lake Meredith, Texas[a]

Common name	Scientific name
Gizzard shad	*Dorosoma cepedianum*
Carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Red shiner	*Notropis lutrensis*
Fathead minnow	*Pimephales promelas*
Bullhead minnow	*Pimephales vigilax*
River carpsucker	*Carpiodies carpio*
Golden redhorse	*Moxostoma erythrurum*
Blue catfish	*Ictalurus furcatus*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Plains killifish	*Fundulus kansae*
Mosquitofish	*Gambusia affinis*
White bass	*Morone chrysops*
Green sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Longear sunfish	*Lepomis megalotis*
Redear sunfish	*Lepomis microlophus*
Redear x green sunfish	*Lepomis* sp.
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Logperch	*Purcina caprodes*
Walleye	*Stizostedion vitreum vitreum*
Mississippi silverside	*Menidia audens*

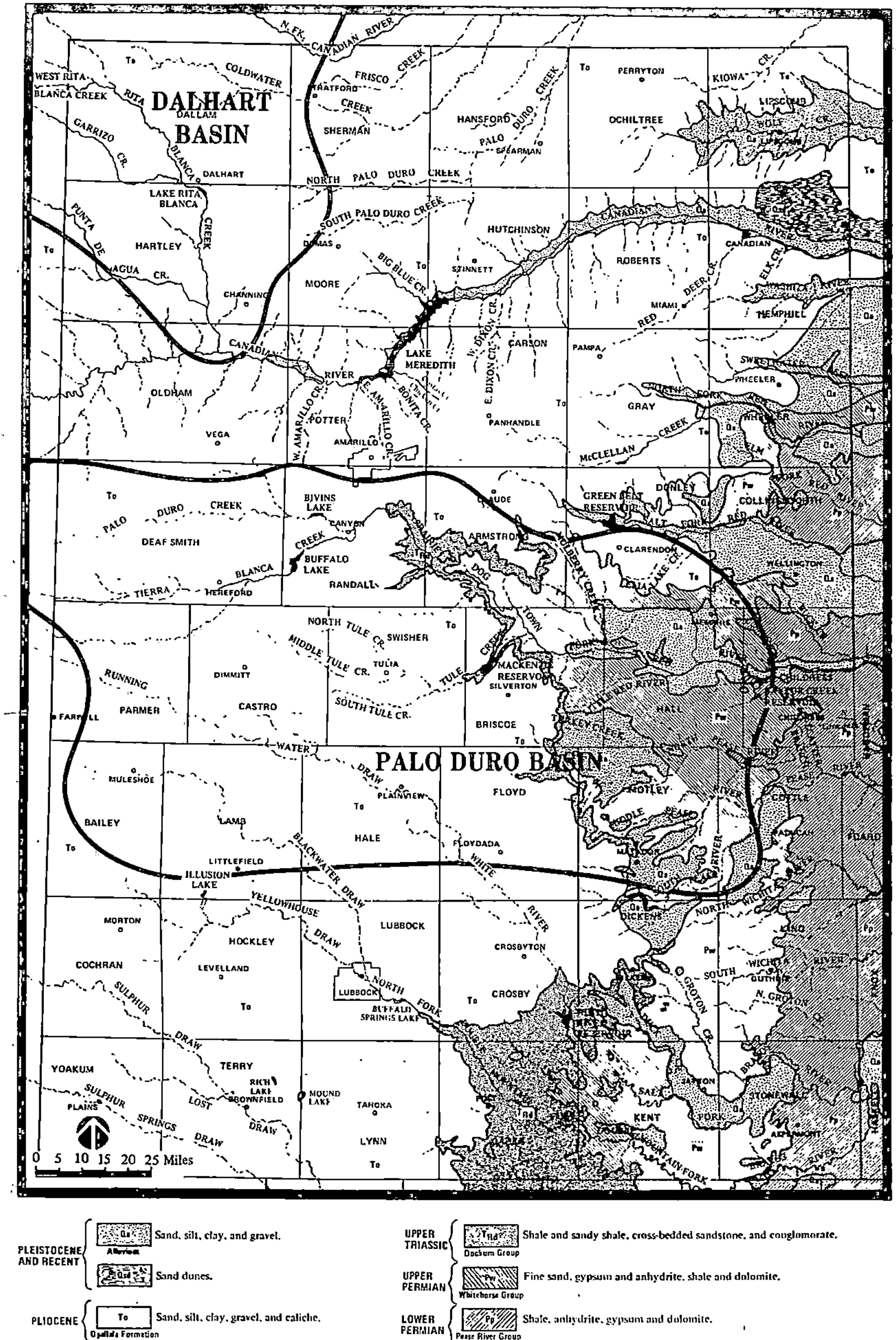
[a]From Kraai and Prentice (1974a).



Escarpment of high plains

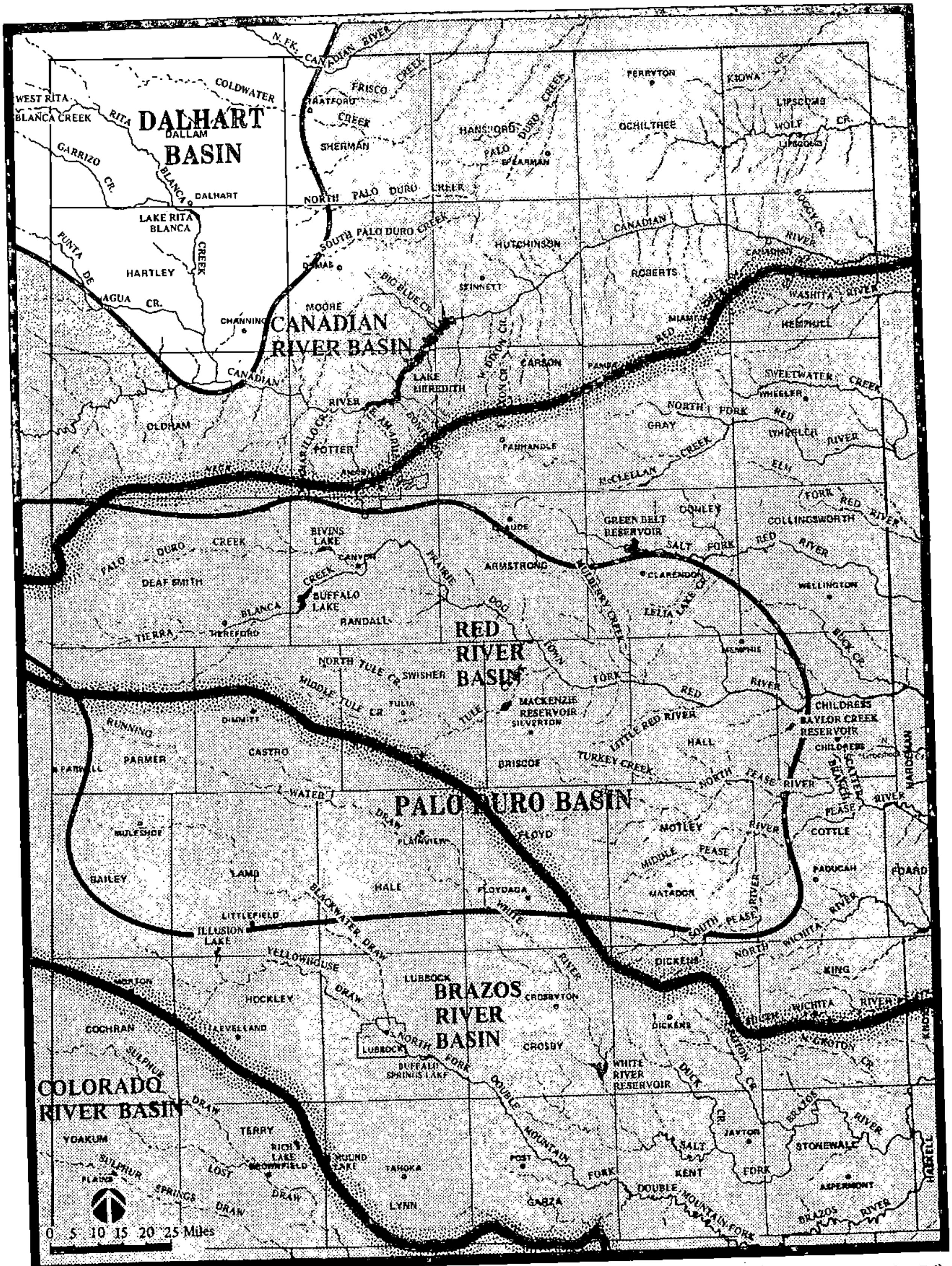
Sources: Adapted from TBWE (1960); Baker et al. (1963).

Figure 3-1. Physiographic sections.



Sources: Kunze and Lee (1968); Rawson (1967); Irelan and Mendieta (1967); Leifeste et al. (1971).

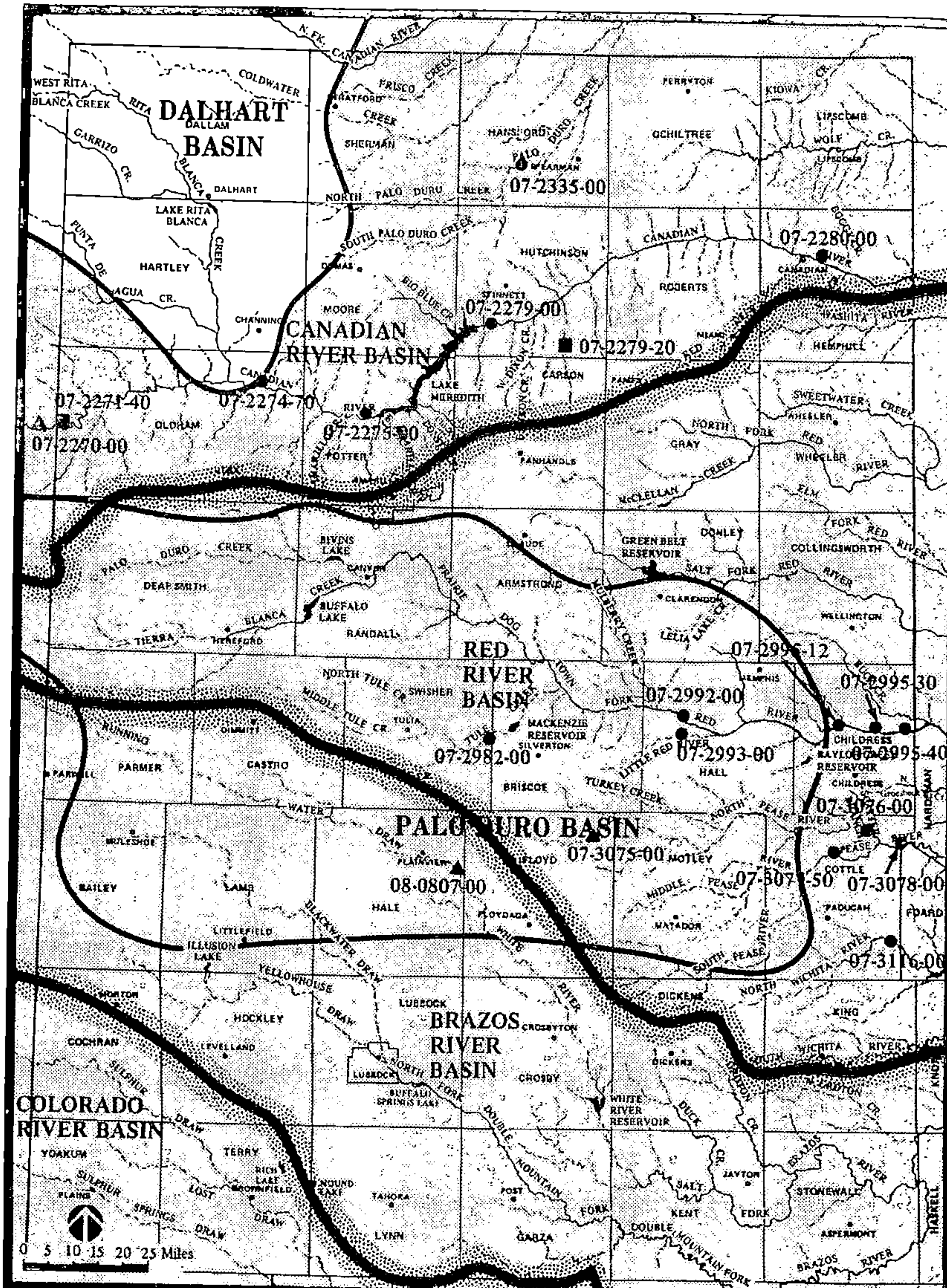
Figure 3-2. Geologic outcrops.



Source: Adapted from USGS (1976).

Major river drainage basin boundaries.

Figure 3-3. River basin boundaries.

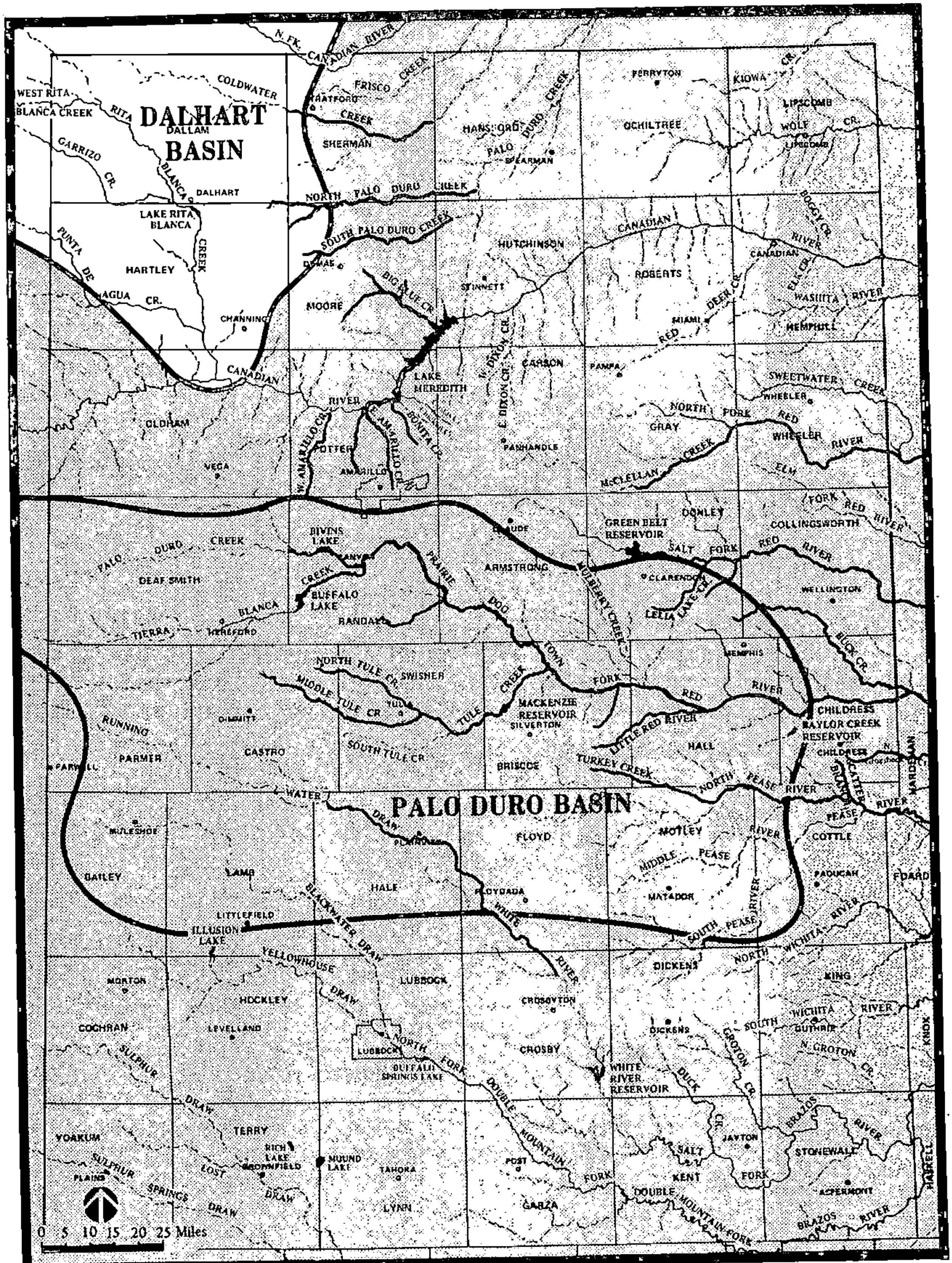


Major river drainage basin boundaries.

Sources: USGS (1978a,b)

- ● Gaging and water-quality station.
- ▲ Gaging station only.
- ■ Water-quality data only.

Figure 3–4. Locations of gaging and water-quality stations.



Source: USGS, 1979c

Figure 3-5. Flood-prone river reaches.

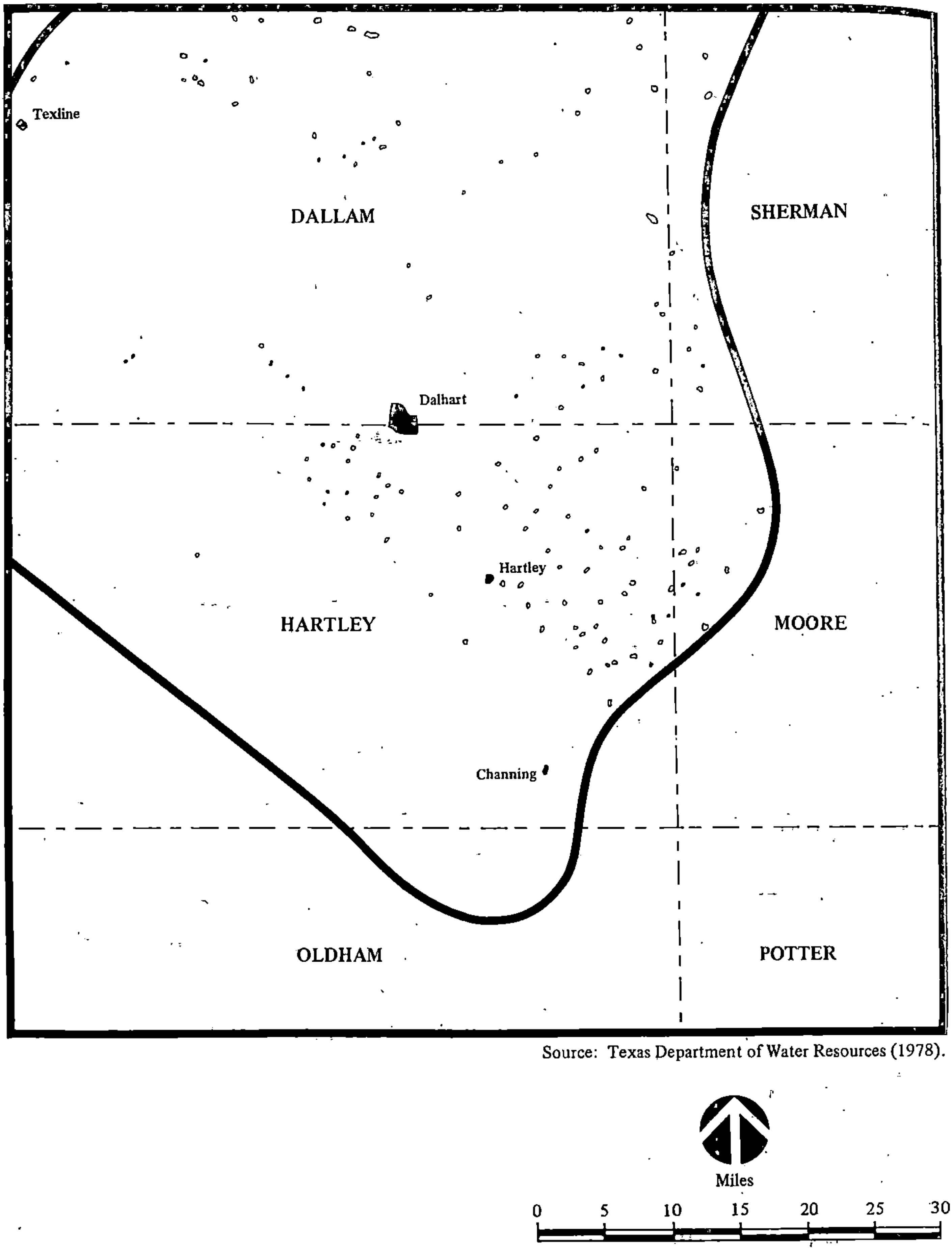
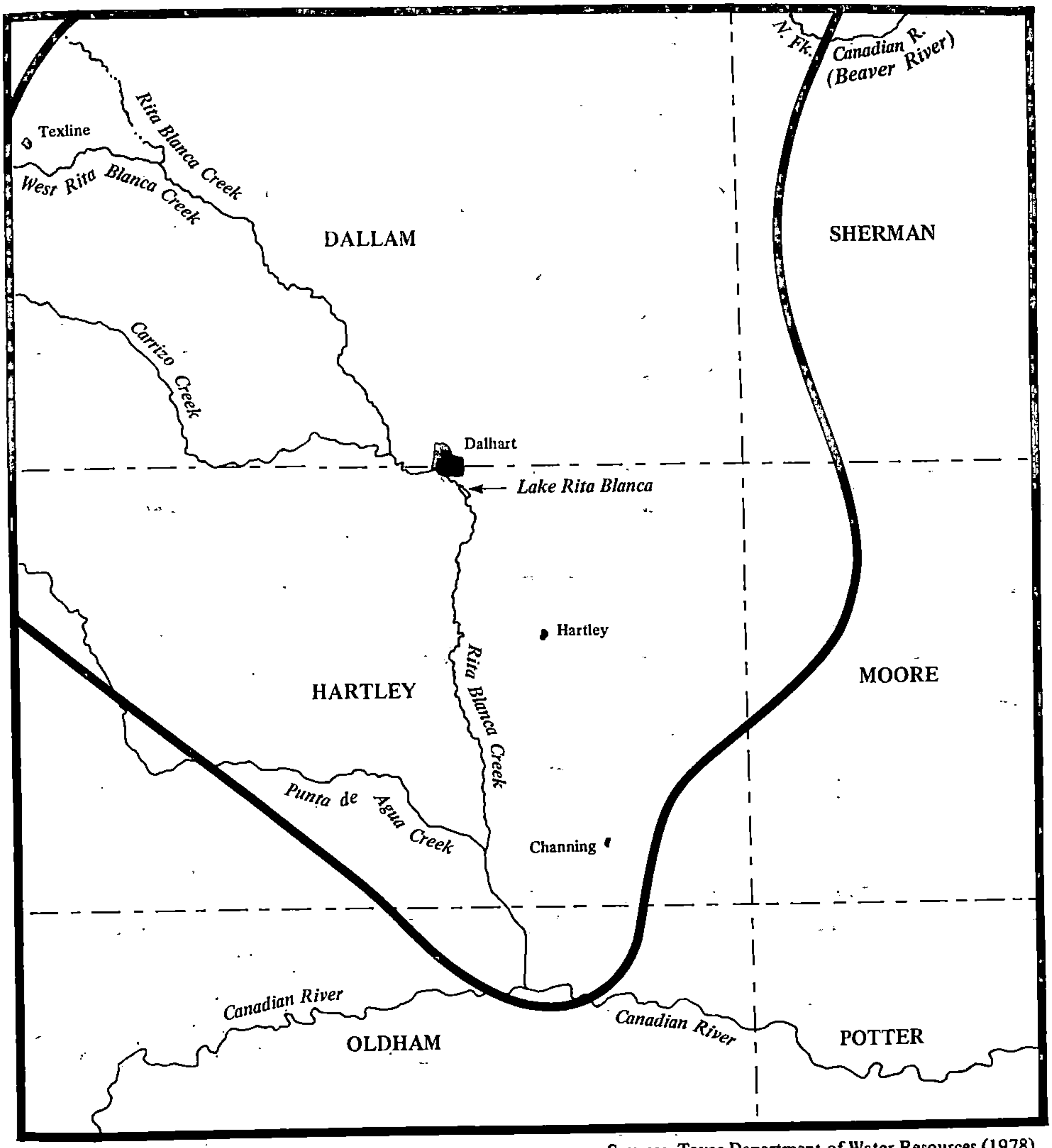


Figure 3-6. Major permanent and temporary playa lakes of the Dalhart basin.



Source: Texas Department of Water Resources (1978).

Legend:

Perennial streams

Intermittent streams

Miles

0 5 10 15 20 25 30

Figure 3-7. Major lentic and lotic aquatic habitats of the Dalhart basin.

4 Environmental Media Systems

This section outlines some aspects of the physical environment of the Dalhart basin. Geologic and hydrologic data will be provided in a separate geologic characterization report; therefore, the data presented here cover only the atmosphere and background radiation.

4.1 ATMOSPHERE

Atmospheric factors are important in assessing the environmental impact of, and defining the safety and design requirements for, the construction and operation of a radioactive-waste repository. For the study area, the primary atmospheric factors of interest are the same as those examined for the regional studies, but they are presented in greater detail. These atmospheric factors are climate, severe weather, paleoclimatology, restrictive dispersion conditions, terrain, atmospheric transport and diffusion conditions, and air quality.

Meteorological data collected from Amarillo, Texas (approximately 35 miles south-southeast of the southern boundary of the Dalhart basin) were used to characterize the general climate, severe weather, and dispersion conditions in the area. Because of similar terrain and meteorological characteristics, the data collected at Amarillo provide a reasonably representative meteorological data set for the Dalhart basin.

4.1.1 GENERAL CLIMATE

The climate of the Dalhart basin is semiarid; the basin is located between the dry, desert climate to the west and the wet, humid climate to the east and southeast. A standard method of classifying climate regimes in the world is based on the agriculture, the temperatures, and rainfall of that area. This method is known as the Koeppen Method. The Koeppen classification of the Dalhart basin is steppe, which is characterized by sparse vegetation, warm temperatures, and periods of little precipitation. Figure 4-1 shows the Koeppen classification of the United States (Petterssen, 1958).

The Dalhart basin can show large variations from normal in annual total precipitation (normal total is 20.28 inches per year), varying from a low of 9.56 inches to a high of 39.75 inches. Persistent periods of extreme temperatures (below 0°F and above 100°F) are normally rare. However, the area is subject to large drops in temperature (e.g., 54°F) over relatively short periods (less than 12 hours) during the passage of rapidly moving cold fronts in the winter. The relative humidity in the area of the Dalhart basin is normally low, averaging approximately 54 percent. Sunshine is relatively abundant, with the area averaging 73 percent of the total possible sunshine per year. Wind speeds are high on the average. Because of the high winds, sparse vegetation, and low normal precipitation, the area has a high potential for wind erosion and dust storms. Severe weather is infrequent (USDC, 1974, 1978, 1979; Baldwin, 1973). Table 4-1 presents the normals, means, and extremes for various meteorological parameters.

4.1.2 CLIMATOLOGY

The monthly precipitation in the area of the Dalhart basin has varied from zero to 10.73 inches; the average monthly precipitation varies from 0.53 to 3.45 inches. Most of the precipitation occurs during May through October (Table 4-1) and is attributed to the warm moist air moving northward from the Gulf of Mexico. The maximum monthly snowfall at Amarillo was 17.3 inches; the maximum 24-hour snowfall was 13.5 inches. Even though snowfall has occurred from September through May (Table 4-1), snow seldom remains on the ground for more than a few days. Snowfalls result from strong cold polar air outbreaks from the north, and any snow on the ground normally dissipates quickly (USDC, 1978). Normal monthly average temperatures range from 36.0°F in January to 78.7°F in July. Occurrences of extreme cold (below 0°F) and extreme heat (above 100°F) are rare, averaging less than 2 and 3 days per year, respectively. The record high temperature in the Dalhart basin is 108°F; the record low is -16°F (USDC, 1978).

High average wind speeds, sparse vegetation, and low precipitation can cause significant soil erosion by wind and the generation of fugitive dust. A standard approach used by the U.S. Department of Agriculture for determining possible wind erosion involves calculation of a climatic factor C. This factor includes a term to account for the cube of the average wind speed and a term to account for surface moisture, Thornthwaite's precipitation-evaporation index (PEDCo, 1973). The moisture content of surface materials is generally a more direct indicator of wind-erosion potential than is the precipitation-evaporation (PE) index. However, moisture-content measurements are not routinely made, whereas precipitation and evaporation measurements are normally frequently available. Since the PE index is based on the ratio of precipitation to evaporation (Huschke, 1959), the smaller the value, the more indicative it is of a dry climate. The annual PE index for the area of the Dalhart is 40 inches. For comparison, the desert areas to the west have an annual PE index of 34 inches, while eastern Texas has a value of 87 inches (USEPA, 1977a).

Calculations based on wind speeds and the PE index for the Dalhart basin show that the relative annual wind-erosion climatic factor is higher than 150, which is indicative of a very high erosion potential. This value reflects the high wind speeds and the semiarid climate of the area (Chepil et al., 1962).

4.1.3 SEVERE WEATHER

Extreme wind, defined as the fastest passage of 1 mile of wind at 30 feet above the ground, is an important factor in specifying wind loadings for buildings and other structures. A standard index used for the design and construction of structures is the annual extreme fastest mile wind associated with a 100-year recurrence interval (normally defined as the operating-basis wind speed). The fastest mile wind includes all wind events except tornadoes. The 100-year recurrence is used for structures that are sensitive to wind loads and for situations dangerous to life. Isopleths of these maximum winds in the United States are presented in Figure 4-2. These maximum wind estimates were calculated by the National Bureau of Standards for 129 locations in the United States (Simiu et al., 1979). The appropriate extreme wind value for the Dalhart basin is approximately 85 mph.

The frequency and intensity of tornadoes are important factors in the design of aboveground facilities. Tornadoes can induce damage by wind-blown missiles, extreme pressure differentials, and extreme wind-loading forces. The frequency of tornadoes in the Dalhart basin was calculated from data obtained from the National Severe Storms Forecast Center in Kansas City, Missouri. The area averages approximately 3.5 tornadoes per year. Actual tornado occurrences in the area indicate that a tornado can be expected to strike any point in the Dalhart basin approximately once every 10,000 years.

The intensity of the tornadoes in the area seldom exceeds a Fujita-Pearson F value of 2 (wind speed 113 to 157 mph and considerable damage), and most of the tornadoes have F values of 0 (wind speed 40 to 72 mph and light damage) (Fujita, 1971).

The possibility that the aboveground facilities may be flooded must be considered in the design of the repository. The maximum 24-hour rainfall associated with a 100-year recurrence interval is the value that is most frequently used for this purpose. This value for the Dalhart basin varies from 5.5 inches in the northwest corner to 6.5 inches in the southeast corner, with 6.0 inches as the average for the area (Hershfield, 1961).

Other severe-weather events--thunderstorms, hail, heavy fog, and freezing rain--may also affect the operation of a waste repository. The Dalhart basin can expect freezing rain on an average of 8 days during the year, thunderstorms about 50 days during the year, hail 5 days a year, and heavy fog (visibility less than 0.25 mile) about 25 days a year (Baldwin, 1973; USDC, 1978).

4.1.4 PALEOCLIMATOLOGY

Climates of the past provide an indication of the long-term variability of the climate in a region and a basis for estimating future climatic changes that may affect the future impact of a repository. Considering the expected storage time commitments for radioactive waste at a repository, the most significant historical time period is the last 500,000 years. Qualitative estimates of temperature and precipitation regimes have been made for this period, and the extent of glaciation and flooding can be fairly accurately estimated from geologic evidence. It should be noted that much of the available paleoclimatological information is generalized for large geographical areas (continents, hemispheres, etc.); hence, specific climatic conditions for the Dalhart basin only can be inferred from these generic climatological descriptions.

Periodically, at intervals of about 250 million years, there have been major glacier advances from the polar regions. The Pleistocene Epoch, which began about a million years ago, is the latest glacial period. This epoch ended approximately 10,000 years ago with the beginning of the Holocene Epoch, although continuous ice sheets are still in existence at the polar regions (Sellers, 1965).

Advances of glaciers from the polar regions are called glacial, or ice, ages; the retreats are interglacial ages. Within the Pleistocene there have been at least four glacials and three interglacials. A summary of the ages and subages of the Pleistocene is presented in Table 4-2. The Dalhart basin was not covered by ice during the last major glacial maximum (Pleistocene).

The southern edge of the Kansan ice sheet ended approximately 350 miles from the northeast corner of the Dalhart basin. Furthermore, although the southward extension of the glacial ice sheet was not as great as that of the three previous advances, the Wisconsin Glacial was the coldest and driest of the four (Sellers, 1965). As indicated in Table 4-2, there were a series of glacier advances and retreats (interstadials) during the Wisconsin Glacial. The last advance, the relatively recent Valders Readvance, ended approximately 10,000 years ago (Sellers, 1965).

The advance of glaciers was initially associated with the appearance of a cold, damp climate, followed by a cold, dry climate that developed over the ice sheet itself (Schwarzbach, 1963). Precipitation over the glaciated area was probably not as high as that over the same region at present. Average temperatures in the temperate latitudes of the Northern Hemisphere were approximately 14 to 29°F lower than present values during the coldest glaciation (Wisconsin) of the Pleistocene. At the peak of this glaciation, spruce forests covered Texas, and reindeer and musk-oxen were found in the central United States (Sellers, 1965).

During glaciation periods in North America, the westerly wind belt was displaced toward the equator (Brooks, 1970; Schwarzbach, 1963). This change resulted in some areas south of the glacier receiving increased (pluvial) rainfall (Schwarzbach, 1963). In the United States, pluvial rainfall occurred in the Great Basin and in the Great Plains (Schwarzbach, 1963). In the Great Plains, the pluvial rainfall increased the abundance of aquatic snails, as evidenced by fossils. Several lakes were formed or expanded during the pluvial, especially in the western United States, many areas of which are now deserts (Flint, 1967; Schwarzbach, 1963). A pluvial lake existed approximately 100 miles west of the Dalhart basin in New Mexico. The pluvial periods in nonglacial regions also coincided with the advances of the mountain glaciers in the western United States (Brooks, 1951).

During the Pleistocene, mountain glaciers formed in the western United States south of the limit of the continuous ice sheet. These glaciers were discontinuous and formed on individual mountains as a function of latitude and altitude (Flint, 1967). Several mountain glaciers in the Pleistocene were located within 200 miles northwest of the Dalhart basin in Colorado and New Mexico.

In summary, it can be inferred that the climate of the area during the glacial/pluvial periods of the Pleistocene was probably cooler, wetter, and stormier than at present. Therefore, flooding was also probably more frequent.

The interglacials of the Pleistocene were typically free of ice and were drier than the present climate (Sellers, 1965). Moreover, temperatures were similar to, or at times slightly warmer than, those at present (Schwarzbach, 1963; Sellers, 1965), average world temperatures being approximately 3.1°F higher than those at present (Sellers, 1965).

The current epoch is the Holocene, which, as previously indicated, began approximately 10,000 years ago and is considered to be interglacial. A brief summary of the climate of this epoch is presented in Table 4-3. The most significant events are the occurrence of the Cochrane Glacial Readvance (6800 to 5600 B.C.), the Climate Optimum (5600 to 2500 B.C.), and the Little Ice Age (A.D. 1500 to 1900). However, these oscillations of the interglacial climate in the United States during the Holocene have been less severe than those experienced during the Pleistocene, when conditions varied between glacial and interglacial (Lamb, 1966). There are indications that a long-term global cooling trend is still under way, although there has been a relatively recent short-term period (approximately 40 to 100 years ending about 1950) of global warming (Kukla and Matthews, 1972; Lamb, 1966).

4.1.5 RESTRICTIVE ATMOSPHERIC DISPERSION CONDITIONS

Restrictive dispersion can be described in terms of mixing levels and also periods of poor dispersion conditions that persist for a relatively long time.

The term "mixing level" is defined as the height above the surface below which relatively vigorous vertical mixing occurs. Therefore, the mixing level indicates the practical vertical limit of dispersion and is significant for dispersion over large distances and for cases involving significant plume rise. Mixing levels are generally estimated from the analysis of upper air temperature profiles obtained by balloon soundings. The mixing level changes both diurnally and seasonally. Diurnally, the mixed level is usually highest during the afternoon, corresponding to the maximum time of ground-level heating. Seasonally, the lowest mixing levels are found during the winter and the highest during the summer. The afternoon mixing level is considered to be the most representative and appropriate indication of mixing conditions for the Dalhart basin. Afternoon mixing levels as used for this application are defined as the intersection of the vertical temperature profile at 1200 hours Greenwich mean time with the dry adiabatic extension of the maximum surface temperature observed from 1200 through 1600 hours local standard time (Holzworth, 1972).

The annual average afternoon mixing level for the Dalhart basin is approximately 7215 feet. The average afternoon mixing levels for the area during winter, spring, summer, and autumn are approximately 4100, 9185, 9185, and 6070 feet, respectively (Holzworth, 1972). In general, mixing heights in the Dalhart basin area can be characterized as somewhat higher (generally indicative of better dispersion) than typical conditions throughout the contiguous United States.

Poor dispersion conditions that persist for long periods have the potential for increased ground-level concentrations of emissions. Specifically, the conditions of interest for this study are occurrences of mixing heights of less than 5000 feet on at least 2 consecutive days with wind speeds of less than 9 mph and no significant precipitation. These are the conditions that are frequently associated with the stagnation of large-scale high-pressure systems (Holzworth, 1972).

The occurrence of restrictive dispersion conditions, based on the criteria discussed above, can be summarized from data available from Amarillo. Episodes of poor dispersion are relatively infrequent in the Dalhart basin area, with only two episodes in a 5-year period (Holzworth, 1972).

4.1.6 TERRAIN

The characteristics of the terrain can significantly influence atmospheric dispersion and transport conditions. Air flows in a complex terrain (e.g., mountains, valleys, and ridges) are different from those found over flat land, and they have different effects on wind speed, wind direction, and atmospheric stability distributions. Topographic effects are most significant in the near vicinity of a release since large-scale weather patterns become more dominant at greater distances. It is therefore necessary to evaluate the various types of land formations and their effects on atmospheric transport and dispersion conditions, considering the types of release that may occur from a waste repository and the distances of interest.

Since most of the area consists of flat to rolling plains and tablelands, large-scale topographic effects on meteorology are not expected. Possible exceptions are very local effects, induced by small playas, stream valleys, and hummocks, which may influence local wind flows and atmospheric turbulence.

4.1.7 ATMOSPHERIC TRANSPORT AND DIFFUSION CONDITIONS

Atmospheric transport and diffusion conditions are primarily dependent on wind speed, wind direction, and atmospheric stability, with each of these parameters variable with the time of year. To assess the dispersion conditions of the Dalhart basin, these parameters were examined using National Weather Service data from Amarillo. This weather station should provide fairly representative data for determining expected dispersion conditions in the Dalhart basin (see Section 4.1.6 for a discussion of terrain and its relationship to local dispersion conditions).

Annual, seasonal, and monthly wind speed and direction distribution roses for Amarillo (Figures 4-3, 4-4, and 4-5) show that the predominant wind direction for the Dalhart basin is southerly for the months of March through October. During the winter months (December, January, February) winds from the north through southwest begin to dominate because of cold air masses moving southward from the north. Although the wind speeds tend to be fairly consistent throughout the year, the highest wind speeds tend to be in the spring (March, April, May) because of the proximity of pressure systems moving past the area. Table 4-4 provides monthly, seasonal, and annual distributions of atmospheric stability classes for Amarillo based on the period January 1, 1974, through December 31, 1978. Atmospheric stability is classified based on the Pasquill-Turner scheme using time of day, wind speed, insolation, and cloud cover (Gifford, 1968). These data show a predominance of neutral conditions, especially during the spring months (due in part to the higher average wind speeds during this season). In the summer (June, July, August) increase in unstable conditions (A, B, and C stabilities) occurs. The greatest frequency of stable conditions (E, F, and G stabilities) is found in the fall (September, October, November) and winter months. The frequency of stable conditions for these seasons is about 10 to 12 percent higher than in either spring or summer.

Analysis of data on dispersion climatology indicates that the average atmospheric dispersion conditions in the Dalhart basin are relatively good for all times of the year.

4.1.8 AIR QUALITY

The construction and operation of an underground waste repository will require the aboveground handling, storage, and disposal of several thousand tons of mined material daily. The operations of crushing, transporting, and disposing of the mined material will be similar to other large mining operations in that fugitive dust will be generated, which may affect local air quality. Federal, State, and local air-quality standards as well as nondeterioration statutes can therefore affect the siting of a new source of emissions.

The national ambient air-quality standards for particulate matter, listed in Table 4-5, will be a significant air-quality factor in the location and operation of the repository (USEPA, 1979a). The particulate emissions from the repository plus the background particulate concentration must not cause either the primary or the secondary national ambient air-quality standard to be exceeded. Regulations for the State of Texas indicate that any facility that may emit air contaminants must apply for a construction permit. This application must show that the proposed facility will not cause a significant deterioration of the ambient air quality in the area, will use the best available control technology, will have provision for monitoring as may be required, and will meet applicable new-source performance standards. If the source is a major stationary source (emitting more than 100 tons per year, 2000 pounds per day, 200 pounds per hour or more and will have allowable emissions exceeding 50 tons per year, 1,000 pounds per day, or 100 pounds per hour of any air contaminant for which a national ambient air-quality standard has been issued), further requirements must be met (Texas Air Control Board, 1979, Regulation VI). The Texas regulation for the control of particulate matter (fugitive dust) from construction, roads, streets, and alleys apply only to areas that are nonattaining for particulates (Texas Air Control Board, 1979, Regulation I, Rule 04.001-04.005). If the facility is to have stacks or vents from which pollutants will be emitted, additional regulations for the control of these pollutants may apply. In particular, if the facility is to have a fossil-fired boiler, then the new-source performance standard for fossil-fuel-fired steam generators (USEPA, 1977b) or for industrial boilers (not yet issued) may apply.

Regulations promulgated by the U.S. Environmental Protection Agency for the prevention of significant deterioration (PSD) restrict the amount by which pollutant concentrations in an area that is attaining the ambient standards for a pollutant (particulate matter or sulfur dioxide) may be increased over a baseline concentration by the construction of new sources and the modification of existing sources (USEPA, 1978a). The particulate emissions from all new and modified sources in an area (for PSD Class II areas) since August 7, 1977, may not increase the particulate concentration by more than 19 micrograms per cubic meter for the annual geometric mean or 37 micrograms per cubic meter for the maximum 24-hour concentration. A source is classified as a major source if it emits more than 250 tons per year of a pollutant or more than 100 tons per year for certain designated sources, such as fossil-fuel-fired steam generators; a major source is not subject to a full PSD review if the allowable emissions are less than 50 tons per year, 1000 pounds per day, or 100 pounds per hour, whichever is more restrictive. A new source cannot be located in an area that has been designated as nonattaining unless certain offset criteria are satisfied.

Proposed regulations would not include fugitive emissions in the determination of whether a source is "major" except for fugitive emissions related to certain specified sources (USEPA, 1979b), which include fossil-fuel-fired boilers. This could mean (depending on the size and the type of nonfugitive emission sources at the facility) that the facility may not be subject to full new-source review and its monitoring requirements. The proposed rules would also delete the 50-ton per year exemption. The proposed regulations would also change the baseline date from August 7, 1977, to the time after August 7, 1977, at which the first permit application for a major source modification is filed.

Table 4-6 presents the 1974 through 1978 ambient air-quality suspended-particulate data summaries (USEPA, 1976a, 1977c, 1978b; Texas Air Control Board, 1977, 1978) for the particulate monitors in the vicinity of the Dalhart basin. A detailed characterization of the air quality throughout the Permian region is difficult because of the large distances separating the particulate monitors and the fact that the monitors are located in towns and cities, which usually produce higher particulate concentrations than the surrounding rural and undeveloped areas. In general, the particulate data summaries presented in Table 4-6 indicate that the Dalhart basin could have suspended-particulate concentrations greater than the national secondary ambient air-quality standards. Since particulate concentrations in the part of the State that includes the Dalhart basin can be attributed largely to fugitive dust and the area is generally rural, the area has been declared attaining for suspended particulates by the EPA (USEPA, 1978c). Figure 4-6 shows the location of the particulate monitors listed in Table 4-6.

Another air-quality factor to be considered is the impact of particulate emissions on areas that have been designated as Class I areas in the prevention of significant deterioration. The Clean Air Act Amendments of 1977 (U.S. Congress, 1977) specify increments over which the particulate concentrations in Class I areas may not be increased (5 micrograms per cubic meter for the annual geometric mean and 10 micrograms per cubic meter for the 24-hour maximum may be exceeded once during the year). There are no Class I areas within 100 miles of the Dalhart basin; however, the Capulin Mountain National Monument in New Mexico (about 50 miles west-northwest of the Texas portion of the Dalhart basin) has been recommended for designation as a Class I area (USDI, 1979).

Review of existing and permitted emission sources in the Dalhart basin indicates that many of the larger particulate sources are located along major highways and near major towns. In the Dalhart basin, most of the particulate emissions are from area sources. Emission sources will be examined in more detail in later studies.

4.2 BACKGROUND RADIATION

Data on the variation in background radiation in an area are useful for putting into perspective potential radiation doses to individuals (or populations) from man-made sources of radiation. In addition to background radiation from cosmic, terrestrial, and fallout sources, data on radioactivity concentrations in water, air, and milk provide the characterization required at the study-area level.

The largest sources of the ionizing radiation to which people are exposed are the natural radiation environment and the fallout from weapons testing. The dose delivered by these sources is neither constant nor uniform for all individuals; it varies with altitude, geologic features, and the extent of weapons testing. Radioactivity concentrations in environmental media are also variable. Among the many things that affect concentrations are fallout, geologic features, meteorological factors, and land- and water-use patterns.

4.2.1 COMPONENTS OF BACKGROUND RADIATION

Background radiation delivers external radiation doses to persons from cosmic, terrestrial, and fallout sources. For purposes of this study, it also includes radioactivity concentrations in water, air, and milk. However, these concentrations are not translated into dose rates. Both external radiation doses and radioactivity concentrations are discussed in the following paragraphs.

4.2.1.1 External Radiation Doses

Cosmic Radiation

The term "cosmic radiation" refers both to the primary energetic particles of extraterrestrial origin that strike the earth's atmosphere and to the secondary particles generated as a result of this interaction. The primary radiation itself consists of two components: "galactic" particles external to the solar system and "solar" particles emitted by the sun. The intensity of cosmic radiation, and thus the dose, increases somewhat with latitude and significantly with elevation.

Terrestrial Radiation

Terrestrial radioactivity is produced in the environment by the naturally occurring radioactive isotopes of a number of elements that are found in the earth's crust. The radionuclides of primary importance are potassium-40 and the radionuclides generated in the decay chains of uranium-238 and thorium-232. Radiation doses from terrestrial radiation are highly dependent on the type of soil and rock in an area.

Fallout Radiation

Fallout radiation results from the deposition of radioactive material created during the testing of nuclear weapons. The large-scale atmospheric tests of 1961-1962 were the major sources; however, the continued French and Chinese tests have maintained a relatively constant annual fallout deposition. Cesium-137 is the major source of radiation doses from long-lived fallout, and a number of short-lived radionuclides contribute to doses during the first few years after their production.

4.2.1.2 Radioactivity Concentrations in Air, Water, and Milk

Measurements of background radioactivity in various environmental media permit a generic characterization of prevailing radiation concentrations and indicate the degree of natural variation that can be expected. Background levels at any one location are not constant; they vary with time because they are affected by external events, such as cosmic ray bombardment, fallout from weapons testing, and seasonal influences. These levels can also vary spatially, depending on geologic characteristics, land- and water-use patterns, and meteorological factors.

Radiological assessments of air, water, and milk permit an evaluation of basic pathways through which people may be either directly or indirectly exposed. To derive meaningful interpretations and conclusions from the observed values, a statistically significant amount of data must be collected. Both naturally occurring and manmade radionuclides are usually identified in environmental radiological monitoring. Typically, potassium-40, cesium-137, iodine-131, and selected nuclides from the uranium and thorium decay chains are included in the analysis of environmental media. Often, airborne particulates are qualitatively analyzed for gross alpha and beta radioactivity; these assessments do not provide isotopic identification. Milk samples are often analyzed for strontium-89 and strontium-90.

4.2.2 AREA BACKGROUND DOSES AND CONCENTRATIONS: DATA COLLECTION AND RESULTS

The nature of natural background radiation and its spatial variation over the continental United States have been treated extensively in the literature (NCRP, 1975; Oakley, 1972; USEPA, 1976b, 1977d). Background-radiation doses have been estimated for a number of locations in Texas and surrounding states. Background-radioactivity concentrations in water, air and milk are also reported in the literature for locations in Texas and surrounding states (USDOE, 1978, 1979; USERDA, 1976; USEPA, 1975-1979). A number of the locations cited in the literature are within or near the Dalhart basin.

4.2.2.1 External Radiation Dose Rates

Table 4-7 lists the radiation doses that a person would receive from background radiation for each of the counties in the Dalhart basin. The total values, in millirem per year, represent the sum of the terrestrial, cosmic, and fallout components. No adjustments have been made for the effects of buildings on radiation dose--that is, the shielding from external radiation afforded by buildings and radiation from building materials.

The cosmic ray dose equivalent rates were calculated from county elevations by using the relationship between elevation and dose rate shown in Figure 4-7 (Oakley, 1972). The mean value of the elevation range for each county (Dallas Morning News, 1977) was used in determining the dose rates.

The terrestrial dose equivalent rates given in Table 4-7 are based on information obtained from the analysis of nationwide aerial surveys, in particular the surveys conducted in the Aerial Radiological Measurement Surveys (ARMS) program (Jobst, 1977). The ARMS data indicate that there are three distinct areas of background radiation in the United States: the Coastal Plain areas, the non-Coastal Plain areas (excluding Denver), and the Denver area. The Dalhart basin is assumed to fall into the category of a non-Coastal Plain area, and locations within it were assigned a value of 46 mrem per year (Oakley, 1972, Table 14).

A uniform value of 5 mrem per year, independent of the location, has been used for fallout radiation. This is consistent with the information presented in the literature (Oakley, 1972, Figure 11).

Figure 4-8 presents the total background doses for each of the counties in the Dalhart basin. It can be seen that there is a variation of background-radiation levels among the basins. The largest difference in dose-rate levels in counties in the Dalhart basin is 8 mrem per year (Dallam versus Moore). The mean annual background doses for the counties in the Dalhart basin is 114 mrem per year.

4.2.2.2 Radioactivity Concentrations in Air, Water, and Milk

No data on background radioactivity concentrations in air, water, and milk samples collected in the Dalhart basin are available.

Because of the limited amount of background radiation data available on environmental media for the regions of interest, the Dalhart basin has been characterized by compiling data from sampling locations in the general area. Data from sampling stations in Texas, Oklahoma, and New Mexico have been chosen from the available literature to reflect typical background radiological characteristics that may reasonably be expected to apply also to the conditions and variances existing in the Dalhart basin. Figure 4-9 shows the specific cities in the three states from which radiological data have been compiled and their relative proximity to the basin. Because of the limited data available at the study-area level, a radiological monitoring program will be required to establish the detailed radiological characteristics after a location/site has been selected.

Tables 4-8 through 4-16 present the results of analyses performed on various air, water, and milk samples collected from the cities shown in Figure 4-9. The radioactivity levels of environmental media are not constant but vary both spatially and temporally. Data from samples collected in Santa Fe, New Mexico, Oklahoma City, Oklahoma, Austin, Texas, and Dallas, Texas, are published quarterly by the U.S. Environmental Protection Agency as part of the Environmental Radiation Ambient Monitoring System (ERAMS). For report purposes, the monthly and/or quarterly data have been reduced to annual averages where applicable. Analytical results from Amarillo, Texas (Pantex Plant) have been published in the literature (USDOE, 1978, 1979; USERDA, 1976). As indicated in Tables 4-8, 4-9, and 4-10, only data from Stations OA-11 and OA-12 have been reported. It is assumed that these monitoring locations are the control stations for the environmental radiological monitoring program of the Pantex Plant. The two stations are located in directions of low prevailing winds and are more than 9 miles from the plant.

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Table 4-1. Normals, means, and extremes of meteorological parameters for Amarillo, Texas

Month	Temperatures °F: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)				38		38					38		38		38	
J	49.4	22.5	36.0	81	1950	-11	1959	899	0	0.54	2.33	1968	T	1976	1.74	1968
F	53.0	26.4	39.7	88	1963	-14	1951	708	0	0.56	1.83	1948	T	1943	1.28	1971
M	60.0	31.2	45.6	94	1971	-3	1948	601	0	0.77	3.99	1973	T	1950	2.27	1973
A	70.9	42.1	56.5	98	1965	14	1945	275	20	1.23	3.74	1942	T	1964	1.57	1942
M	79.2	51.9	65.6	102	1953	28	1954	81	99	2.83	9.81	1951	0.19	1966	6.75	1951
J	88.0	61.2	74.6	108	1953	42	1955	10	298	3.45	10.73	1965	0.01	1953	6.15	1960
J	91.4	65.9	78.7	105	1978	53	1950	0	425	2.95	7.59	1960	0.12	1946	4.09	1943
A	90.4	64.7	77.6	106	1944	49	1956	0	391	2.93	7.55	1974	0.39	1947	4.26	1945
S	82.9	56.7	69.8	102	1947	33	1945	20	164	1.93	5.02	1950	0.03	1977	3.42	1941
O	72.9	46.1	59.5	95	1956	25	1976	206	36	1.83	7.64	1941	0.00	1952	3.45	1948
N	60.0	32.5	46.3	85	1975	0	1976	561	0	0.53	2.26	1961	T	1960	1.29	1971
D	51.5	25.5	38.5	81	1955	-4	1978	822	0	0.73	4.52	1959	T	1976	3.11	1943
YR	70.8	43.9	57.4	108	JUN 1953	-14	FEB 1951	4183	1433	20.28	10.73	JUN 1965	0.00	OCT 1952	6.75	MAY 1951

Month	Precipitation in inches: Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct.: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile Ø: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ½ mile or less	Temperatures °F: Max.: (b) 90° and above	32° and below	Min.: 32° and below	0° and below	Average station pressure mb. Elev. 3604 feet m.s.l.
(a)	38		38		17	17	17	17	37	15	34	34		37	37	37	37	37	37	37	37	37	17	17	17	17	6
J	12.9	1960	6.7	1960	62	69	49	45	13.1	SW	62	NE	1953	69	5.1	13	7	11	4	1	*	3	0	5	27	1	891.6
F	17.3	1971	13.5	1971	62	70	48	41	14.2	SW	70	NW	1956	69	5.2	11	7	10	4	1	*	4	0	2	22	*	891.0
M	14.7	1961	9.8	1957	55	66	41	33	15.6	SW	72	W	1950	72	5.2	12	8	11	4	1	1	3	*	1	15	0	887.2
A	6.4	1947	5.1	1947	54	66	37	31	15.6	SW	74	SW	1942	72	5.0	12	8	10	5	*	3	2	1	*	3	0	888.5
M	0.5	1978	0.5	1978	60	72	41	35	14.8	S	84	SW	1949	72	5.0	11	11	9	8	0	9	2	6	0	*	0	888.5
J	0.0		0.0		63	76	44	38	14.4	S	75	NW	1974	77	4.3	13	12	5	8	0	9	1	13	0	0	0	890.3
J	0.0		0.0		61	73	42	38	12.5	S	66	SW	1948	77	4.5	13	12	6	9	0	10	1	21	0	0	0	892.8
A	0.0		0.0		65	76	46	42	12.1	S	65	E	1946	77	4.2	15	10	6	8	0	9	1	16	0	0	0	892.9
S	T	1945	T	1945	71	80	50	46	13.0	S	68	NE	1942	73	4.0	16	7	7	6	0	4	2	6	0	0	0	892.7
O	3.9	1976	3.2	1976	62	71	42	41	13.0	SW	68	S	1949	75	3.8	17	6	8	5	*	2	2	1	*	2	0	893.3
N	13.6	1952	12.2	1952	65	73	47	48	13.2	SW	59	NW	1970	72	4.3	15	7	8	3	*	1	2	0	1	13	*	891.8
D	8.5	1943	7.4	1971	62	68	47	47	13.0	SW	62	NE	1953	68	4.7	13	8	10	4	1	*	3	0	3	27	*	890.7
YR	17.3	FEB 1971	13.5	FEB 1971	62	72	44	40	13.7	SW	84	SW	MAY 1949	73	4.6	161	103	101	68	5	49	26	64	12	108	2	890.9

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: lowest temperature -16 in February 1899; maximum monthly snowfall 28.7 in February 1903; maximum snowfall in 24 hours 20.6 in March 1934.

Source: USDC (1978).

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

ϕ Through 1974

Table 4-2. Ages and subages of the Pleistocene Epoch[a]

Age or subage	Thousands of years ago
Nebraskan Glacial (Kageran Pluvial)	600 ± 325
Aftonian Interglacial	500 ± 270
Kansan Glacial (Kamasian Pluvial)	420 ± 240
Yarmouth Interglacial	300 ± 130
Illinoian Glacial (Kanjeran Pluvial)	187 ± 76
Sangamon Interglacial	106 ± 36
Wisconsin Glacial (Gamblian Pluvial):	
Iowan, Farmdale Readvance (Lower Gamblian Pluvial)	37 ± 16
Tazewell, Hackensack Readvance (Lower Gamblian Pluvial)	23 ± 5.5
Brady Interstadial	18.7 ± 3.2
Cary, Mankato,[b] Port Huron Readvance (Upper Gamblian Pluvial)	14.9 ± 2.7
Two Creeks Interstadial	11.4 ± 2.2
Valders Readvance (Makalian Pluvial)	10.3 ± 1.8

[a]From Sellers (1965).

[b]The date of the Mankato Readvance is uncertain. Although some authors equate it with the Valders Readvance, recent evidence suggests that it occurred earlier.

Table 4-3. A brief chronology of the climate of the last 10,000 years[a]

Dates	Region	Climate
9000 to 6000 B.C.	Southern Arizona	Warm and arid
6800 to 5600 B.C.	North America	Cool and dry, with possible extinction of mammals, particularly in Arizona and New Mexico; Cochrane Readvance in Alaska and southeast Canada
5600 to 2500 B.C.	Northern Hemisphere	Warm and moist, becoming warm and dry by 3000 B.C. (Climatic Optimum); intermittent drought in the western United States after 5500 B.C.; maximum glacial retreat in Alaska near 3500 B.C.
2500 to 500 B.C.	Northern Hemisphere	Generally warm and dry with periods of heavy rain in the western United States after 660 B.C. and intense droughts in the western United States near 510 B.C.; glaciation in Alaska between 2380 and 1340 B.C. and near 600 B.C.
330	United States	Drought in the Southwest
600	Alaska	Glacial advance
800	Mexico	Start of moist period
1000 to 1100	Utah	Snowline 985 feet higher than today
1200	Alaska	Glacial advance
1180 to 1215	United States	Wet in the west
1220 to 1290	United States	Drought in the west

Note: See footnote at end of table.

Table 4-3. A brief chronology of the climate of the last 10,000 years[a] (continued)

Dates	Region	Climate
1276 to 1299	United States	"Great Drought" in the Southwest
1300 to 1330	United States	Wet in the west
1500 to 1900	United States	Generally cool and dry (Little Ice Age); periodic glacial advances in North America (1700 to 1750); drought in the southwestern United States from 1573 to 1593
1880 to 1940	Northern Hemisphere	Increase of winter temperatures by 1.5°C (2.7°F); drop of 17 feet in the level of the Great Salt Lake; Alpine glaciation reduced by 25 percent and arctic ice by 40 percent; rapid glacial recession in the Canadian Rockies (1932 to 1938)
1920 to 1958	United States	25 percent decrease in mean annual precipitation in the Southwest
1942 to 1960	Northern Hemisphere	Temperature decrease and halt of glacial recession

[a]From Sellers (1965).

Table 4-4. Atmospheric stability distributions for Amarillo, Texas (January 1, 1974, through December 31, 1978)

Month	Stability class						
	Unstable			Neutral,	Stable		
	A	B	C	D	E	F	G
January	0.00	0.73	4.60	68.87	16.77	8.23	0.81
February	0.00	1.42	5.41	75.09	14.27	3.37	0.44
March	0.00	1.53	4.03	79.44	11.21	3.15	0.65
April	0.25	1.83	8.75	74.58	11.83	2.33	0.42
May	0.73	2.66	13.15	71.37	9.60	2.26	0.24
June	1.08	3.92	14.42	72.42	6.58	1.50	0.08
July	0.97	3.79	14.60	64.35	13.79	2.26	0.24
August	0.32	2.82	13.71	65.32	13.95	3.47	0.40
September	0.17	2.25	10.42	63.83	16.83	6.08	0.42
October	0.00	2.26	7.02	66.13	18.55	5.65	0.04
November	0.08	1.00	7.42	61.67	21.25	7.42	1.17
December	0.00	0.16	5.24	64.68	21.53	7.10	1.29
Spring	0.33	2.01	8.64	75.14	10.87	2.58	0.43
Summer	0.79	3.51	14.24	67.31	11.49	2.42	0.24
Fall	0.08	1.84	8.27	63.90	18.87	6.37	0.66
Winter	0.00	0.75	5.07	69.37	17.63	6.32	0.86
Annual	0.30	2.03	9.08	68.94	14.69	4.41	0.55

Table 4-5. National ambient air-quality standards for suspended particulate matter[a]

Parameter	Primary standard ($\mu g/m^3$)	Secondary standard ($\mu g/m^3$)
Annual average geometric mean	75	60
Maximum 24-hour concentration, not to be exceeded more than once per year	260	150

[a]USEPA (1979a).

Table 4-6. Suspended particulate air-quality data

Location	Site ID number	1974 Highest 24-hour value ($\mu g/m^3$) 1st	1974 Highest 24-hour value ($\mu g/m^3$) 2nd	1974 Geometric mean ($\mu g/m^3$)	1975 Highest 24-hour value ($\mu g/m^3$) 1st	1975 Highest 24-hour value ($\mu g/m^3$) 2nd	1975 Geometric mean ($\mu g/m^3$)	1976 Highest 24-hour value ($\mu g/m^3$) 1st	1976 Highest 24-hour value ($\mu g/m^3$) 2nd	1976 Geometric mean ($\mu g/m^3$)	1977 Highest 24-hour value ($\mu g/m^3$) 1st	1977 Highest 24-hour value ($\mu g/m^3$) 2nd	1977 Geometric mean ($\mu g/m^3$)	1978 Highest 24-hour value ($\mu g/m^3$) 1st	1978 Highest 24-hour value ($\mu g/m^3$) 2nd	1978 Geometric mean ($\mu g/m^3$)
Texas																
Amarillo	45 007 0002 F01	225	178	93	110	107	68	87	84	51	336[a]	217	58	146	117	64
Amarillo	45 007 0002 P01	122	105	--	107	103	--	--	--	--	--	--	--	--	--	--
Amarillo	45 007 0003 F01	--	--	--	98	70	--	132	128	41	--	--	--	--	--	--
Dumas	45 154 0001 F01	--	--	--	--	--	--	280	258	90	--	--	--	--	--	--
Lubbock	45 334 0001 F01	340	289	--	496	268	84	199	190	71	379[a]	285	81	285	119	61
Lubbock	45 334 0001 P01	113	74	--	212	175	78	--	--	--	--	--	--	--	--	--
Lubbock	45 334 0023 F01	--	--	--	--	--	--	--	--	--	115	110	71[b]	184[a]	115	63[b]
Pampa	45 401 0001 F01	313	80	--	81	71	--	275	118	52	--	--	--	--	--	--
Plainview	45 415 0001 F01	--	--	--	--	--	--	181	181	91	--	--	--	--	--	--
Oklahoma																
Guymon	37 118 0920 F01	226	201	103	311	203	--	228	172	98	--	--	--	--	--	--
New Mexico																
Clovis	32 024 0001 F01	100	98	56	247	177	71	253	241	78	--	--	--	--	--	--
Lovington	32 074 0001 F02	203	147	50	249	123	44	259	235	49	--	--	--	--	--	--

Note: Oklahoma and New Mexico data not reviewed for 1977 and 1978.

[a]High concentration due to dust storm activity.
[b]Data does not meet EPA criteria for calculating annual means.

Table 4-7. External radiation levels for the Dalhart basin

County	Level (mrem/yr)			
	Cosmic rays[a]	Terrestrial[b]	Fallout[c]	Total
Dallam	68	46	5	119
Hartley	64	46	5	115
Moore	60	46	5	111
Oldham	62	46	5	113
Sherman	62	46	5	113

[a]Based on mean elevation of county, using Figure 4-7.

[b]Representative of non-Coastal-Plain areas of the United States (data from Table 14 of Oakley (1972), rounded up from 45.6).

[c]Taken as a constant value for all counties (Oakley, 1972, Section 3.3.2).

Table 4-8. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross alpha and beta measurements of air particulates[a]

Location	Annual average concentration $(pCi/m^3)^b$											
	1974		1975		1976		1977		1978		1979	
	α	β	α	β	α	β	α	β	α	β	α	β
Santa Fe, New Mexico	NR	0.05	NR	0.02	NR	0.07	NR	0.21	NR	0.10	NR	0.02
Oklahoma City, Oklahoma	NR	NR	NR	0.06	NR	0.10	NR	0.12	NR	0.22	NR	0.04
Amarillo, Texas (Pantex Plant)												
Station OA-11	NR	NR	NR	NR	0.0006	0.02	0.0009	0.05	0.0004	0.01	NA	NA
Station OA-12	NR	NR	NR	NR	0.0012	0.04	0.0011	0.05	0.0009	0.02	NA	NA

Abbreviations: NR = not reported; NA = not available.

[a]From USDOE (1978, 1979); USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1×10^{-12} curie.

Table 4-9. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross plutonium and uranium measurements of air particulates[a]

Year	Location	Annual average concentration ($aCi/m^3 \pm 2\sigma$)[b]					
		Pu-238	Pu-239	U-234	U-235	U-238	Total uranium
1974	Santa Fe, New Mexico	3.6 ± 0.8	58.6 ± 5.6	63.2 ± 6.4	9.2 ± 1.6	69.6 ± 7.0	NR
	Oklahoma City, Oklahoma	10.1 ± 2.2	50.4 ± 6.1	46.3 ± 5.5	ND[c]	46.3 ± 5.5	NR
	Amarillo, Texas (Pantex Plant)						
	Station OA-11	NR	NR	NR	NR	NR	NR
	Station OA-12	NR	NR	NR	NR	NR	NR
1975	Santa Fe, New Mexico	1.7 ± 0.4	5.6 ± 0.8	46.3 ± 3.2	2.5 ± 0.5	44.9 ± 3.1	NR
	Oklahoma City, Oklahoma	4.8 ± 0.8	26.4 ± 2.3	35.2 ± 2.2	2.1 ± 0.4	35.2 ± 2.4	NR
	Amarillo, Texas (Pantex Plant)						
	Station OA-11	NR	NR	NR	NR	NR	NR
	Station OA-12	NR	NR	NR	NR	NR	NR
1976	Santa Fe, New Mexico	3.4 ± 2.2	7.4 ± 1.0	45.8 ± 3.2	4.1 ± 0.5	46.8 ± 3.4	NR
	Oklahoma City, Oklahoma	4.6 ± 1.1	8.4 ± 1.6	36.6 ± 3.2	6.2 ± 1.1	41.0 ± 3.5	NR
	Amarillo, Texas (Pantex Plant)						
	Station OA-11	NR	0.0 ± 9.3	NR	NR	NR	2809 ± 717
	Station OA-12	NR	0.0 ± 9.4	NR	NR	NR	388 ± 334

Note: See footnotes at end of table.

Table 4-9. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross plutonium and uranium measurements of air particulates[a] (continued)

		Annual average concentration ($aCi/m^3 \pm 2\sigma$)[b]					
Year	Location	Pu-238	Pu-239	U-234	U-235	U-238	Total uranium
1977	Santa Fe, New Mexico	4.6 ± 0.8	24.2 ± 4.6	63.0 ± 4.5	4.6 ± 0.7	61.0 ± 4.5	NR
	Oklahoma City, Oklahoma	11.1 ± 2.5	18.8 ± 3.4	74.2 ± 5.0	3.4 ± 0.7	81.0 ± 5.4	NR
	Amarillo, Texas (Pantex Plant)						
	Station OA-11	NR	0 ± 17	NR	NR	NR	1073 ± 849
	Station OA-12	NR	0 ± 13	NR	NR	NR	1059 ± 802
1978	Santa Fe, New Mexico	4.0 ± 2.6	53.6 ± 3.9	35.8 ± 3.5	3.2 ± 0.7	42.4 ± 5.2	NR
	Oklahoma City, Oklahoma	6.0 ± 1.2	67.5 ± 4.8	38.0 ± 4.4	9.4 ± 2.5	38.5 ± 4.4	NR
	Amarillo, Texas (Pantex Plant)						
	Station OA-11	NR	20 ± 35	NR	NR	NR	4770 ± 3940
	Station OA-12	NR	80 ± 74	NR	NR	NR	3320 ± 3450

Abbreviations: NR = not reported; ND = not detected.

[a]From USDOE (1978, 1979) and USEPA (1975-1979).
[b]One attocurie (aCi) is equal to 1×10^{-18} curie.

Table 4-10. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross tritium oxide, radium-226, and radium-228 measurements of air[a]

Location	Annual average concentration ($pCi/m^3 \pm 2\sigma$)[b]				
	Tritium oxide			Radium-226, 1978	Radium-228, 1978
	1976	1977	1978		
Amarillo, Texas (Pantex Plant)					
Station OA-11	0.00 ± 0.99	0.00 ± 0.05	1.3 ± 4.0	0.002 ± 0.001	0.003 ± 0.004
Station OA-12	0.00 ± 0.99	0.00 ± 0.11	1.6 ± 4.1	0.0002 ± 0.0006	0.004 ± 0.002

[a]From USDOE (1978, 1979).
[b]One picocurie (pCi) is equal to 1×10^{-12} curie.

Table 4-11. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross alpha and beta, strontium-90, and radium-226 measurements of drinking water[a]

Year	Location	Average concentration (pCi/ℓ ± 2σ)[b]			
		Gross α	Gross β	Strontium-90	Radium-226
1975 (April to June)	Santa Fe, New Mexico	ND	2.2 ± 0.9	NR	NR
	Oklahoma City, Oklahoma	No sample			
	Austin, Texas		3.1 ± 1.2	NR	NR
1976 (July 1975 to June 1976)	Sante Fe, New Mexico	No sample			
	Oklahoma City, Oklahoma	ND	9.8 ± 1.8	1.3 ± 0.7	0.2 ± 0.1
	Austin, Texas	ND	2.5 ± 1.0	−0.2 ± 0.3	0.2 ± 0.1
1977 (July 1976 to June 1977)	Sante Fe, New Mexico	3.9 ± 1.8	3.2 ± 1.3	0.3 ± 0.3	0.2 ± 0.02
	Oklahoma City, Oklahoma	<2.0 ± 2.0	7.9 ± 1.3	1.3 ± 0.6	NR
	Austin, Texas	<2.0 ± 2.0	2.3 ± 1.0	0.4 ± 0.6	NR
1977 (July to December)	Sante Fe, New Mexico	<2.0 ± 2.0	<1.0 ± 1.0	−1.7 ± 7.3	NR
	Oklahoma City, Oklahoma	<2.0 ± 2.0	7.4 ± 1.5	0.6 ± 0.5	NR
	Austin, Texas	<2.0 ± 2.0	3.2 ± 1.2	0.2 ± 0.8	NR

Abbreviations: ND = not detected; NR = not reported.

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1 x 10^{-12} curie.

Table 4-12. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross iodine-131 measurements of drinking water[a]

Location	Annual average concentration (pCi/ℓ ± 2σ)[b] 1977	1978
Santa Fe, New Mexico	-0.3 ± 0.2	0.33 ± 0.12
Oklahoma City, Oklahoma	0.4 ± 0.3	-0.29 ± 0.08
Austin, Texas	-0.2 ± 0.1	-0.22 ± 0.05

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1 x 10^{-12} curie.

Table 4-13. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross tritium measurements of drinking water[a]

Location	Average concentration ($pCi/\ell \pm 2\sigma$)[b]					
	1974	1975	1976	1977	1978	1979 (January to March)
Santa Fe, New Mexico	250 ± 200	300 ± 200	400 ± 200	400 ± 200	300 ± 200	200 ± 200
Oklahoma City, Oklahoma	200 ± 200	200 ± 200	250 ± 200	300 ± 200	200 ± 200	400 ± 200
Austin, Texas	0.0 ± 200	150 ± 200	275 ± 200	275 ± 200	325 ± 200	200 ± 200

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1×10^{-12} curie.

Table 4-14. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross plutonium and uranium measurements of drinking water[a]

Year	Location	Average concentration (pCi/ℓ ± 2σ)[b]				
		Pu-238	Pu-239	U-234	U-235	U-238
1975 (July 1974 to June 1975)	Santa Fe, New Mexico	0	0.009 ± 0.007	2.49 ± 0.320	0.060 ± 0.015	0.853 ± 0.119
	Oklahoma City, Oklahoma	0.004 ± 0.004	0.009 ± 0.006	0.025 ± 0.009	0.001 ± 0.002	0.014 ± 0.006
1976 (July 1975 to June 1976)	Santa Fe, New Mexico	NS	NS	NS	NS	NS
	Oklahoma City, Oklahoma	0.002 ± 0.002	0.003 ± 0.003	0.039 ± 0.016	0.003 ± 0.003	0.019 ± 0.011
1977 (July 1976 to June 1977)	Santa Fe, New Mexico	0	0.003 ± 0.003	2.42 ± 0.610	0.056 ± 0.034	0.659 ± 0.165
	Oklahoma City, Oklahoma	NS	NS	NS	NS	NS
1977 (July to December)	Santa Fe, New Mexico	0	0.027 ± 0.008	0.211 ± 0.042	0.002 ± 0.003	0.080 ± 0.018
	Oklahoma City, Oklahoma	0.008 ± 0.006	0.010 ± 0.006	0.092 ± 0.020	0.003 ± 0.003	0.075 ± 0.020

Abbreviations: NS = no sample.

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1×10^{-12} curie.

Table 4-15. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross gamma emitters and strontium-89 and strontium-90 measurements of pasteurized milk[a]

Year	Location	(g/ℓ ± 2σ)	Average annual concentration (pCi/ℓ ± 2σ)[b]				
		K	Cs-137	Ba-140	I-131	Sr-89	Sr-90
1974	Albuquerque, New Mexico	1.45 ± 0.11	ND	0 ± 8	0 ± 7	NA	NA
	Oklahoma City, Oklahoma	1.47 ± 0.12	13 ± 7	0 ± 8	0 ± 7	NA	NA
	Austin, Texas	1.49 ± 0.12	0 ± 7	0 ± 8	0 ± 7	NA	NA
	Dallas, Texas	1.47 ± 0.12	ND	0 ± 8	0 ± 7	NA	NA
1975	Albuquerque, New Mexico	1.46 ± 0.11	5 ± 7	-2 ± 8	-1 ± 7	1 ± 5	1 ± 1
	Oklahoma City, Oklahoma	1.43 ± 0.13	11 ± 7	-1 ± 9	0 ± 8	-2 ± 5	6.5 ± 1.7
	Austin, Texas	1.51 ± 0.12	7 ± 7	-2 ± 9	0 ± 7	-1 ± 5	1.1 ± 1.9
	Dallas, Texas	1.50 ± 0.12	10 ± 7	-1 ± 9	0 ± 7	1 ± 5	4.7 ± 1.4
1976	Albuquerque, New Mexico	1.45 ± 0.12	6 ± 7	-3 ± 9	1 ± 7	NA	NA
	Oklahoma City, Oklahoma	1.47 ± 0.12	6 ± 7	0 ± 9	0 ± 8	0 ± 5	3.6 ± 0.9
	Austin, Texas	1.48 ± 0.11	6 ± 7	-2 ± 9	0 ± 7	0 ± 5	1.1 ± 0.9
	Dallas, Texas	1.48 ± 0.12	6 ± 7	-4 ± 9	0 ± 0	-1 ± 5	4.7 ± 1.4
1977	Albuquerque, New Mexico	1.51 ± 0.12	5 ± 7	2 ± 9	3 ± 7	2 ± 5	1.0 ± 0.5
	Oklahoma City, Oklahoma	1.55 ± 0.12	5 ± 8	4 ± 10	2 ± 8	2 ± 5	3.4 ± 1.0
	Austin, Texas	1.50 ± 0.12	5 ± 8	2 ± 9	1 ± 7	1 ± 5	1.0 ± 0.5
	Dallas, Texas	1.50 ± 0.12	6 ± 7	2 ± 9	0 ± 7	3 ± 5	2.7 ± 0.7
1978	Albuquerque, New Mexico	1.46 ± 0.12	4 ± 7	1 ± 9	2 ± 7	0 ± 5	1.4 ± 0.8
	Oklahoma City, Oklahoma	1.47 ± 0.12	5 ± 7	2 ± 9	2 ± 7	-2 ± 5	5.5 ± 1.8
	Austin, Texas	1.45 ± 0.12	4 ± 7	1 ± 9	1 ± 7	0 ± 5	1.3 ± 1.2
	Dallas, Texas	1.50 ± 0.12	5 ± 8	2 ± 9	0 ± 7	0 ± 5	3.9 ± 1.1

Abbreviations: ND = not detected; NA = no analysis.

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1 x 10^{-12} curie.

Table 4-16. Background radiological characteristics of selected environmental media for regions surrounding the Dalhart basin: gross plutonium and uranium measurements of pasteurized milk[a]

Year	Location	Average annual concentration ($pCi/\ell \pm 2\sigma$)[b]			
		Pu-238	Pu-239	U-234	U-238
1974	Albuquerque, New Mexico	<0.015	<0.015	NA	NA
	Oklahoma City, Oklahoma	<0.015	<0.015	NA	NA
1975	Albuquerque, New Mexico	<0.015	<0.015	0.073 ± 0.027	0.021 ± 0.014
	Oklahoma City, Oklahoma	<0.015	<0.015	0.077 ± 0.028	0.072 ± 0.027
1976	Albuquerque, New Mexico	<0.015	<0.015	0.180 ± 0.018	0.110 ± 0.013
	Oklahoma City, Oklahoma	<0.015	<0.015	0.072 ± 0.014	0.037 ± 0.010
1977	Albuquerque, New Mexico	<0.0	0.005 ± 0.004	0.110 ± 0.024	0.125 ± 0.031
	Oklahoma City, Oklahoma	<0.004 ± 0.004	0.006 ± 0.006	0.151 ± 0.039	0.084 ± 0.027

Abbreviation: NA = no analysis.

[a]From USEPA (1975-1979).
[b]One picocurie (pCi) is equal to 1×10^{-12} curie.

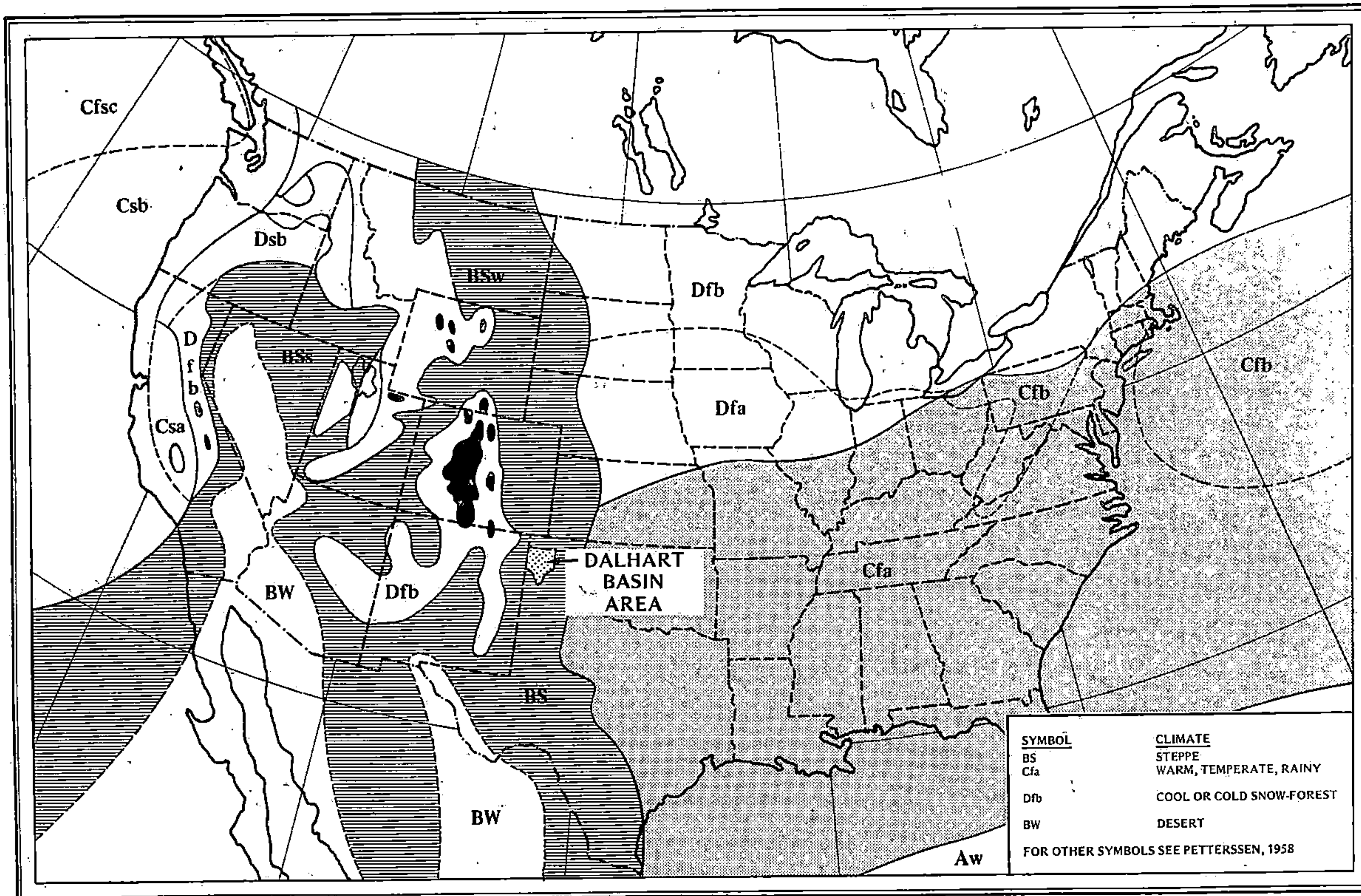
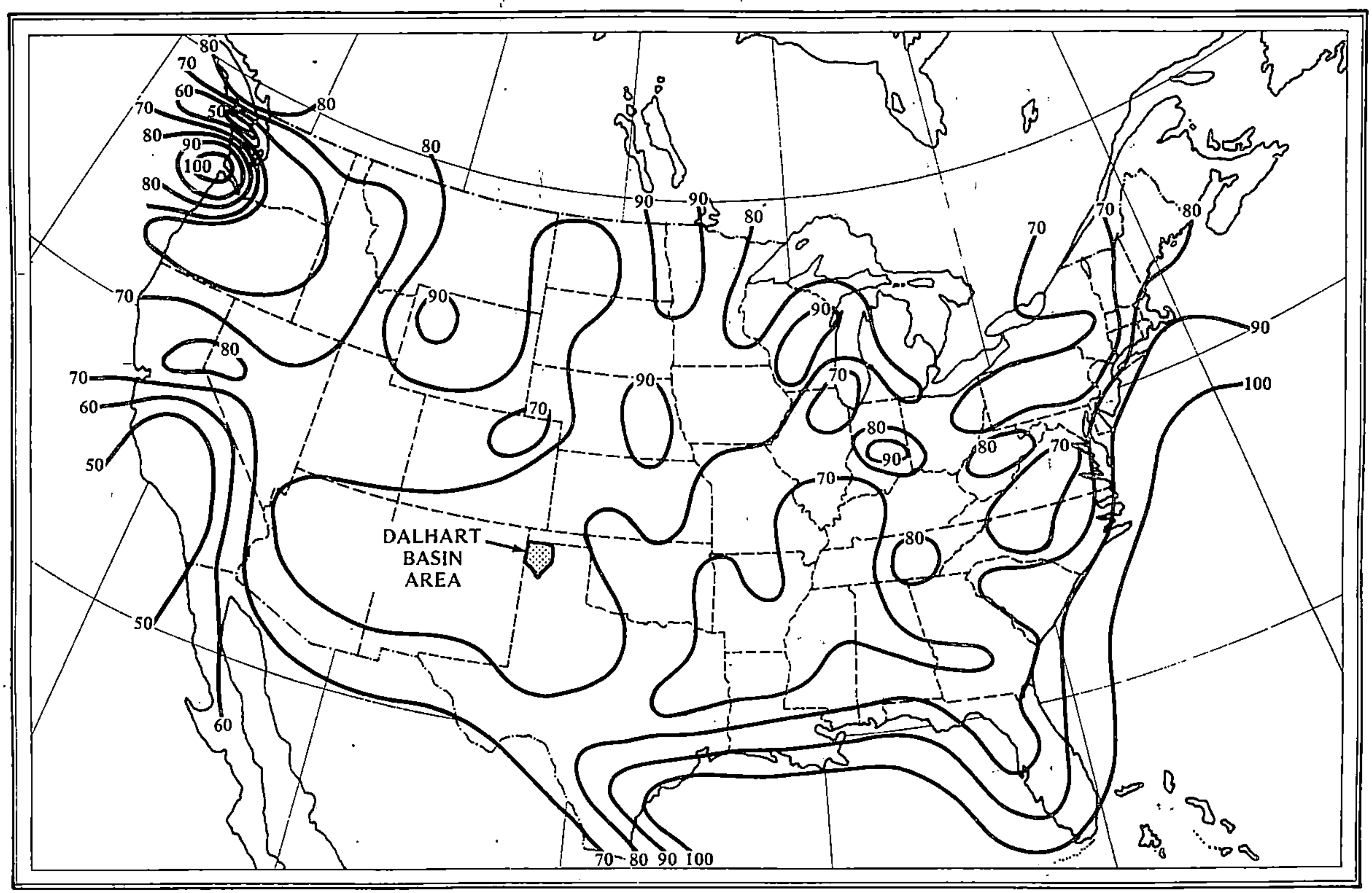


Figure 4-1. The climatic regions of the United States according to the Koeppen classification.



BASED ON SIMIU, 1979

Figure 4-2. 100-year recurrence interval wind speeds (mph)

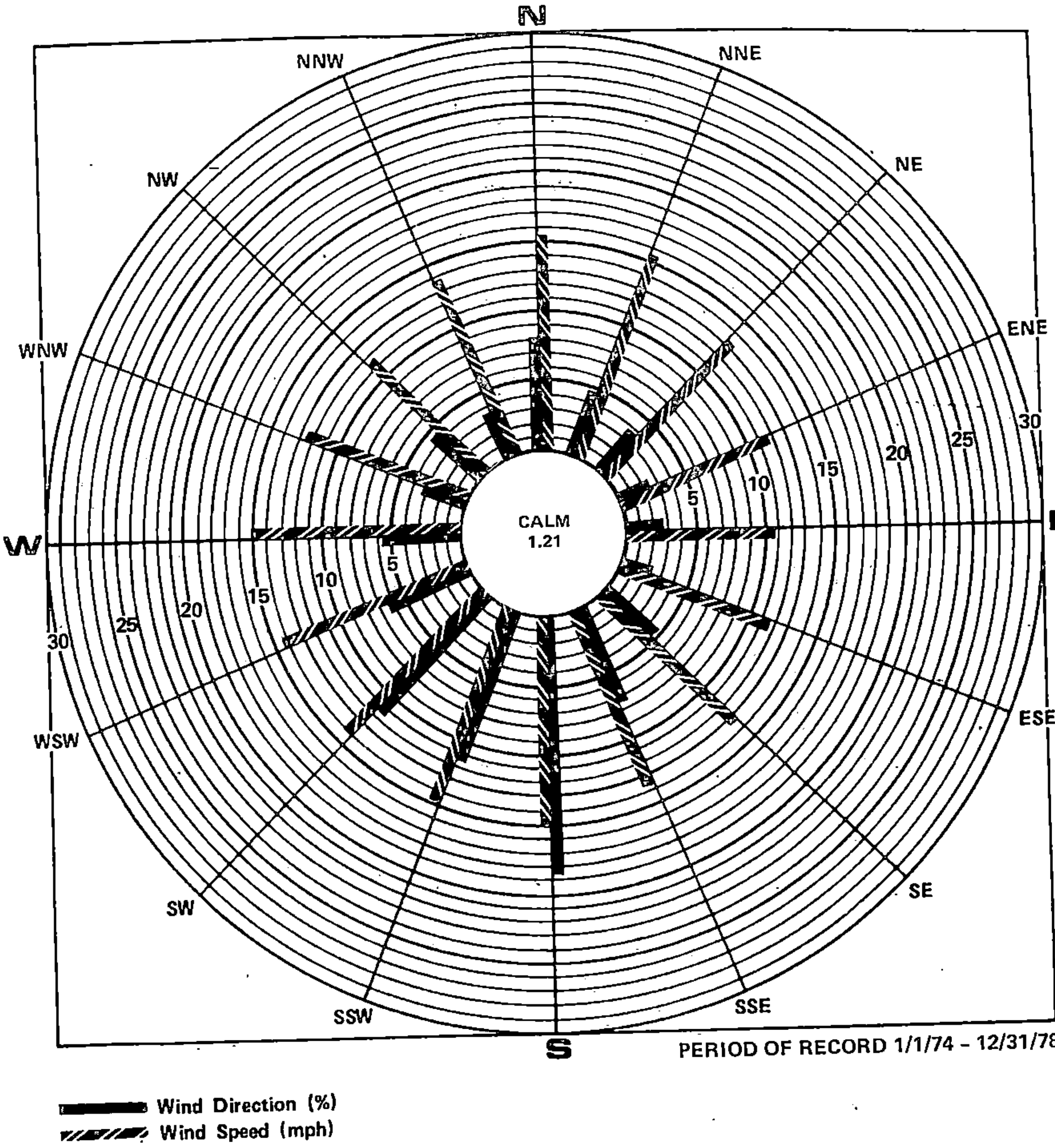
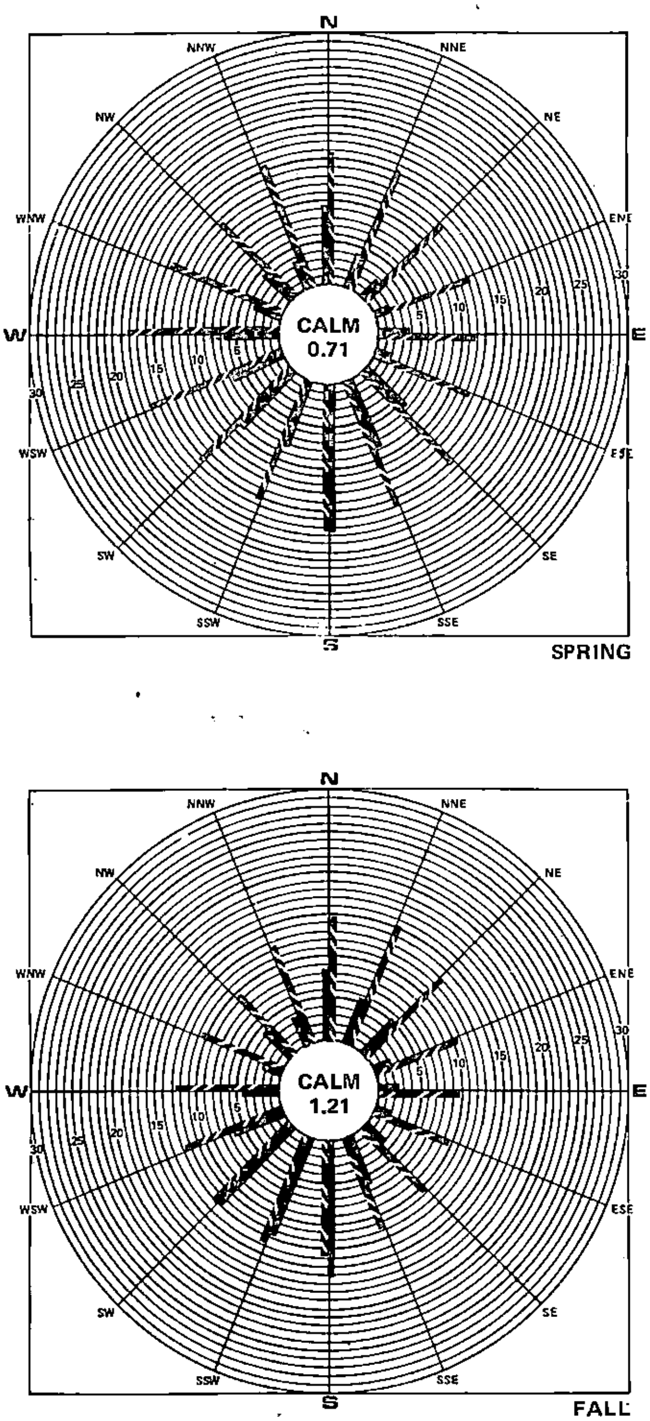


Figure 4-3. Annual wind rose for Amarillo, Texas.



PERIOD OF RECORD 1/11/74 - 12/31/78
WIND DIRECTION (%)
WIND SPEED (MPH)

Figure 4-4. Seasonal wind roses for Amarillo, Texas.

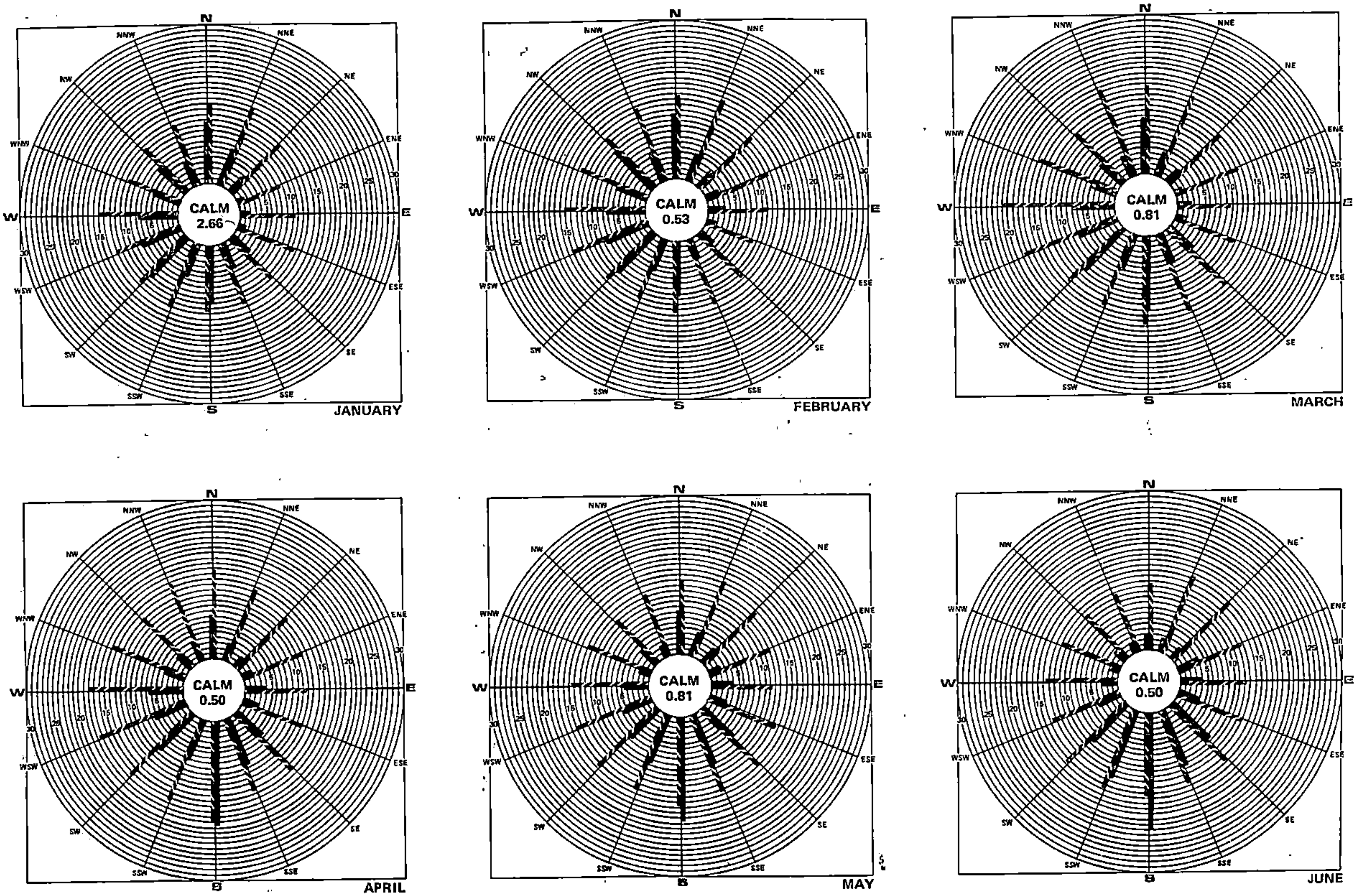
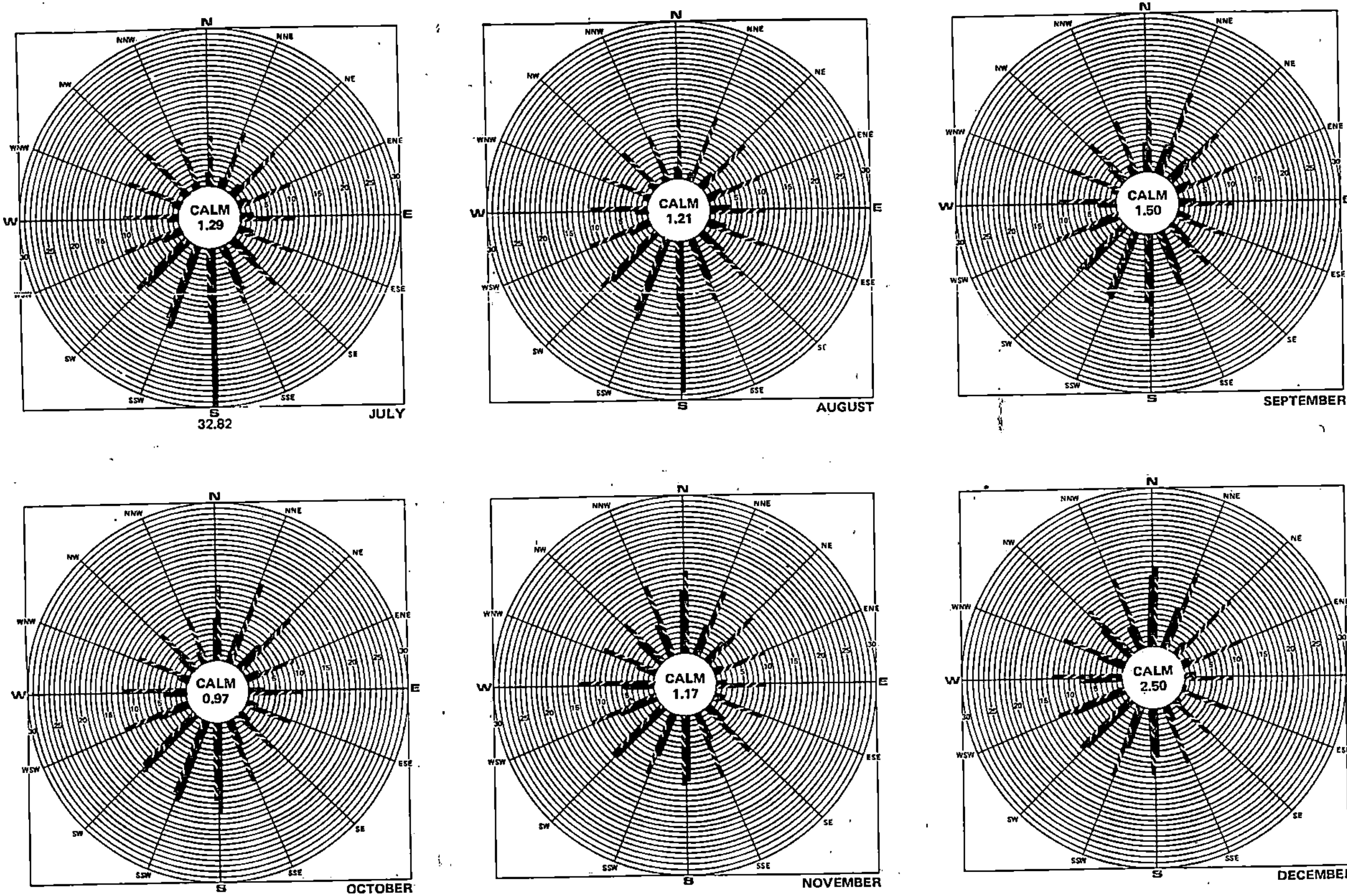


Figure 4-5. Monthly wind roses for Amarillo, Texas.

PERIOD OF RECORD 1/1/74 - 12/31/78
WIND DIRECTION (%)
WIND SPEED (MPH)



PERIOD OF RECORD 1/1/74 – 12/31/78
WIND DIRECTION (%)
WIND SPEED (MPH)

Figure 4-5. Monthly wind roses for Amarillo, Texas (continued).

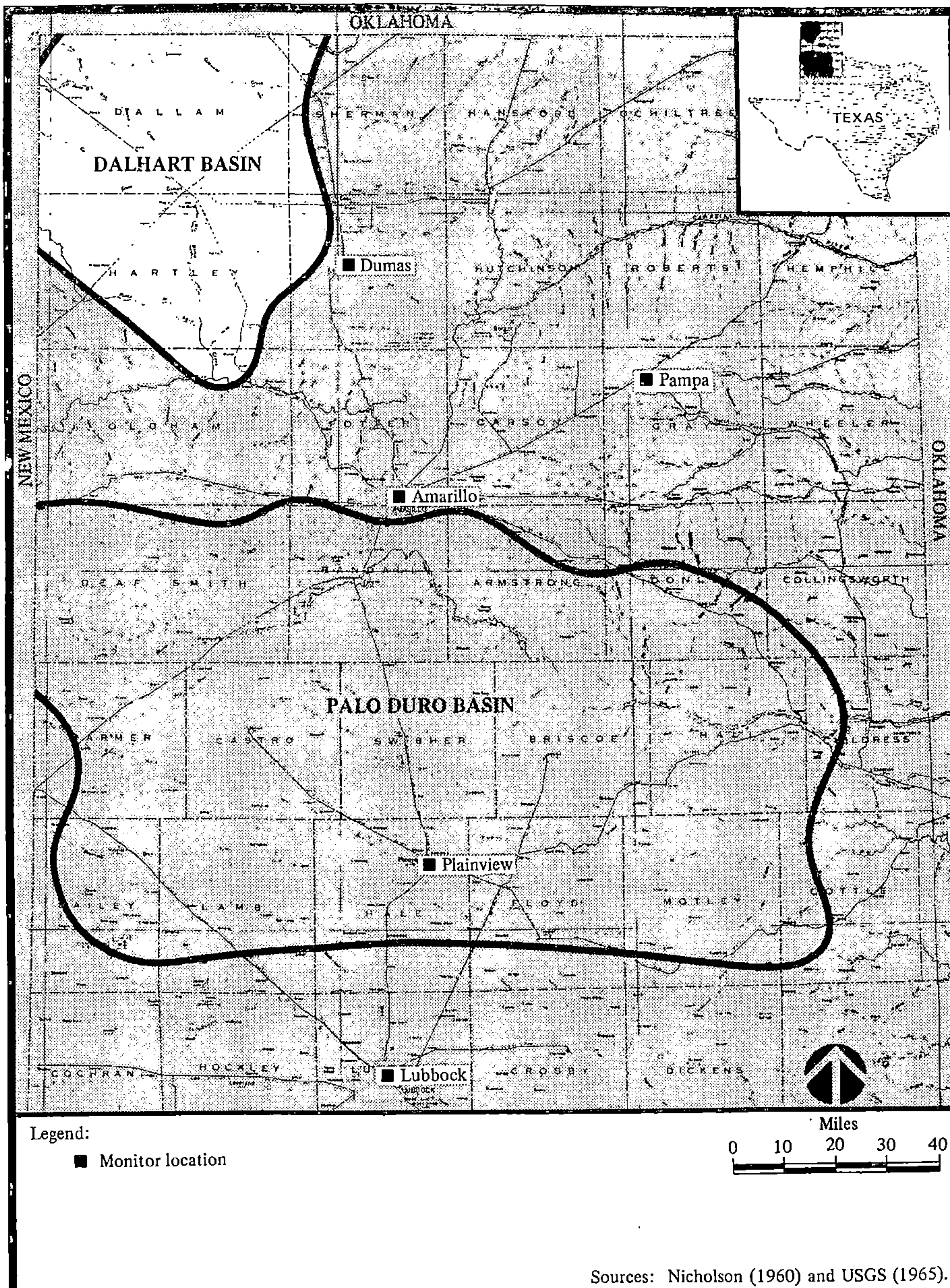
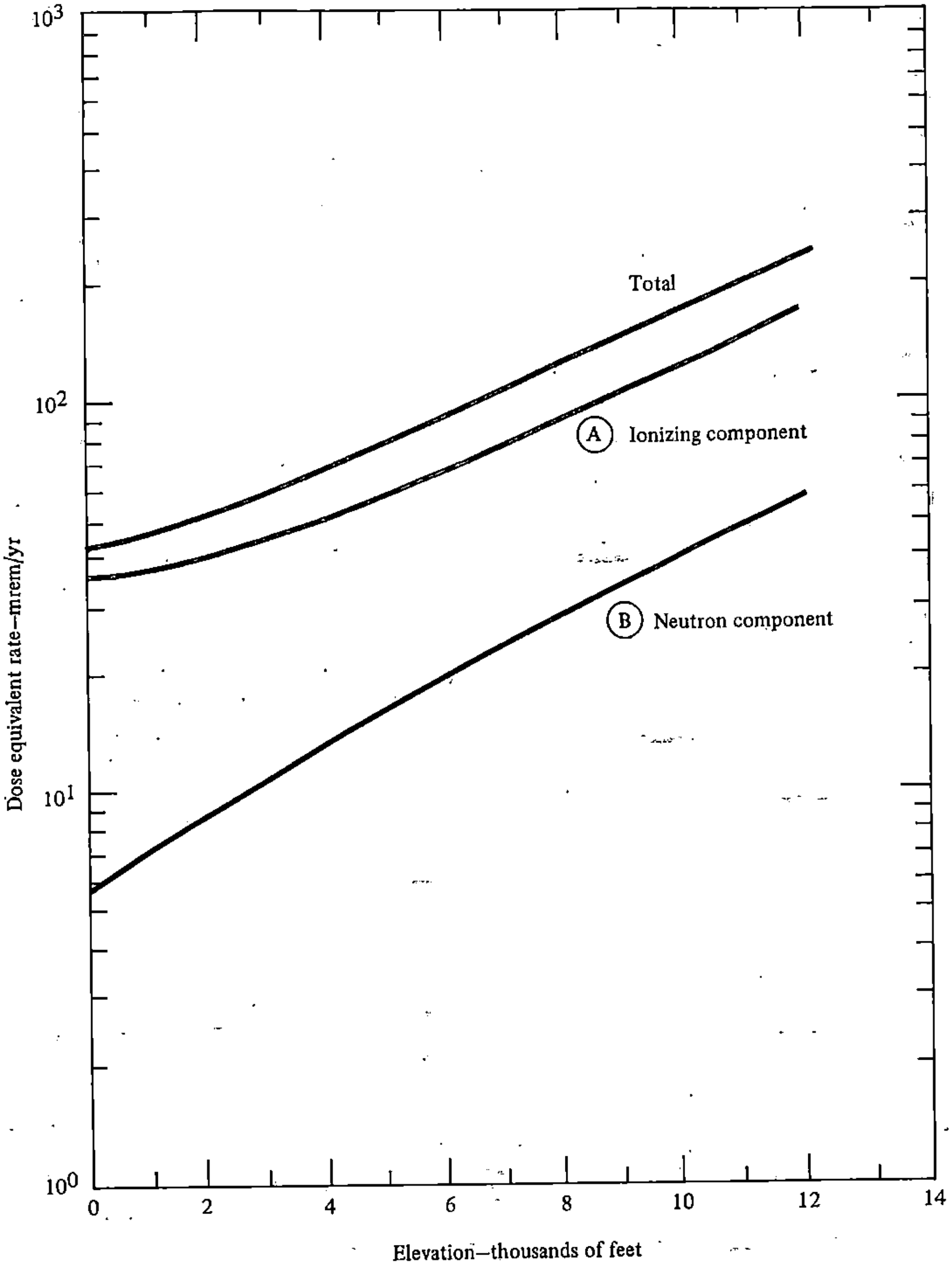


Figure 4-6. Locations of particulate monitors (listed in Table 4-6).



Source: Oakley (1972)

Notes.

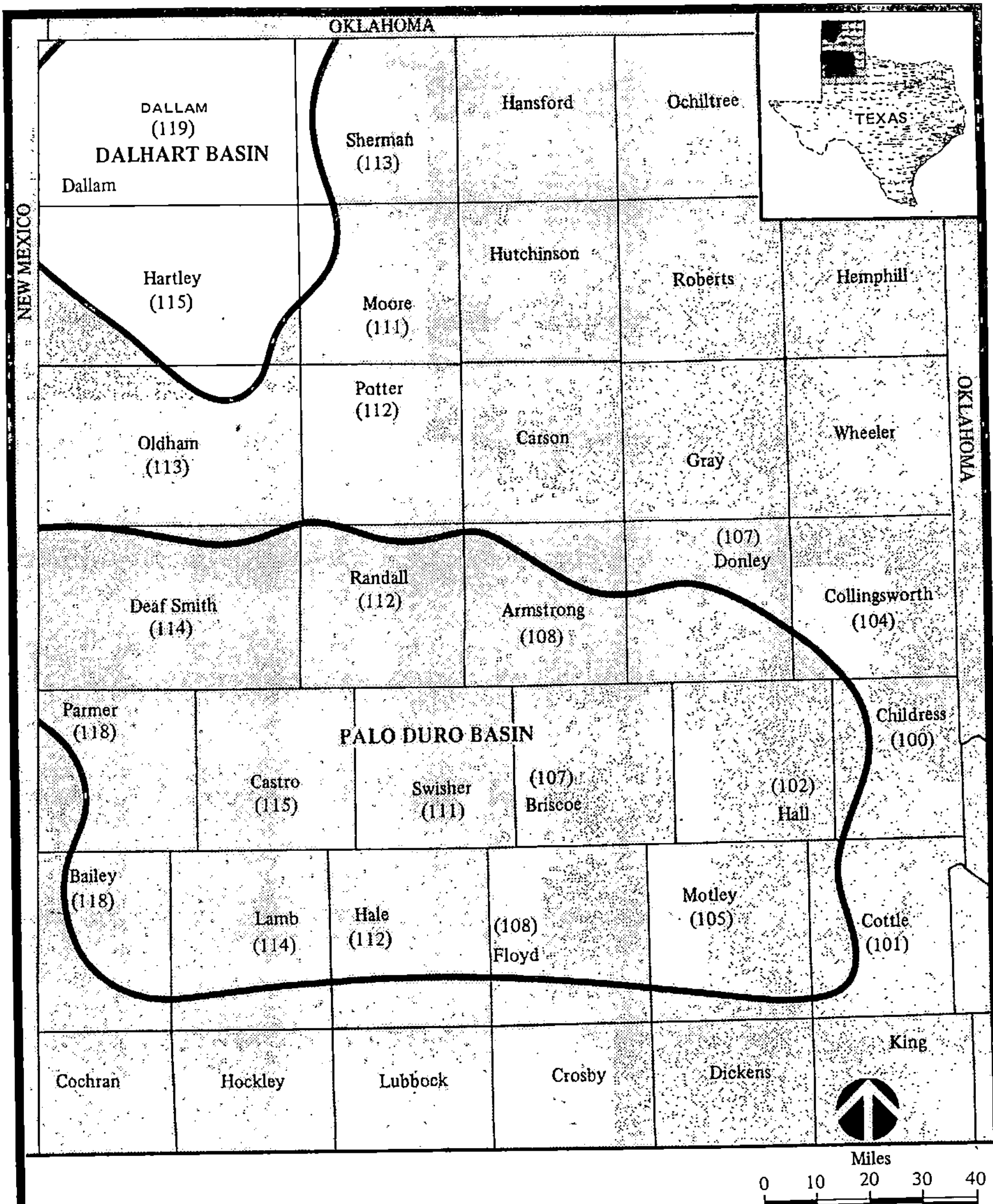
(A) Ionizing component determined by lead-squares fit to profile of Lowder and Beck (1966) and normalized to sea-level value of 2.44 or 35.3 mrem/yr.

(B) Neutron component $5.6\ \text{mrem/yr} \times \exp\left(\frac{1033 - P_e}{165}\right)$

$1033\ g/cm^2$ = Sea-level pressure of U.S. standard atmosphere

P_e = Pressure at elevation e

Figure 4–7. Cosmic ray dose equivalent vs. elevation.



Note: Indicated mrem/yr is given in the parentheses.

Source: Oakley (1972).

Figure 4-8. Dalhart external background radiation levels (sum of external doses from cosmic, terrestrial, and fallout sources), mrem/yr

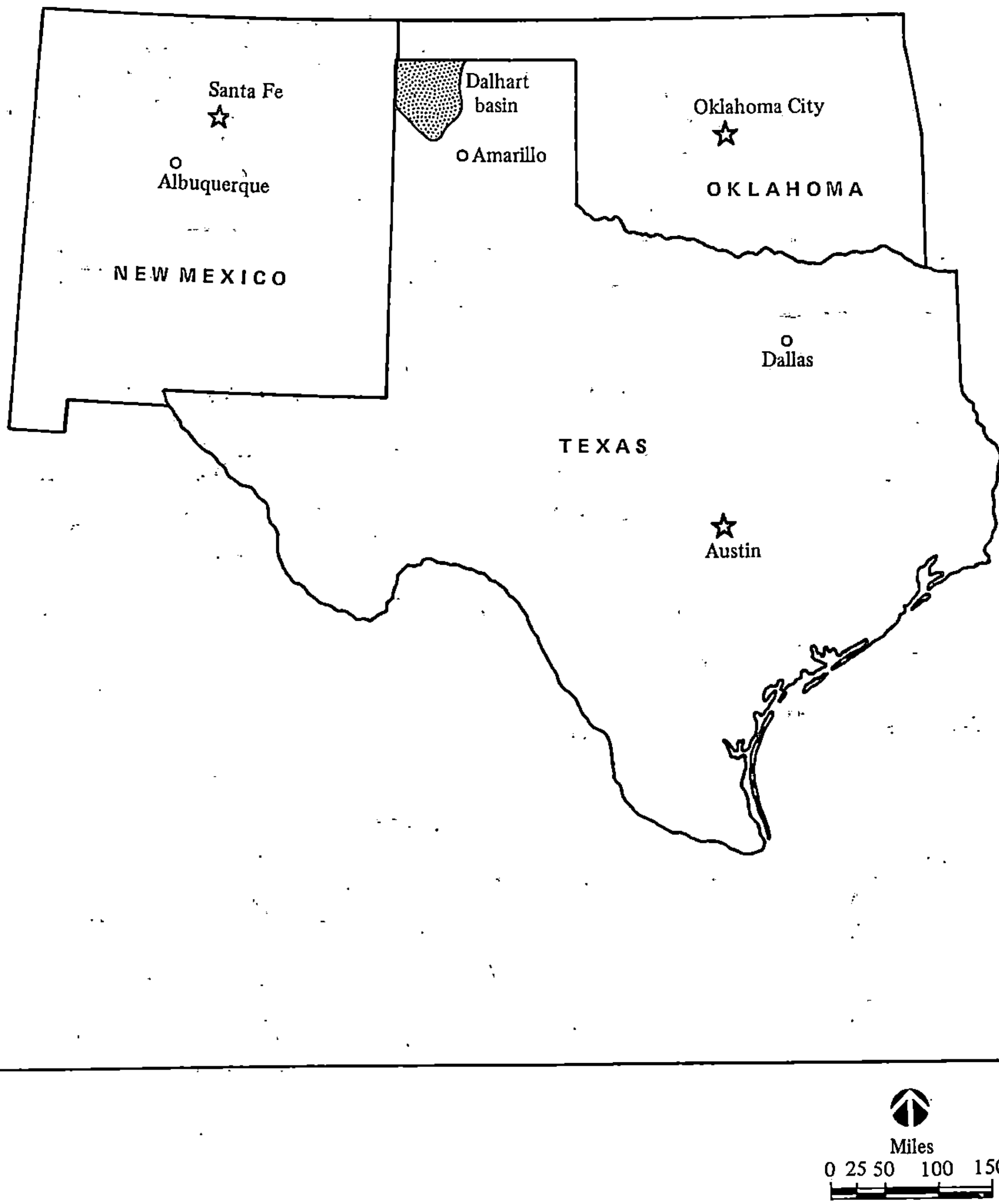


Figure 4-9. Sampling locations of environmental media for regions surrounding the Dalhart basin.