DOE/EIS-0026-D

DRAFT
ENVIRONMENTAL IMPACT STATEMENT

Waste Isolation Pilot Plant

POOR ORIGINAL

Volume 2 of 2
Appendices

April 1979

1789 001

U.S. DEPARTMENT OF ENERGY

8001220 598

Appendix A

ALTERNATIVE GEOLOGIC ENVIRONMENTS

1789 002

CONTENTS

Appendix A

ALTERNATIVE GEOLOGIC ENVIRONMENTS

For the near future (10 to 15 years), the only method available for the permanent disposal of transuranic and high-level wastes is emplacement in cavities mined in a geologic formation. Several types of geologic formations show promise as burial environments--salt, crystalline rock, argillaceous rock, and tuff. Which of these is to be used for a repository depends on when the choice among them is to be made; the longer one waits to make this decision, the greater the number of choices that are open. The time scales for these choices are summarized in Chapter 2 of this document.

A comprehensive review of the candidate geologic media appears in the draft generic environmental impact statement (GEIS) for the Management of Commercially Generated Radioactive Waste (DOE, 1978). Another recent review has been made by the Interagency Review Group (IRG) on Nuclear Waste Management, whose reports (IRG, 1979; IRG Subgroup, 1978) contain recommendations about the choice of geologic media. References to other reviews and to detailed data appear in the GEIS and in the IRG reports.

After presenting background material that explains the bases for choosing a rock medium, this appendix reviews each of the four candidate media.

A.1 GENERAL BASIS FOR CHOOSING A ROCK MEDIUM

The selection of a specific medium depends on two major properties: geologic and hydrologic characteristics, which must resist forces that might expose the buried waste to the biosphere, and structural characteristics, which must permit the construction of a mined cavity without disturbing the geologic and hydrologic characteristics.

The geologic characteristics are important because the purpose of a waste repository is to provide a place in which a solid material can be buried permanently. As long as the material remains solid, it has little chance of leaving its place of burial because it can do so only if some process opens the earth to the depth of the burial point or if the surface is removed to that depth. Therefore geologic formations that have been stable for long periods are sought for repository locations, on the assumption that the long-inactive disruptive forces in the earth there will remain inactive.

Material buried in solid form might return to the surface in another way: by being engulfed in a stream of water that dissolves the material and carries it to the surface. Because the forces that influence the flow of underground water are less catastrophic (and potentially more likely) than those that might uncover a deeply buried solid, the hydrologic characteristics of a medium may have greater influence on its selection than the geologic characteristics. A satisfactory rock medium must present little threat that its hydrologic and geologic characteristics could provide a mechanism or pathway by which the waste could return in harmful quantities.

The structural characteristics of the rock are important because a repository must be designed, constructed, and operated in such a fashion that it will not upset the geologic and hydrologic characteristics. Because a repository is an engineered structure, its ability to isolate the waste will depend on the material in which it is constructed. Consequently, the selection of the geologic medium must facilitate the engineering design of a structure that will have a minimum probability of releasing its contents.

To be able to design the underground structure to minimize its impact on the hydraulic environment, the burial medium must be chosen with special attention to its mechanical, physical, and chemical properties. In repositories that contain heat-producing waste, the burial medium must be able to withstand the thermal stresses induced by that waste. Furthermore, establishing an effective design requires analytical models for the structure that take into account the properties of the geologic medium; without meeting this fundamental requirement, it would be extremely difficult to be confident that the design of the repository meets the fundamental requirements. The ability to conduct the engineering analysis depends strongly on thorough knowledge of the properties of a proposed medium. For this reason, the preferred medium must have well-studied properties.

To decide in detail whether the properties of a geologic medium are satisfactory requires that several questions be answered, including the following:

- Will the subsurface structure be able to remain open and operable over the planned lifetime of the repository?
- Can the structure be used for waste disposal without adversely affecting the surrounding geologic and hydrologic environments?
- Can the structure be used without adversely affecting its own structural integrity?
- Will the structural material be adversely affected by heat, or will it react chemically with the waste?
- Will the surrounding geologic material react chemically with the waste?

By reviewing these questions along with others, it is possible to identify specifically the important properties of a geologic medium. Among the chemical properties, it is necessary to understand the solubility and chemical stability of the medium, its ability to resist chemical change during heating, and the corrosiveness of fluids that exist in it. Important mechanical properties include tensile and compressive strength and stress-strain relationships as expressed by elastic and bulk moduli. Important physical properties include thermal conductivity, thermal expansion, heat capacity, and decrepitation temperature. These properties are not known equally well for all the candidate media.

In addition to knowing these basic data, it is important to have a well-developed mathematical model for predicting the mechanical behavior of a repository in the chosen medium. This model must predict the stresses, deformations, and temperatures that the geologic medium will experience. It must model the mechanisms by which the structure or its surroundings can fail; it can then test the conditions (stress, temperature, etc.) under which failure could occur.

Each of the four sections that follow reviews a geologic medium in the context of this discussion. Table A-1 compares the three major geologic media according to a number of important properties.

A.2 SALT

When geologic media were first evaluated for the emplacement of radioactive waste, salt was judged to be the best choice for a number of reasons, including long-term geologic stability, spatial predictability, suitability for engineering analysis, thermal and mechanical properties, ease of repository construction, freedom from circulating groundwater, chemical stability, and existence of extensive masses of uniform material. The original report of a committee established by the National Academy of Sciences-National Research Council (NAS-NRC 1957) recommended that salt be evaluated as a storage medium because it has excellent thermal and physical properties. The report pointed out that the existence of salt formations for several hundred million years demonstrates that they have been isolated from disturbing forces on the surface and from circulating groundwater; consequently, there is an extremely high probability that they will remain isolated in the future. Other desirable features of salt formations are their uniform consistency, simple geologic structure, and predictable stratigraphic character over large regions. Furthermore, the mechanical and physical properties of salt are known well enough to provide a good basis for the engineering analyses necessary for designing a repository.

Experiments to confirm the evaluation of salt as a suitable geologic medium began in 1965 under Project Salt Vault (Bradshaw and McClain, 1971), which operated for 2 years. Other experiments have been conducted over the past decade at the Asse experimental repository in the Federal Republic of Germany (Kuehn et al., 1976). The experiments have confirmed the basic understanding of the fundamental properties of salt and the engineering analysis required to design a repository in salt.

Project Salt Vault brought to the attention of repository designers the phenomenon of brine migration: small amounts of brine that occur in salt (usually less than 1% by weight) move toward emplaced heat sources. It has been asserted that accumulations of brine in salt can lower its mechanical strength. As long as the brine remains distributed, however, its impact on strength will be minimal. Migration phenomena and reduction in strength can be considered potential problems only when elevated temperatures with large thermal gradients are present. Migration of brine toward heat sources is being investigated to determine whether it can increase the water content of the salt near hot waste and affect the strength of the salt there.

In a TRU-waste repository, reduced strength of salt due to the presence of brine is of minimal significance because little heat-producing waste will be emplaced there. For centuries underground mines have been built in salt; the stability of these mines has not been measurably affected by the presence of brine. The TRU waste in the repository will not provide significant heat-induced perturbing forces on the structure or its surroundings.

The intrinsic properties that make salt an attractive medium include uniformly low permeability, high thermal conductivity, abundance in thick masses, and plasticity that enables fractures to heal themselves at feasible

Table A-1. Comparison of Media

Property	Salt	Basalt or granite	Shale
BASIC PROPERTIES			
Plasticity	High	None	Variable
Solubility	High	Very low	Very low
Sorptive capacity	Low (depends on impurities)	Fair	High
Compressive strength	Moderate	High	Moderate
Thermal diffusivity	High	Low	Low
Thermal stability against chemical decomposition	High	High; potential dewatering of clay in basalt	High; potential dewatering of clay
IN-SITU PROPERTIES			
Porosity	0.5% Interstitial	1% Cracks	5-30% Cracks
Permeability	Essentially none	Decreases with depth	Very low
Water presence	Isolated from flowing groundwater	Present, open to flowing groundwater	Present, open to flowing groundwater
Corrosiveness of indigenous fluid	High	Low to moderate	Low to moderate
Tectonic stability	Very stable	Very stable areas can be found	Very stable areas can be found
Geologic structure	Relatively simple areas can be found	Fracture systems often complex	Like salt
Geohydrology	Moderate difficulty in characterizing	Difficult to characterize	Difficult to characterize
PRACTICAL MATTERS			
Availability	Good	Good	Good
Need to use explosives	No	Yes	Possibly
Understanding of medium for repository use	Well studied	Not well studied	Not well studied
Waste rock	Reuse some; pile needs protection from erosion and runoff	Reuse some; pile probably does not need protection	Reuse some; pile needs protection, but less than salt
Mathematical modeling	Relatively simple; well developed	Relatively complex; not fully developed	Relatively complex; not fully developed

repository depths. However, the high solubility of salt requires that extensive knowledge of regional and site hydrology be obtained before a repository site is selected; it will be necessary to develop an understanding about possible future groundwater flow at a chosen site.

The solubility of rock salt in water is two orders of magnitude greater than that of any other candidate medium. If man-made or natural events caused a breach in the repository, circulating groundwater could release the radionuclides in the waste, although the sorptive capacity of the geologic materials along the flow paths would retard the release of these nuclides. A thorough knowledge of these sorption properties is required for the particular rocks and the particular groundwaters at a repository. Generally, the sorptive capacity of salt is low and dependent on the impurities in salt.

Extensive salt mining in many locations around the United States and abroad has resulted in a well-developed salt-mining technology. One particular advantage associated with salt mining is that, after shaft construction, explosives are not needed. Electrically powered continuous-mining machines can construct the storage rooms; diesel-powered carriers haul the mined salt to branch-corridor conveyors, which are frequently extended to keep the hauling distances as short as possible.

Salt differs from basalt and shale in the potential environmental impacts of the waste rock from mining that has to be stored at the surface. The surface-storage pile would have to be designed to limit wind erosion and precipitation runoff in order to minimize potential environmental impacts during and after repository operation.

In summary, salt is the best understood of all candidate geologic media with respect to its possible use as a waste-repository medium, and it offers advantages in thermal properties and plasticity. It is found in many places in the United States (Figure A-1). In addition, a bedded-salt repository would offer an opportunity to experiment with high-level waste and demonstrate the disposal of commercial spent fuel in salt. The Interagency Review Group on Nuclear Waste Management has concluded (IRG Subgroup, 1978, Appendix A, p. 67) that "with appropriate selection of a site and appropriate hydrogeology and conservative engineering, salt could be an appropriate repository medium."

A.3 CRYSTALLINE ROCK

Basalt, granite, and other crystalline igneous and metamorphic rocks have been proposed as geologic media for a repository; extensive deposits that have been stable for millions of years exist in the United States. The evaluation of these media is in an early stage of data collection, and an effort is under way to compile the information systematically. The basic mechanical properties (compressive strength, tensile strength, modulus of elasticity, etc.) of these rocks have been established through laboratory tests. The properties of the aggregate are, however, considered to be substantially different from the small samples of whole rock because crystalline rocks are fractured and cannot be reconstituted (unlike fracture salt, which will "weld" under lithostatic pressure). It is technically possible to build openings in crystalline rocks; still under development are analytical procedures that will completely evaluate the impact of thermal loads on mine structures in such rock or the surrounding rock formations.

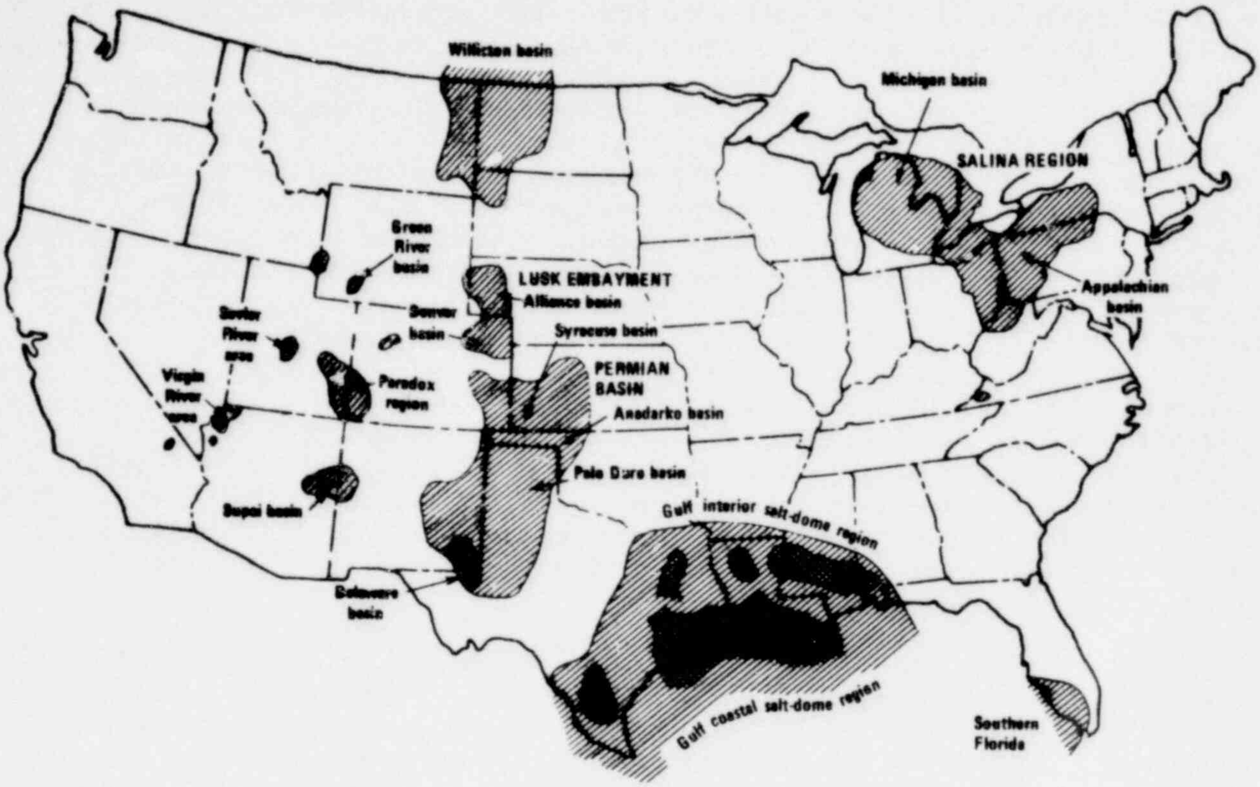


Figure A-1. Rock-salt deposits in the United States.

Crystalline rocks do not dissipate heat as well as salt does; the thermal conductivities of crystalline rocks are about one-fourth that of salt. Each repository in crystalline rocks will be designed with heat loads adjusted to the thermal conductivity prevailing at the site. For some time heat transfer through crystalline rock has been considered a potential problem because the effects of cracks on thermal conductivity are not well known; heat dissipation in a medium with a random pattern of cracks is presently difficult to analyze. Experiments measuring heat conduction in granite are under way in Sweden and at the Nevada Test Site (NTS). The test at NTS showed that the cracks in NTS rocks affected the thermal conductivity by less than 10%. Tests conducted at both locations confirm that temperature distributions in hard rock can be calculated with a high level of accuracy.

Although large formations of salt, while soluble in water, are impervious to the flow of water, large formations of crystalline rocks are full of fractures that would provide convenient paths for water flow. In a backfilled, sealed repository built below the water table in crystalline rock, the cracks and void spaces may eventually fill with water. Because the cracks throughout the formation are mostly small, the ratio of water volume to rock volume is small. Nevertheless, a major drawback is that it is not yet possible to calculate the total flow and mass transport under the fracture-flow conditions. In addition, it is not yet possible to identify the effects that thermal loading will exert on the flow of water into or out of a sealed repository. Techniques for making these calculations are being developed.

1789 009

Because the water in crystalline rocks is more mobile than the water in salt, it may contribute to slow leaching of the radioactive nuclides from the waste. Although this condition might appear to be a problem, the magnitude of the problem is diminished because granite and basalt have sorptive properties that cause the radioactive elements in the water to be removed by chemically reacting with the rock. Water found in these formations typically has low ionic strengths that reduce the possible adverse effects on these sorptive properties. Because of these favorable natural conditions, it appears that the corrosion of waste canisters stored in a crystalline-rock repository will be slow; the canister may maintain its integrity over many hundreds of years.

Flow through a fractured medium will depend on the connectedness and size of the fractures. Their size is controlled to a large extent by the normal stresses acting across the fractures; since these stresses increase with depth, the permeability of crystalline rock usually decreases with depth. Although a model has not been established to accurately evaluate fracture flow, experience has shown that at depths of 1500 feet or more below the surface the fracture permeability is so low that it may not be a significant threat even when conservatively evaluated.

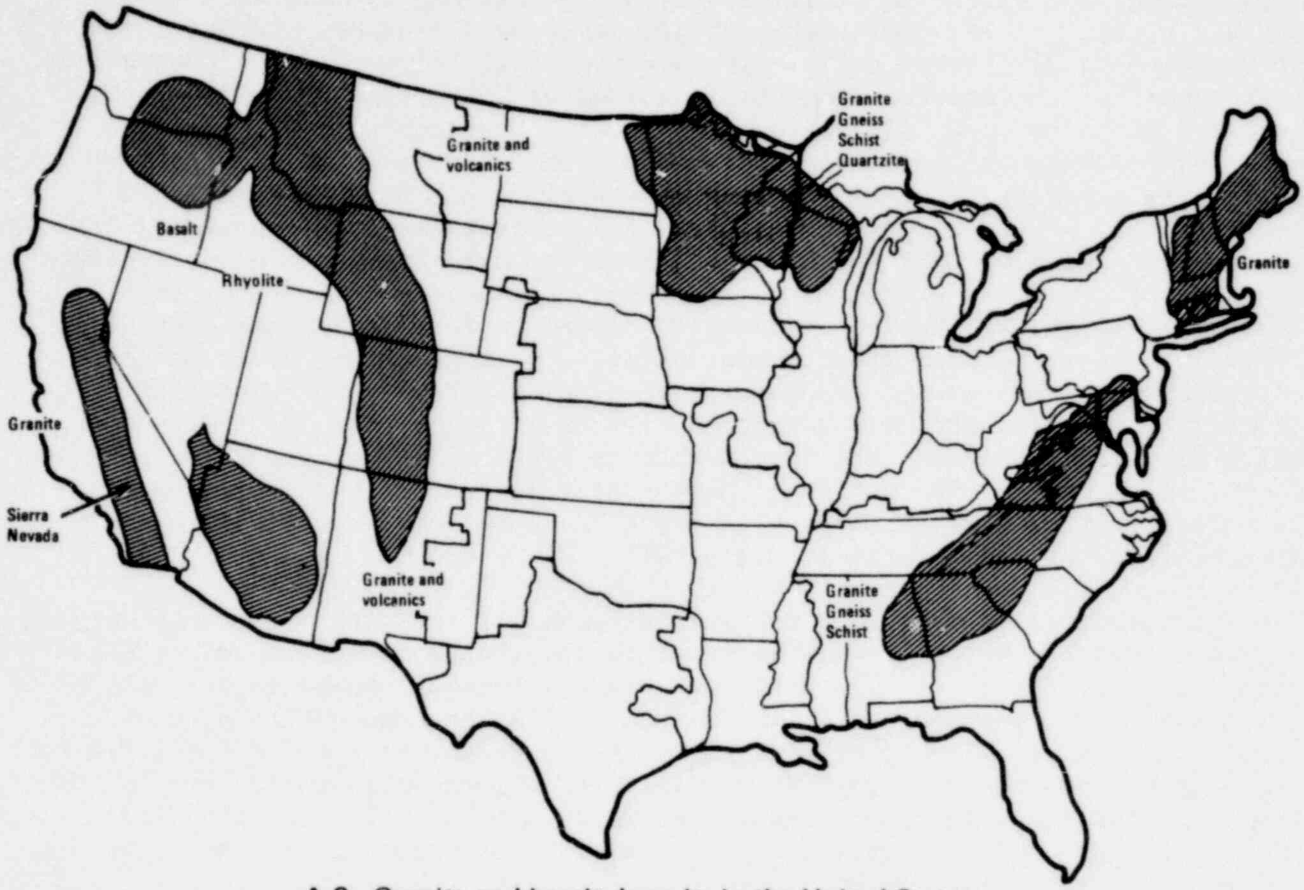
A major difference between crystalline rock and salt will be in the methods of construction. While it will be possible in salt to use mining machines, crystalline rock will require drill-and-blast techniques whose impact on the integrity of a repository is still unknown. It might appear that such techniques could adversely affect the rock within a few meters around the mined openings. Since the rock beyond this affected volume will provide the required isolation, it is not clear that drill-and-blast construction will affect the long-term integrity of a repository. Experiments will be necessary to answer this question.

Major formations of granite and basalt exist in the United States; Figure A-2 shows their general locations. Reconnaissance studies have shown that the attractive granite formations include those in New England, the Rocky Mountain uplift, the Sierra Nevada Mountain Range, the Appalachian Mountains, and the Canadian Shield in northern Minnesota and Wisconsin. The basalt formations of interest are Columbia Plateau Flood Basalts in Washington, Oregon, and Idaho. Because both the granite and the basalt formations are extensive, there is ample opportunity to find suitable sites. The field studies providing data on the suitability of crystalline rocks are being conducted by DOE at the Hanford Reservation, at the Nevada Test Site, and in Sweden. Sweden and Canada also have such programs.

A.4 ARGILLACEOUS ROCKS

Argillaceous rocks, especially shales, have also been proposed as geologic media for repositories. Argillaceous rocks vary widely in their characteristics: some shales are relatively plastic, with a high water content; others are relatively brittle, with a low water content. Because of the variation in their structure, these rocks vary widely in mechanical properties. Their strength in a direction perpendicular to the layers is often substantially different from their strength parallel to the layers. Shales exhibit good

1789 010



A-2. Granite and basalt deposits in the United States.

strength properties in compression but little or no strength under tensile load. Shales with a high water content may be highly plastic, deforming slowly under in-situ stresses; while good for closing cracks, this feature is poor for designing, constructing, and operating a mine that must remain open for 20 years. The anisotropy of shale and the possible variations in its properties make shale repositories difficult to model and analyze generically. Site-specific analyses and designs will be necessary for each proposed shale repository.

The ability of argillaceous rock to dissipate heat is comparable to that of crystalline rock. While facilitating uniform heat flow, the presence of substantial quantities of water in shale may set a relatively low upper limit on the temperature of the waste to avoid producing high-pressure gas through the conversion of water to steam. The design of a repository in shale will adjust the thermal output of the waste to avoid this possiblity. Experiments using heaters have been conducted in two different types of shale. The results of tests in wet layered shale are consistent with the above picture. Tests in nonlayered low-water-content shale indicate heat-dissipation characteristics similar to those of granite and basalt. These tests confirm that temperature distributions in different types of shale can be calculated with an acceptable level of accuracy (Tyler et al., 1979).

1789 011

Shale, a material of low in-situ permeability (Magara, 1971), is insoluble in water; it deforms under lithostatic loads, closing inherent joints. Because of these properties, water does not move easily through shale, even though shale may contain substantial quantities of formation water. Although heat could produce a major driving force to move the water, most of the waste to be received at a TRU-waste repository will not provide such a heat.

Argillaceous rocks, like crystalline rocks, may provide an aqueous environment conducive to slow corrosive attack on the encapsulated waste. Entrapped waters found in shale are of intermediate ionic strength, which moderately inhibits corrosive action on canisters. After a canister has been penetrated, the dissolution of the waste inside would also be slow because of the intermediate-level ionic strength of the waters. The presence of radionuclides in the water will be mitigated by two major factors: the slow rate of water movement through the tight shale formations and the strong sorptive affinity of the shale minerals, which reduces the concentration of radionuclides in the water through chemical reactions.

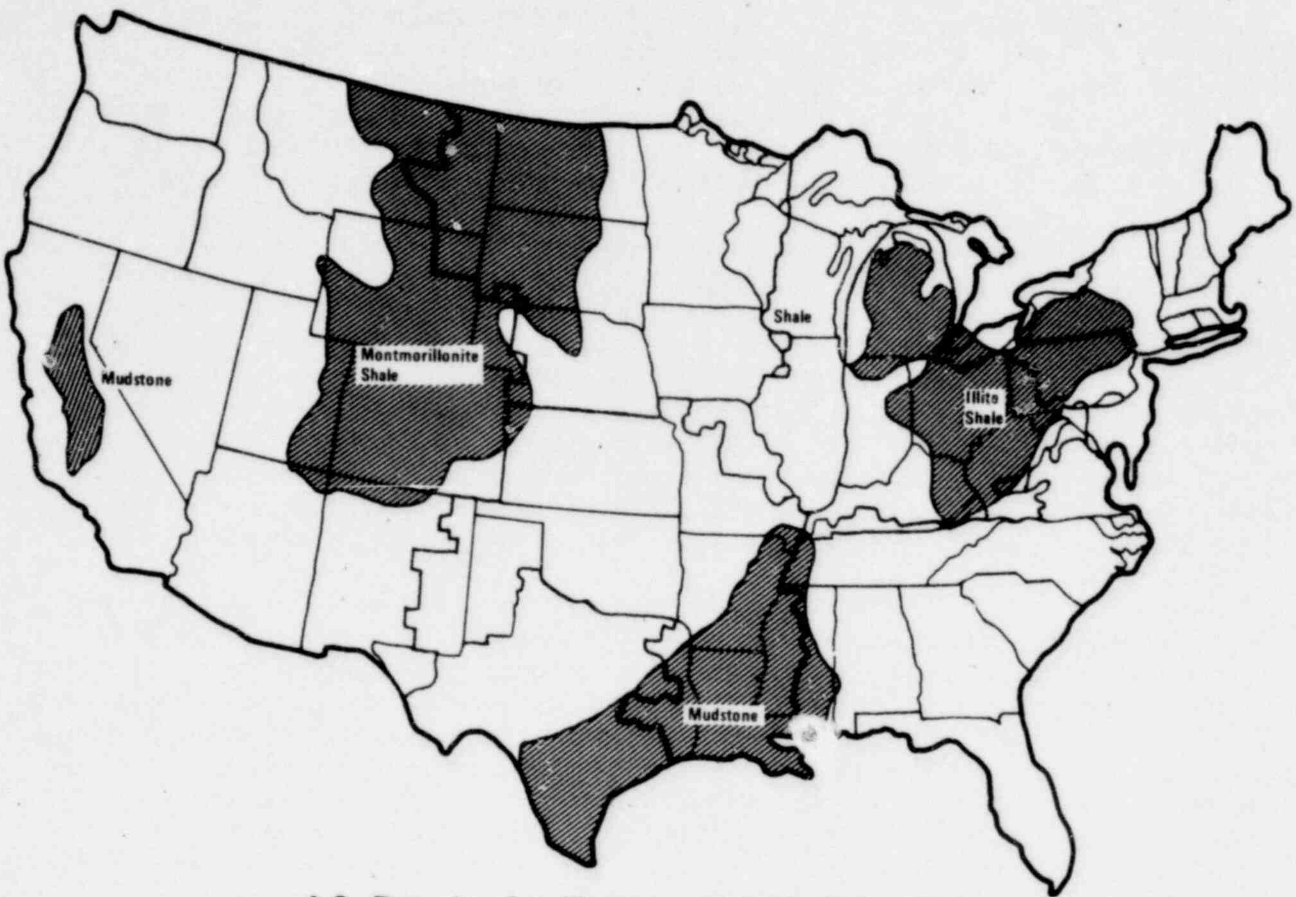
The methods for constructing a repository in shale will vary: the soft layered type of shale could be mined with machines, while the harder argillites might require drill-and-blasting techniques. A major concern about the construction and operation of a repository in shale is the possible occurrence of squeezing zones: thin layers of unusually soft, plastic material that could be squeezed by the lithostatic forces into mined openings. A study of the Eleana argillite at the Nevada Test Site showed that a repository in this type of formation would require substantial expenditures for necessary structural supports underground because of the presence of squeezing zones (Fenix and Scisson, 1978; Yaner and Owen, 1978).

Large formations of argillaceous material are located in the United States; the largest is the Pierre Shale, in portions of North Dakota, South Dakota, Colorado, Montana, and Wyoming. Figure A-3 shows the location of this and other major argillaceous formations in the United States.

A.5 TUFF

Tuff is composed of material ejected from volcanoes; some of the best tuff formations are located in volcano calderas. It has only recently been considered for repositories; data on its suitability have been gathered for approximately 1 year. There are two types of tuff to consider. Welded tuff has low porosity, low permeability, high strength, good thermal stability, and moderate chemical sorptivity. Nonwelded tuff has high porosity, low permeability, high water content, low strength, good thermal stability when dry, unusual thermal expansion properties, and extremely high chemical sorptivity. The first investigations of these materials suggest that they are promising media for the geologic disposal of waste.

1789 012



A-3. Deposits of argillaceous rock in the United States.

Because of the process by which tuffs are deposited, the high-strength, thermally stable, welded tuff is usually surrounded by at least a partial envelope of nonwelded tuff. This arrangement could produce a nearly ideal set of multiple barriers under the proper mineralogical and hydrological conditions.

The complexity of the geologic setting of tuffs makes the engineering design of a repository rather difficult. According to present knowledge, however, this complexity may provide significant benefits.

1789 013

REFERENCES

Bradshaw, R. L., and W. C. McClain, 1971. Project Salt Vault: Demonstration of the Disposal of High-Activity Solidified Wastes in Underground Salt Mines, ORNL-4555, Oak Ridge National Laboratory, Oak Ridge, Tenn.

DOE (U.S. Department of Energy), 1978. Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, prepared by the Pacific Northwest Laboratory, Richland, Wash.

Fenix and Scisson, Inc., 1978. Minability Study of the Terminal Waste Storage Program--Eleana Investigation, NVO-0038-15, prepared for the U.S. Department of Energy.

IRG (Interagency Review Group), 1979. Report to the President by the Interagency Review Group on Nuclear Waste Management, TID-29442, U.S. Department of Energy, Washington, D.C.

IRG Subgroup (Interagency Review Group), 1978. Alternative Technology Strategies for the Isolation of Nuclear Waste (draft), TID-28818, U.S. Department of Energy, Washington, D.C.

Kuehn, K., et al., 1976. "Recent Results and Developments on the Disposal of Radioactive Waste in the Asse Salt Mine," IAEA/NEA International Symposium on Management of Radioactive Wastes from the Nuclear Fuel Cycle.

Magara, K., 1971. "Permeability Considerations in Generation of Abnormal Pressures," Journal of the Society of Petroleum Engineers, Vol. 11, pp. 236-242.

NAS/NRC (National Academy of Sciences-National Research Council), 1957. The Disposal of Radioactive Waste on Land, A Report of the Committee on Waste Disposal, Division of Earth Sciences, Publication 519.

Tyler, L. D., J. F. Cuderman, J. L. Krumhausl, and A. R. Lappin, 1979. "Near-Surface Heater Experiments in Argillaceous Rocks," in Proceedings OECD/NEA Meeting on in situ Heating Experiments in Geologic Formations, September 12-15, 1978, in press.

Yaner, P. I., and G. N. Owen, 1978. Nevada Test Site Terminal Waste Storage Program Subtask 1.3: Facility Hardening Studies: Design Cost Scoping Studies, JAB-99-123, prepared for the U.S. Department of Energy by John Blume and Associates.

1789 014

Appendix B

THE NATIONAL WASTE TERMINAL STORAGE PROGRAM AND ALTERNATIVE GEOLOGIC REGIONS

1789 016

CONTENTS (continued)

LIST OF FIGURES

Appendix B

THE NATIONAL WASTE TERMINAL STORAGE PROGRAM

AND ALTERNATIVE GEOLOGIC REGIONS

The National Waste Terminal Storage (NWTS) program (DOE, 1979) is directed at the development of facilities for the emplacement and disposal of high-level and TRU wastes within deep geologic formations in order to provide safe, long-term isolation of the waste from human activities and from the environment. The program contains these elements:

1. Geologic studies to identify suitable geologic media and potential sites in various geographic regions.

2. Analysis of the behavior of radioactive waste in candidate geologic structures.

3. Engineering and design of operating repositories and associated specialized equipment.

4. Development of packaging and storage methods for unreprocessed spent fuel.

This appendix discusses the nature and status of the first program element listed above.

B.1 REGIONAL STUDIES

Site evaluation activities include geologic studies and supporting regulatory activities. These start with tectonic and hydrologic considerations that apply on a broad national scale; they are subsequently applied to candidate regions and then to investigations of areas within regions, finally resulting in work at specific sites. The confirmation of a potential repository site requires a detailed study of the geologic, hydrologic, environmental, and socioeconomic characteristics of the site. For a site to be acceptable, it must be established, in the framework of licensing regulations, that no credible circumstances would be encountered that would result in releases of radionuclides from the emplaced waste to the biosphere in quantities that would constitute a hazard to the public.

Geologic media being studied include salt domes, bedded salt, granite, shale, and basalt. These are found in many parts of the United States. Other materials, such as tuff and carbonate rocks, may also meet the requirements for candidate host rock.

1789 018

Most investigations of geologic disposal to date have centered on salt formations, and the primary emphasis of the NWTS program remains salt domes and bedded-salt formations. Regional studies have been completed on the Permian basin of the Central United States, the Salina region (comprised of the Michigan and Appalachian basins) in the northeast, the Paradox basin of Utah, and the salt domes inland from the Gulf of Mexico. In addition, because they are DOE sites already committed to nuclear purposes, the Hanford Site in south-central Washington and the Nevada Test Site are being examined to determine whether suitable sites exist among the rocks they contain. The status of the site-selection studies is summarized in Section B.3. Sections B.4 through B.8 describe the regional studies and the work at the Hanford Site.

B.2 SAFETY STUDIES

A systematic evaluation of the safety and reliability of geologic disposal of radioactive waste is required in order to insure the viability of specific designs at specific sites being considered for repositories. In the NWTS program this evaluation is almost entirely in terms of the disposal of commercial high-level waste. These studies contain the following elements:

1. Models for analyzing disruptive events, both natural and man-induced.

2. Thermal analysis models.

3. Studies of interactions between the emplaced waste and surrounding rock and groundwater.

4. Waste-migration models.

5. Borehole-plugging studies.

6. Systems analysis for linking all those effects together.

A basic program containing these elements, the Waste Isolation Safety Assessment Program (WISAP), is in progress. This program is independent of that used for the safety analysis reported in Chapter 9 of this document; one of its tasks, therefore, is to make analyses that parallel the Chapter 9 analyses. The principal purpose of the WISAP, however, is to aid in the site-selection and site-characterization activities of the NWTS program and eventually to enter into the environmental assessments required by the National Environmental Policy Act of 1969 for whatever sites are on the final list of alternative candidate sites.

B.3 STATUS OF SITE-SELECTION STUDIES

As indicated in Section 2.4.1 of this document, the earliest dates for the qualification of sites are as follows:

Geologic medium and location	Date
Bedded salt 1 (Delaware basin)	Now
Dome salt (Gulf interior region)	1981
Basalt (Hanford)	1981/1982
Bedded salt 2	1982
Bedded salt 3	1983
Various nonsalt media (Nevada Test Site)	1983/1984
Various nonsalt media (non-DOE sites)	1984/1985

The WIPP reference site is the first entry on the list above. It is described in detail in the main body of this impact statement. The remainder of this section discusses the status of the other entries in the list.

B.3.1 Gulf Interior Salt Domes

The Gulf interior salt-dome region contains several hundred domes scattered across northeastern Texas, northern Louisiana, and central Mississippi. Picking a site in this region amounts to picking a particular dome, as they are discrete entities. At this point the main criteria are size, depth to top, and the nature of previous disturbances. Attention has been narrowed to eight domes, three each in Texas and Mississippi and two in Louisiana. Hydrologic characteristics, on the other hand, can be and are being studied regionally.

Most of the present knowledge of these domes has been from the study and analysis of information from U.S. Geological Survey and state files and of drill-hole, seismic, and other geophysical data purchased from commercial interests. Indirect geophysical methods, such as aerial photogrammetry and infrared remote sensing, have also been used.

Little field work has been done on these domes. There has been no drilling by the NWTS program. The problem is access. Surface and mineral rights are often in private hands, and each owner must be negotiated with individually. Louisiana and Mississippi have taken steps to limit or control exploration related to a waste repository. Even gaining access to Federal lands controlled by agencies other than the DOE has been slow. Nevertheless these problems are being worked out, and plans as of March 1979 call for field work to start in all areas by mid-June.

For all this, salt domes appear to be viable alternatives to bedded-salt sites. Several European countries are considering salt domes seriously, and the Federal Republic of Germany has an experimental repository operating now in a salt-flow structure.

1789 020

B.3.2 Hanford Basalt

The Columbia Plateau basalts cover a vast region of central Washington, northern Oregon, and western Idaho; much of it might in principle be of interest for waste disposal. For the practical reason that the Hanford Site is already Federal land administered by the DOE for nuclear purposes, the detailed investigation of these basalts has centered on those of the Pasco Basin, in which Hanford lies.

Geologic study of the area goes back over a decade. Studies in the present context started in 1976, since when there has been much mapping and and geophysical work and 16 new holes have been drilled for cores, logging, and hydrologic tests.

The basic geology consists of a series of lava flows separated by porous, water-bearing beds. There has been essentially no mineral exploration in these basalts, and there is little prospect for it. This, plus the extensiveness of the flows, implies that if any part of the structure proves satisfactory for waste disposal, there will probably be a great deal of choice in site selection.

The use of basalt can rely but little on experience and analysis made for salt. Therefore high on the program is measurement of the physical, thermal, and chemical properties of the basalt, both alone and in the presence of groundwater. A Near-Surface Test Facility is being built in the northeastern portion of the Hanford Site for in-situ testing, especially with electrical heaters.

B.3.3 Nevada Test Site

The Nevada Test Site (NTS) is a large site, about 40 by 60 miles in size. It lies in the Basin and Range physiographic province and at the northern edge of the Mohave Desert ecosystem. Elevations range from 3000 to 7000 feet, and the climate and biological features vary greatly with elevation.

The primary mission of the NTS is the underground testing of nuclear weapons. Indeed it is the only test site for this purpose now available to the United States. Residual fission products and transuranic nuclides on the surface and underground mean that the NTS is committed for the indefinite future to retention and care by the U.S. Government.

The NTS contains a variety of geologic environments that might be considered for waste disposal. However, potential interference with or by nuclear testing restricts areas that might be considered to those in the southwestern portion of the Site. Four such areas are under consideration; two are granite areas, one is shale, and one is tuff.

All four areas have been investigated by surface geologic mapping and geophysics, and two by drilling. Drilling into one of the granite areas is discouraging: the granite was encountered much deeper than aeromagnetic surveys had implied. The other area drilled was in tuff, and it continues to look promising. The two areas yet undrilled will be drilled some time in 1979.

The NTS is in seismic risk zone 2, near zone 3. The Basin and Range province is well known to be seismically active. The problem of living with this seismicity is finding a block of material with suitable properties sufficiently distant from active faults. Closely related is the question of vulcanism; 12 to 13 miles southwest of the NTS there is evidence of volcanic activity as recently as 280,000 to 300,000 years ago.

The hydrologic characteristics of the NTS and its environs are well studied in the areas used or affected by nuclear testing but not in the southwestern area being considered for waste disposal.

B.3.4 Paradox Basin

Regional geology is still being studied in the Paradox basin. In addition, three holes have been drilled in a structure called the Salt Valley anticline, one of the salt diapirs of the basin. The deepest of the three was continuously cored to a depth of about 4000 feet. Several types of geophysical logs have been run in these holes; and open-hole injection, pumping, and swabbing hydrologic tests were conducted. The most recent activity has been vertical seismic profiling, in which a seismic source in one hole is detected in another hole.

B.3.5 Permian Basin

Permian basin studies have concentrated on the Texas Panhandle. There is essentially no Federal land in the area, and access for drilling and other direct field work is difficult. Nevertheless a great deal of information is available from geophysical measurements and holes drilled by oil companies, and there have been a few holes drilled and logged by the NWTS program on the east edge of the Palo Duro basin.

B.3.6 Salina Region

Site studies in the Salina region are at a standstill. Exploratory work once proposed in northeastern Michigan has been suspended indefinitely because of objections by the State government. Office work continues on such things as hydrologic modeling of the New York portion of the Appalachian basin and on drilling plans for likely areas in Ohio and New York.

1789 022

B.4 PERMIAN REGION*

B.4.1 Geology

The Permian region is located in portions of Texas, New Mexico, Oklahoma, Colorado, and Kansas, the entire region encompassing approximately 189,000 square miles (Figure B-1). The land surface consists predominantly of flat plains and tablelands, but some hilly and low mountainous areas exist east of the Midland basin in Texas and along the Wichita Mountains uplift in Oklahoma. Elevations range from 1500 to 2000 feet above sea level in the eastern portion of the region to 5000 feet above mean sea level in the west.

The Permian region has been tilted, warped, eroded, and invaded by at least one major sea since Permian time (280 to 220 million years ago). Rocks that predate the Permian period show local faulting and complex folding, but the Permian and younger strata are virtually free of deformation and in most areas have a dip of less than 0.5 degree. Most of the modern structures are probably of shallow origin and do not appear to reflect recurrent movement along Paleozoic or older structures.

The Permian region experienced a complex tectonic history during the Precambrian and Paleozoic Eras, culminating in the Wichita, Ouachita, and Arbuckle periods of mountain building, all of which occurred during the Pennsylvanian period (approximately 310 to 280 million years ago). It was in this tectonic framework that the region developed. A second period of mountain building, referred to as the Laramide orogeny, resulted in the uplifting of the Rocky Mountains just to the west of the Permian region about 65 million years ago, but this affected the region very little. In summary, the Pennsylvanian period of basin formation and crustal uplift is the only major tectonic activity that has affected the Permian region since Precambrian time, approximately 1 billion years ago. Structural readjustments since the Pennsylvanian have had little effect on the post-Permian rock units, including the extensive salt sequences.

The entire Permian region lies within seismic risk zone 1, which indicates that ground rupture should not be anticipated in the region. Recorded seismic activity is low compared with that of most other parts of the United States. Earthquakes with Modified Mercalli intensities of V to VII are scattered sparsely over the region. Of the region underlain by salt, the only part that has undergone significant activity is the area on the flanks of the Amarillo uplift and along its west-northwesterly continuation across the Bravo dome and the Dalhart basin.

The Permian region has long been one of the major oil- and gas-producing regions of the United States. The hydrocarbon reservoirs of eastern New Mexico and west Texas range from Ordovician to Permian in age. Limestones deposited during Permian and Pennsylvanian time served as stratigraphic traps for hydrocarbons and have been the major producing strata in the Silurian, Devonian, and Ordovician systems. Future exploration is anticipated to the north of the presently producing fields in southeastern New Mexico. In relation to the Upper Permian salt-bearing formations, most of the drilling for development and exploration will be at depths greater than those of the salt formations.

---

*Source: NUS (1978a).

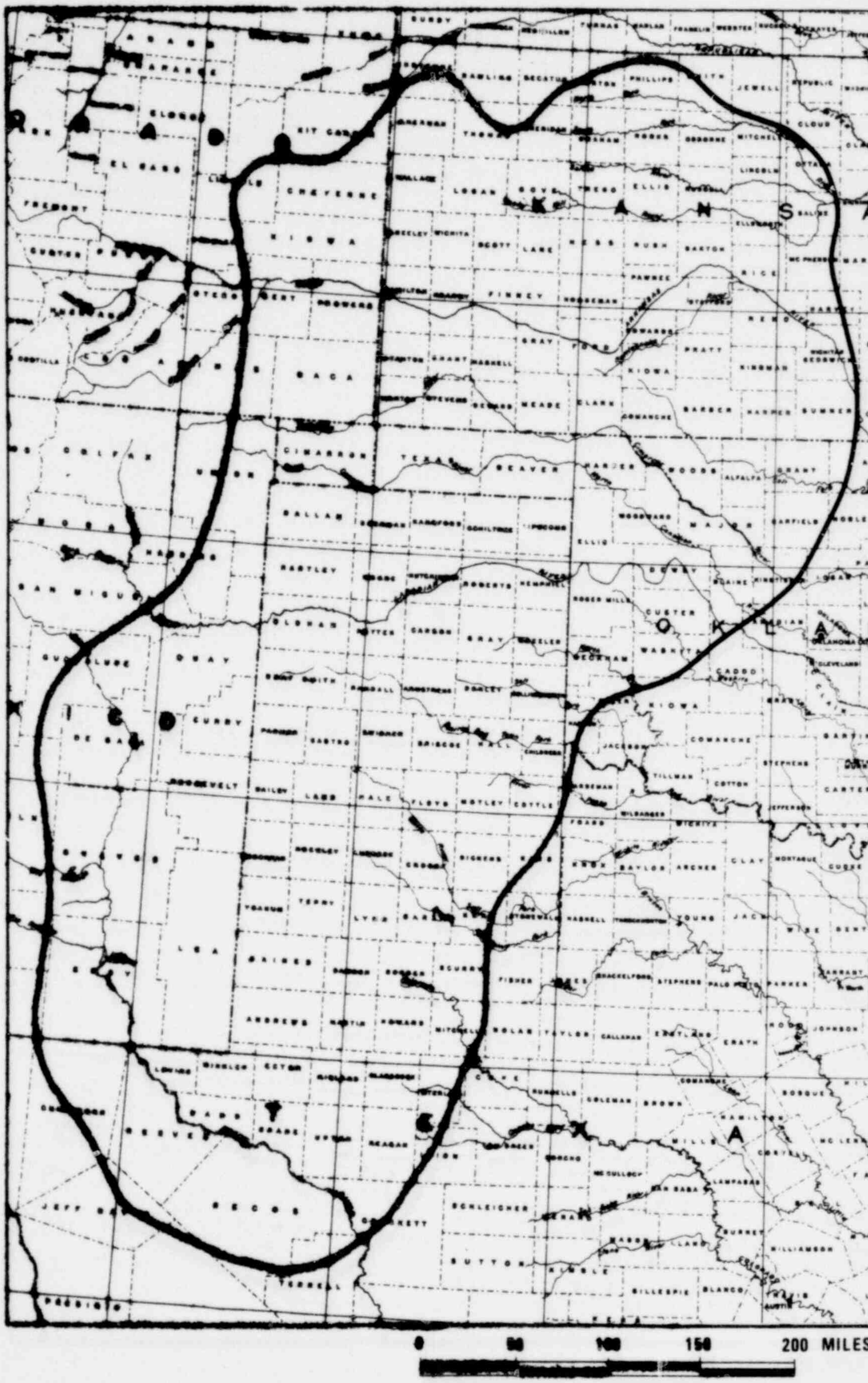


Figure B-1. The Permian bedded-salt basin.

1789 024

Major natural gas fields are present in western Oklahoma and the Texas Panhandle. There is some oil production in the area but far less than that of natural gas. The hydrocarbon-production zones in western Oklahoma and the Texas Panhandle are mainly lower Permian and the Pennsylvanian strata. The majority of the successful wildcat wells have found production horizons in Pennsylvanian and Mississippian strata, but deeper drilling is finding producing zones at depths of 25,000 feet in Silurian and Devonian systems. The principal oil-producing stratum is Pennsylvanian in age. Oil is also produced along the south side of the Palo Duro basin, along the crest of the Matador arch. Production is small from these basins. In addition to oil and gas, helium is produced at three localities, and carbon dioxide is produced from Permian rocks. On the basis of current leasing and drilling activity, it is anticipated that there will be exploration and development efforts for hydrocarbon zones below the Permian salt formations in western Oklahoma and the Texas Panhandle.

The southeastern Colorado portion of the Permian region supports oil and gas production that is small in comparison with that of the other producing provinces in the region. Principal hydrocarbon-production zones for this area are Pennsylvanian and Mississippian strata. Future drilling activity in southeastern Colorado will be in Pennsylvanian and Mississippian strata, which are stratigraphically below the Permian salt formations.

Major natural gas occurrences extend northward from western Oklahoma and the Texas Panhandle into Kansas. Hydrocarbon production zones for the Kansas portion of the Permian region are in Cretaceous, Permian, Pennsylvanian, Mississippian, and Ordovician strata. It is expected that future drilling efforts for Paleozoic strata will continue at a high rate in southwestern Kansas. Helium is also produced in the Kansas portion of the region.

Lignite deposits occur in north-central Kansas, although production from this area is sparse. Lignite has also been mined from limited seams in Cimarron County, Oklahoma, for domestic heating purposes.

Uranium resources are scattered in small deposits across the south-central portion of the Permian region in eastern New Mexico, the Texas Panhandle, and western Oklahoma. A few local deposits are also present in the southeastern Colorado portion of the region. Production has been small because of the limited size of the deposits.

There are no known metal occurrences within the Permian region, though iron and titanium are found near its periphery in Kiowa County, Oklahoma.

The production of various nonmetals has been, and continues to be, one of the major industries in the Permian region. The nonmetallic mineral industry in the region includes construction materials (e.g., stone, sand and gravel, volcanic ash, and scoria). These nonmetals are extracted from depths usually of less than a few hundred feet, and thus extraction would not interact with the salt deposits under consideration. Evaporite (e.g., potash and anhydrite) deposits are also located extensively over much of the region.

B.4.2 Hydrology

The Permian region has a semiarid climate characterized by low rainfall and runoff, high evaporation, and frequent strong winds. The rivers in the region generally rise on the eastern slopes of the Rocky Mountains and flow southeastward across nearly flat plains, which slope eastward at 5 to 15 feet per mile. Rainfall and runoff increase and evaporation decreases to the east. The mean annual precipitation varies from less than 16 inches in the western part to about 30 inches in the eastern part. The mean annual runoff varies from less than 0.2 to about 4 inches from west to east. The quality of many streams in the region is poor because of natural contamination (salt, sulfates, silt) and man-made sources (oil-field brine, feedlot drainage, irrigation runoff, municipal and industrial discharges). In many areas, river water is unsuitable for most municipal, industrial, and agricultural water-supply purposes. Although major floods occur infrequently, localized flooding may occur as a result of intense local precipitation. In most areas, such floods are characterized by rapidly rising and falling peak discharges and high water velocities. Flooding is controlled or mitigated by reservoirs and flood-control dams on many streams in the region. Reservoirs are also used for minimum flow maintenance.

The largest single user of water in the region is agriculture (about 87% of the total consumption). Domestic uses, manufacturing, and steam-electricity generation account for most of the remaining water consumption.

Because of the limited availability and variable quality of surface water, groundwater has become the dominant water resource in the region. Sixty-three percent of the water withdrawn in the region comes from groundwater. Aquifer types include stream-valley alluvium; terrace alluvium; carbonate and gypsum; sand and sandstone; and undifferentiated sandstone, carbonate rock, shale, and basalt. The Ogallala aquifer is a terrace-alluvium aquifer extending from southwest Texas across parts of New Mexico and Colorado, and western Colorado, Oklahoma, and Kansas. It is the most important source of water in the region and is one of the most intensively developed in the United States. The zone of saturation ranges from a few feet to more than 250 feet, and the depth to water ranges from less than 50 to more than 300 feet. The yields of wells range up to 1500 gallons per minute (gpm), depending largely on the saturated thickness. The water is generally of good quality but can be hard locally. Virtually all of the withdrawal in the heavily pumped areas comes from storage (i.e., the water is being mined).

Alluvium and terrace deposits represent deposits of the major streams formed during the period of dissection of the High Plains and consist largely of reworked material derived from the Ogallala Formation. The alluvium and terrace deposits are nearly continuous along the major streams, although there are gaps along some of the streams where alluvial deposits are thin or absent.

The zone of saturation ranges from 0 to 150 feet, and well yields range from less than 100 to 3500 gpm. The water ranges from fresh to highly saline.

The Edwards-Trinity (Plateau) aquifer is a sand and sandstone aquifer at the southern boundary of the Permian region. It consists of massively bedded limestone interbedded with shale. Although the yields of wells in most places average about 250 gpm, they can exceed 3000 gpm in places where the secondary permeability of the limestone is well developed. Water in the aquifer is generally fresh, although the concentrations of total dissolved solids can reach about 3500 mg/l.

The Rush Springs and Gerber-Wellington aquifers in Oklahoma and the Roswell artesian aquifer in New Mexico lie primarily outside the Permian region but do provide an important water resource to the portions of the region that they include.

B.4.3 Climate

The Permian region is in the Southern Plains and Lowlands climatic zone. In general, climatic changes are gradual across the zone because there are no significant climatic barriers. Differences in climatic conditions within this zone are controlled primarily by latitude, general air mass and other storm movements, elevation, and distance to sources of moisture.

The climate is predominantly continental, with cold winters and warm to hot summers. The western portion of the region has a dry climate because of the blocking effect of the mountains to the west. The modifying effect of the Gulf of Mexico results in a warm, humid, and rainy climate for the eastern portion of the region. The northern portions of the region are frequently affected by cold polar and arctic air masses during the winter and less frequently during the summer. Wind and precipitation patterns indicate a relatively high erosion potential.

Fundamental changes in the climate of the region 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 Permian region, 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, and there are indications that a long-term global cooling trend is under way at present.

In the Permian region the 24-hour maximum rainfall with a 100-year recurrence interval ranges from 5 inches in the northwestern portion to 8 inches in the eastern portion. These values are typical for the contiguous United States. The frequency of tornadoes is noticeably greater in the central, northern, and eastern portions of the region. (Texas, Oklahoma, and Kansas are within an area of the United States that is associated with frequent occurrences of tornadoes.) Similarly, most of the northern and central portions of the region experience 100-year maximum winds with speeds of more than 90 mph, which is relatively high in comparison with typical values in the United States. Restrictive-dispersion conditions (inversions) are relatively infrequent in the region compared to the rest of the contiguous United States. The occurrence of restrictive-dispersion episodes increases from east to west across the region.

Air-quality statutes and regulations restrict development in areas that are not attaining the national ambient air-quality standards (unless certain offset 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 throughout the western half of the region and in some eastern areas. Furthermore, the particulate concentrations in the area between Amarillo and Midland, Texas, exceed the national primary ambient air-quality standards for particulates.

B.4.4 Background Radiation

Background radiation is ubiquitous, resulting from cosmic, terrestrial, and fallout sources. The limited data available for the Permian region reveal no anomalous areas.

B.4.5 Demographic, Socioeconomic, and Land-Use Systems

The Permian region is sparsely populated. Only three urban areas in the region support a population of more than 100,000 inhabitants: Wichita, Kansas (approximately 300,000), Lubbock, Texas (approximately 150,000), and Amarillo, Texas (less than 130,000). Odessa and Midland, Texas, have populations of just over 80,000 and 60,000, respectively. The largest urban area within 75 miles of the region is Oklahoma City, Oklahoma (approximately 580,000).

Total earnings for the Permian region in 1970 amounted to approximately 11 billion dollars; by the year 2000, earnings will be approximately 27 billion dollars. The dominant land use is agriculture. The livestock industry yields more earnings than all the field crops combined. Earnings from agriculture, forestry, and fisheries accounted for about 14% of all earnings; in the region manufacturing accounted for approximately 5% of the total earnings. Approximately 68% of the earnings was produced by retail and wholesale trade, government, and institutions. This percentage is expected to increase, whereas the percentages for agriculture and mining are expected to decrease in the coming decades.

Sensitive or conflicting commitments of land areas larger than 10,000 acres include 142,200 acres of Indian lands (trust areas) in Oklahoma. Also within the region are 2 national parks (93,720 acres), 5 national forests (639,321 acres), 3 wildlife refuges (64,606 acres), 11 recreation areas on Bureau of Reclamation projects (1,143,921 acres), 1 military installation (33,848 acres), and other military areas (primarily restricted air spaces), totaling 23,850,624 acres. The area committed to these activities is approximately 22.86% of the Permian region. The bulk of the land is range, agricultural, and open land, with some areas preempted for urban and residential development and for transportation networks.

The Permian region is traversed by a network of highways and rail lines. The highway system is the dominant mode of transportation throughout the region. Railroad trackage has been developed most intensively around major rail hubs within or near the northeastern portion of the region.

B.4.6 Terrestrial Ecosystems

The Permian region covers some 189,000 square miles and includes a variety of soil, topographic, and land-use patterns. About 98% of the region is classified as range or pasture (58%) or cropland (40%).

Most of the natural vegetation in the region is classified as grassland and shrubsteppe (97%), but forests (3%) are scattered along the major river drainages in Kansas, Oklahoma, and eastern Colorado and in the low mountains in the western portion of the region. Forests are not commercially valuable in the region because of their limited distribution. Nevertheless, they provide important wildlife habitats. Wetlands are scarce. However, six typical wetland areas are identified, one of which (the Great Salt Plains in Oklahoma) has been proposed for Registered National Landmark status. The region contains seven national wildlife refuges in wetland areas. The Society of American Foresters has identified two natural areas in Kansas that are set aside for scientific, educational, or recreational purposes. The Nature Conservancy has designated at least three natural areas in the Oklahoma portion of the region. Twenty-four plant species that are proposed for Federal endangered status occur within the region.

Regional wildlife includes some 85 species of mammals, at least 350 species of birds, and more than 100 species of amphibians and reptiles. Forestland, shrubland, and openland species are well represented. Important wildlife includes game species, furbearers, and one species on the Federal list of endangered species, the black-footed ferret. At least 35 game birds and 26 game mammals are found in the region, and hunting and trapping are important. The white-tailed deer, mule deer, and pronghorn are important big-game animals. Cottontail, jackrabbit, and fox squirrel are important small-game mammals. Nonmigratory game birds include the turkey, ring-necked pheasant, lesser prairie chicken, bobwhite, and scaled quail; migratory game birds include waterfowl and the mourning dove. Birds on the Federal list of endangered species include the brown pelican, Mexican duck, bald eagle, peregrine falcon, whooping crane, and Eskimo curlew.

The major land uses in the Permian region are cropland and range and pasture. The major cropland areas are in Kansas and Texas; Texas and New Mexico have the largest amounts of range and pasture land. Important crops include winter wheat, sorghum, and cotton. Cattle, sheep, hogs, and milk cows are important livestock.

B.4.7 Aquatic Ecosystems

A large portion of the Permian region is semiarid, with intermittent streams as the only aquatic habitat. These streams, when flowing, are generally high in mineral content from natural sources (salt springs, brine seeps, or gypsum overburden) and from human activities (petroleum and natural gas production or irrigation return flows). As a result, the most suitable (often the only available) aquatic habitats are near the peripheral portions of the region.

In the northern portion of the region, streams of the Smoky Hill River system, which drain ultimately to the Missouri River, are turbid and moderately salty. During low-flow periods in summer months, particularly in the upper reaches, these streams become ephemeral. Near the northeastern boundary of the region and below the confluence of the Saline and Solomon Rivers, the Smoky Hill River system maintains adequate flow and supports a marginal recreational fishery for catfish and carp. The Topeka shiner, a threatened fish in Kansas, has been recorded from the Smoky Hill and Saline Rivers within the Permian region.

Rivers of the north-central Permian region, including the Arkansas, Cimarron, Canadian, and Red Rivers, have poor water quality as a result of natural and man-induced pollution. These streams (with a possible exception of the Arkansas River) have their origin in semiarid regions and frequently exhibit no flow or subsurface flow conditions. Consequently, suitable habitats for aquatic organisms are mainly outside or near the eastern periphery of the region. A few locally endangered or threatened species may occur in the north-central portion of the region but are expected primarily in the headwater areas of Colorado and New Mexico or near the eastern boundary of the region, where the streams become larger and flow continuously.

Much of the central Permian region, although within the watersheds of the Brazos and Colorado Rivers, consists of playa lakes and dry creeks and is essentially noncontributing. Aquatic habitats are therefore few in number and, when present, are generally not suitable for fish and aquatic invertebrates because of the naturally high salt content of surface waters. A few tributaries (e.g., the Concho River of the Colorado River system, which is essentially spring-fed) maintain flows and water quality that support exploitable fish populations. Such streams are generally near the eastern boundary of the region.

In the south and southwest portions of the Permian region, the Pecos River, although polluted from natural brines and irrigation return flows, supports a diverse fish fauna in tributaries to the mainstem river. Many of the species and subspecies of this region (particularly the several species of desert pupfish and gambusia) have been isolated by natural barriers and are restricted to specific habitats (often a single tributary or spring). Because of their highly restricted distributions and dependence on unique habitats for survival as a species or subspecies, many of these fishes are considered to be endangered.

B.5 SALINA REGION*

B.5.1 Geology

The Salina region includes portions of New York, Pennsylvania, Ohio, Michigan, West Virginia, and Canada (Figure B-2). The entire region encompasses approximately 80,000 square miles of land area in the United States.

About half of the Salina region is in the Great Lakes section of the Central Lowland physiographic province. The lakes and terrain features, such

*Source: NUS (1978b).

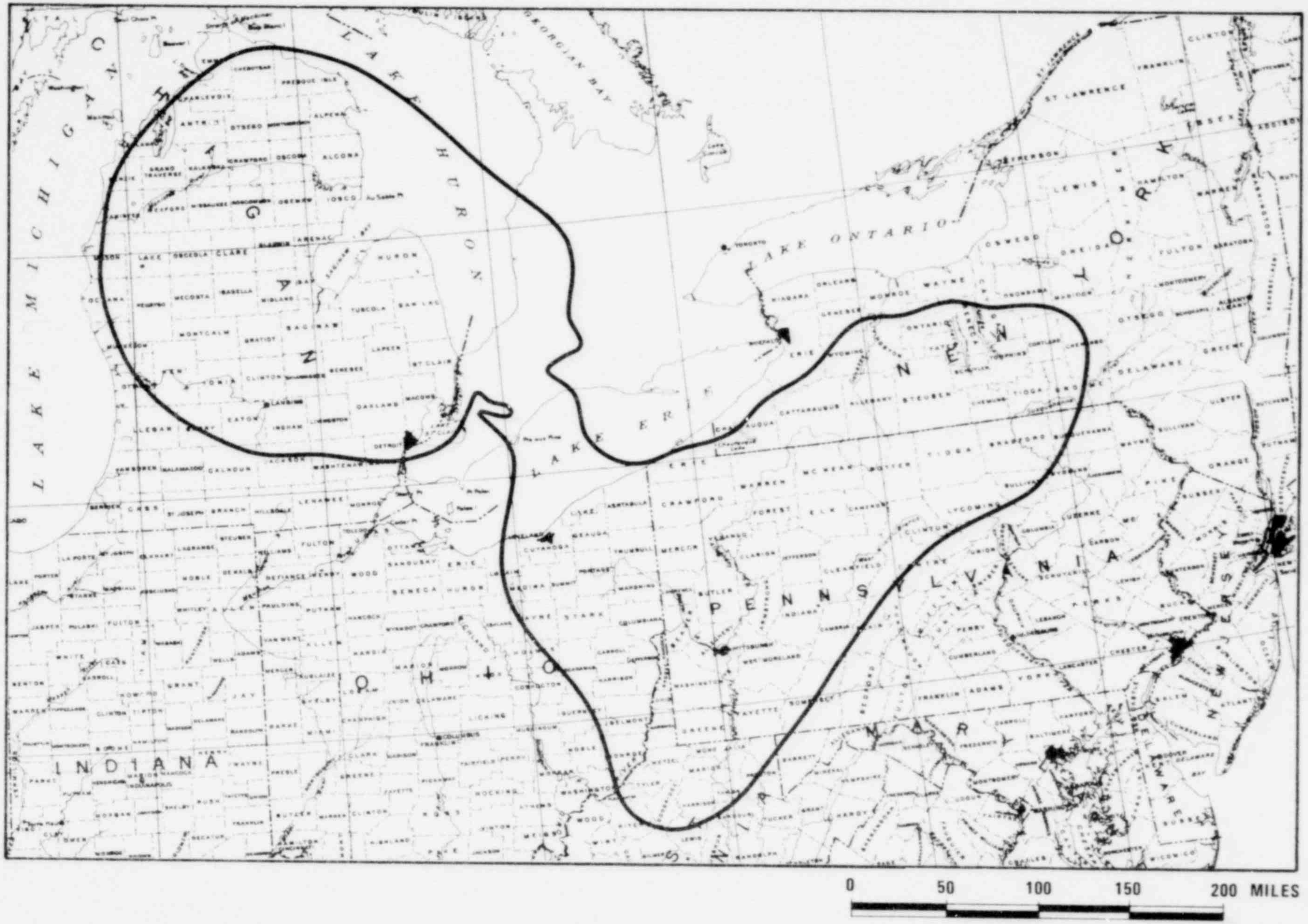


Figure B-2. The Salina bedded-salt region.

as moraines and drumlins, reflect the prominent effects of Pleistocene glaciation in this section. The remainder of the region is a part of the Appalachian Plateaus physiographic province. It is composed of shallow river valleys and broad ridges, with escarpments that provide abrupt changes in elevation. Local elevations generally vary by no more than 300 to 400 feet; however, the elevation increases in going from west to east from about 1000 feet above sea level in Ohio to about 2000 feet above sea level in New York.

The Salina region lies within two major tectonic divisions: the Central Stable region in the west and the orogenic belts of the Atlantic margin in the east. The Central Stable region is founded on Precambrian rocks that compose the stable interior of the North American continent. The eastern areas of the region contain mountainous areas uplifted and deformed during the Paleozoic Era. Separating the eastern and western portions of the region are a series of arches--areas that were stable or gently uplifted and deformed during the Paleozoic Era, when the Appalachian and Michigan basins were subsiding. It was during these periods of subsidence that salt beds were formed. All these structures are extremely old, with no major movements in the earth's crust for approximately 180 million years. Indeed, the Salina region has experienced no major internal tectonic activity since Precambrian time (1 billion years ago). Major structural features within the region are few, uncomplicated, and broad in extent. Minor structures within the region are also relatively few and simple.

The Salina region is one of low seismicity. Earthquakes in the eastern portion of the region are attributed to readjustment of the earth's crust after the most recent Ice Age. Major surface faulting is uncommon. Several seismic events have occurred in the vicinity of Attica in western New York. These earthquakes have been related to the Clarendon-Linden Fault, a north-south-trending tectonic feature. Several moderate earthquakes (Modified Mercalli intensity of V) have occurred near Cleveland, Ohio. Portions of the Salina region in Michigan, Pennsylvania, and West Virginia have been virtually earthquake-free.

Oil and gas fields have been developed in all parts the Salina region. Primary, secondary, and tertiary recovery efforts, which include water flooding and fracturing, may have affected portions of the Silurian salt layers. The most abundant oil and gas fields are in Pennsylvania, West Virginia, and Ohio. Major bituminous coal reserves occur in Pennsylvania, West Virginia, Ohio, and Michigan. Much of the coal is within 300 feet of the surface, well above the salt beds. Metallic ores in the region are of low grade and of limited economic importance. Several nonmetallic minerals of economic importance are extracted in the region: salt, salt brines, silica, and construction materials (sand, gravel, gypsum, etc.). With the exception of salt brines, it is not expected that current or future recovery of these minerals would affect waste-repository siting.

B.5.2 Hydrology

The Salina region is subdivided into three Hydrologic Regions (HR): HR I, southeastern Great Lakes basin; HR II, Susquehanna River headwaters; and HR III, northeastern Ohio River basin.

1789 032

Hydrologic Region I covers the drainage area of Lake Huron, Lake Erie, and Lake Ontario. The terrain is characterized by flat land, lakes, marshes, and peat bogs, reflecting the poor development of regional drainage systems. Streams are relatively short and follow the lows of the once-glaciated terrain. The terrain is therefore more conducive to infiltration than to direct, rapid surface runoff. Water available for withdrawal and use in HR I comes primarily from precipitation within the area. Annual precipitation ranges from 28 to 37 inches; approximately one-third, nearly 12 inches, becomes runoff. Water is generally nonsaline throughout HR I.

Major floods and most damaging floods are usually the result of rain and snowmelt on frozen or nearly saturated ground. Intense summer storms have created destructive floods, but these are ordinarily confined to local areas. Dams are used for flood control and for water-resource management. The largest single use of water in the region is for cooling steam-electricity generating plants. Manufacturing facilities and domestic consumption are also major water users.

Although water-bearing formations underlie all of HR I, the depth to the water table varies with the season, local geologic characteristics, and terrain. With the exception of the lower Michigan Peninsula, productive aquifers (yielding to a well at least 50 gpm of water containing not more than 200 ppm of dissolved solids) are located only along some of the main watercourse alluvial valleys. Because of the abundance of surface-water supplies in HR I, groundwater usage has not been extensively developed and constitutes generally less than 10% of the total water use.

Hydrologic Region II is located in the headwaters area of the Susquehanna River, which flows southeasterly from south-central New York through Pennsylvania and Maryland. The two major tributaries of the Susquehanna River that flow through HR II are the West Branch of the Susquehanna River and the Chemung River. Hydrologic Region II is characterized by deeply eroded, steep-sided, flat-bottomed valleys and flat to gently rolling plateaus varying in relief from several hundred feet in New York to nearly 2000 feet in Pennsylvania. This type of landscape tends to shorten the time for precipitation to run off into streams and consequently promotes the possibility of flooding. Precipitation averaging nearly 38 inches annually in HR II is the major source of water supply. The mean annual runoff varies from about 15 to 25 inches, about half of this occurring during the 3-month period from March through May. Some tributaries of the West Branch of the Susquehanna River are heavily influenced by acid mine drainage. Nevertheless, the dissolved-solids concentration of most streams in HR II seldom exceeds 800 ppm. Generally, floods occur each year in HR II; major flooding can occur in all seasons. Flooding is, however, more frequent in early spring, usually in March. Major floods have been caused by heavy rainfall on top of heavy snowfall and by heavy rainfall on previously saturated ground. Occasionally, local flooding is caused by ice jams or from thunderstorms during the summer months. As in HR I, major water uses are for steam-electricity generation, manufacturing, and domestic consumption.

The abundant water in the Susquehanna River basin is looked to by communities outside the area as a supply source for the future. Currently significant quantities of water are piped to Chester, Pennsylvania, and Baltimore, Maryland. Rural water supply needs will also increase rapidly in the future. This includes rural domestic use, consumption by livestock, and

1789 033

irrigation. The increases are not as dramatic as in the urban areas, but they are nevertheless substantial and must be planned for, particularly where they compete directly with urban needs.

Groundwater in HR II occurs in appreciable quantities in rock strata and is generally of good quality, except near coal mines below Tioga County, Pennsylvania. Deep aquifers in the region may be saline or brackish. Highly permeable glacial deposits along most of the valleys are significant sources of groundwater. These aquifers are very productive and readily recharged. Since most urban communities are situated on water-bearing glacial deposits in the valleys, groundwater has not been widely utilized. Although water-use data are not available for HR II, data for the entire Susquehanna River basin, which includes HR II, indicate that 17% of the total water consumption is supplied by groundwater. Total groundwater use is expected to increase as water demands grow in the region.

Hydrologic Region III lies in the northeastern section of the Ohio River basin. Major streams in this region are the Allegheny River, Monongahela River, Muskingum River, Beaver River, and the main stem of the Ohio River. Hydrologic Region III is located in the Appalachian Plateaus physiographic province, which is characterized by rugged terrain resulting from the differing resistance of the rock to weathering the runoff. Extensive forest cover, poor-quality soils, narrow valleys, steep stream gradients, and flash floods during the dry seasons are characteristic of this area. Vegetation is generally sufficient to retard runoff and minimize erosion. Precipitation averages about 45 inches annually; runoff ranges from about 11 to 25 inches annually. Many minor tributary streams throughout the area normally cease flowing during the dry season, with drought periods adding to their number. Often during late summer and early fall, stream flow from precipitation is negligible, the only flow being from groundwater seepage. Waters of the region are nonsaline, although some tributaries have high concentrations of dissolved solids. In order of gross consumption, major water-usage categories are steam-electricity generation, manufacturing, and domestic use.

Valley-fill sediments, consisting both of glacial outwash and recent alluvium, are the most important source of groundwater in HR III. Highest yields occur generally in the valleys of the Ohio River and its north-side tributaries. Most bedrock systems in the area are relatively poor water bearers, although productive aquifers do occur in some limited rock strata that underlie portions of HR III. High iron concentrations are often found in these waters. Groundwater supplies have been developed in the valley-fill-sediment aquifers primarily for use at the point of need. Because of the large areas covered by these aquifers, most of the stored water has been untouched by current development.

1789 034

B.5.3 <u>Climate</u>

The Salina region is located primarily within the Great Interior climatic zone. Differences in climate are controlled primarily by latitude, general air mass and storm movements, elevation, and distance from moisture. Modifications to the climatic patterns are introduced by the Great Lakes and by the lifting effects of the Appalachian Mountains. The climate is generally characterized as cool in the northern section and warm temperate and rainy in the southern section. Wind and precipitation patterns indicate a very low erosion potential in the region.

Fundamental changes in the climate of the region have occurred over the last million years (the Pleistocene Epoch). In this period there have been four ice ages during which glaciers covered much of the Salina region.

The most recent ice age (Wisconsin Glacial) ended about 10,000 years ago, although continuous ice sheets still exist in the polar regions. 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.

In the Salina region, severe-weather conditions are rather typical of those occurring in most areas of the contiguous United States. The maximum 24-hour rainfall with a 100-year recurrence interval ranges from 4 to 6 inches. The frequency of tornadoes is noticeably greater in southern Michigan and eastern Ohio than in other sections of the region. However, the frequency is significantly lower than that in the Central United States. Sections of the Salina region experience less than 25 to nearly 40 episode-days in 5 years.

Air-quality statutes and regulations restrict development in areas that are not attaining the national ambient air-quality standards (unless certain offset 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 around all major cities and in eastern Ohio, southwestern Pennsylvania, and northern West Virginia.

B.5.4 Background Radiation

Background radiation is ubiquitous, resulting from cosmic, terrestrial, and fallout sources. Limited data available for the Salina region reveal no anomalous areas. Dose-rate levels range from 68.8 mrem/yr at Charlevoix, Michigan, to 116.7 mrem/yr at Wheeling, West Virginia.

B.5.5 Demographic, Socioeconomic, and Land-Use Systems

Many areas within the Salina region are highly urbanized. The heaviest concentrations of urban areas (over 50,000 inhabitants) in the region occur in Ohio, southern Michigan, and western Pennsylvania. The largest urban areas in or near the region include Detroit (nearly 4 million inhabitants), Cleveland and Pittsburgh (nearly 2 million inhabitants each), and Buffalo (over 1 million inhabitants).

Total earnings for the Salina region in 1970 amounted to 66 billion dollars; by the year 2000 earnings will be about 181 billion dollars. Manufacturing accounted for approximately 41% of the total earnings in 1970. Although agriculture and forestry are the dominant land uses, they produce, together with fisheries, about 1% of the total earnings of the region. Mining and other extractive industries likewise account for about 1% of the regional earnings. Retail and wholesale trade, government, institutions, and other services account for approximately 56% of earnings. This percentage is expected to increase, and the percentage for manufacturing is expected to decrease, in the coming decades.

Sensitive or conflicting commitments of land areas larger than 10,000 acres consist of the Allegany Indian Reservation, 9 parks, 5 forests, 1 wildlife refuge, 6 recreation projects, 14 airports, 2 military reservations, and 4 military operations areas. The area committed to these activities totals less than 6% of the Salina region. The bulk of the remaining land is agricultural and open land, with some areas preempted for urban and residential development and for transportation networks.

The Salina region is traversed by a well-developed network of highways, rail lines, and waterways used for commercial transportation.

B.5.6 Terrestrial Ecosystems

The broad mosaic of land-use patterns in the Salina region has a significant influence on the distribution and abundance of terrestrial resources. Major land-use patterns in the region are forestland (44%), cropland (31%), pastureland (6%), and other rural land (6%).

Four ecoregion categories occur in the Salina region: Northern Hardwoods, Beech-Maple Forest, Appalachian Oak Forest, and Mixed Mesophytic Forest. Important natural vegetation includes commercially valuable timber, wetlands, natural areas, and proposed endangered plant species. Commercial forestland in the region is about 90% hardwoods and 10% softwoods. Forestland is about equally divided among sawtimber, poletimber, and seedling/sapling stands. Approximately 2% of the region is classified as wetlands with some importance to waterfowl. Some 28 representative wetland areas and 5 National Wildlife Refuges (predominantly in wetland areas) are located in the region. The Society of American Foresters has identified 10 natural areas in the region. Five plant species that are proposed for Federal endangered status occur in the region.

Regional wildlife includes some 65 species of mammals, at least 400 species of birds, and 73 species of amphibians and reptiles. Forestland, shrubland, and openland species are well represented. Important wildlife includes game species, furbearers, and endangered species. At least 31 game birds and 23 game mammals are found in the region, and hunting and trapping are important. The white-tailed deer is the most important big-game animal; rabbits and tree squirrels are important small-game mammals. Nonmigratory game birds include the ring-necked pheasant, bobwhite, and ruffed grouse; migratory game birds include waterfowl and the mourning dove. Species on the Federal endangered list include the Indian myotis, Kirtland's warbler, peregrine falcon, and bald eagle.

Farming is important in the Salina region. Major crops are corn, hay, winter wheat, and oats. Cattle, swine, and sheep are important livestock.

1789 036

B.5.7 Aquatic Ecosystems

The Great Lakes provide the most extensive commercial fishery within the Salina region. Although shifts have occurred in the abundance of various species because of fishing pressures, introduction of predators, and pollution, commercial harvesting of fish remains a significant industry in the Great Lakes. The Ohio River drainage presents a more limited fishery resource. The commercial fish harvest in this drainage may be considered negligible, as are the present-day collections of mussels and clams. The Great Lakes and the Finger Lakes in upstate New York support a diverse sport fishery. Appalachian streams offer trout fishing; in many lower stretches of tributaries and in the main-stem rivers of the Salina region a warm-water fishery exists. Many streams and lakes are augmented with stocked species to enhance sport fishing. Only two fish species and one invertebrate on the Federal list of endangered species occur in the region.

B.6 PARADOX REGION*

B.6.1 Geology

The Paradox region (Figure B-3) is located in southeastern Utah and southwestern Colorado. The entire region encompasses roughly 10,000 square miles; about 60% of this land area is in Utah. The Paradox region is a tectonic unit (Paradox Fold and Fault Belt) of the Colorado Plateau and is also a feature of Thornbury's (1965) rugged Canyon Lands section of the Colorado Plateau. As such, it has a diverse and varied physiography and exhibits the landforms associated with tectonic and igneous activities as well as with extensive wind and water erosion. Most of the region is above 5,000 feet in elevation, often with high relief and rugged terrain. The area contains some of the most spectacular scenery in the United States.

The rocks of the Paradox region consist of at least 15,000 feet of clastic and evaporitic sediments resting nonconformably on a basement complex of granitics and metasediments. The age of the basement rocks is Precambrian, while the sedimentary strata range in age from Cambrian to Cretaceous. Disconformities and hiatuses abound, some of very long duration. Ordovician and Silurian rocks, for example, are completely absent, and no marine deposition has occurred since the close of the Mesozoic Era. The only Tertiary rocks of significance are intrusive volcanics. The Quaternary is represented only by fluvial deposits, a substantial amount of wind-blown sediments and minor amounts of gravel and till.

The Colorado Plateau Province, of which the Paradox region is a part, is a mildly deformed platform surrounded by the more highly deformed Rocky Mountains. The principal tectonic elements of the Plateau include uplifts, monoclinal flexures, domes of igneous intrusion, platforms, slopes, saddles, and fold-and-fault belts. In addition, the region displays numerous igneous plugs, diatremes, caldron sinks, dikes, and multitudinous systems of joints and small faults.

---

*Source: Bechtel (1978a).

1789 037

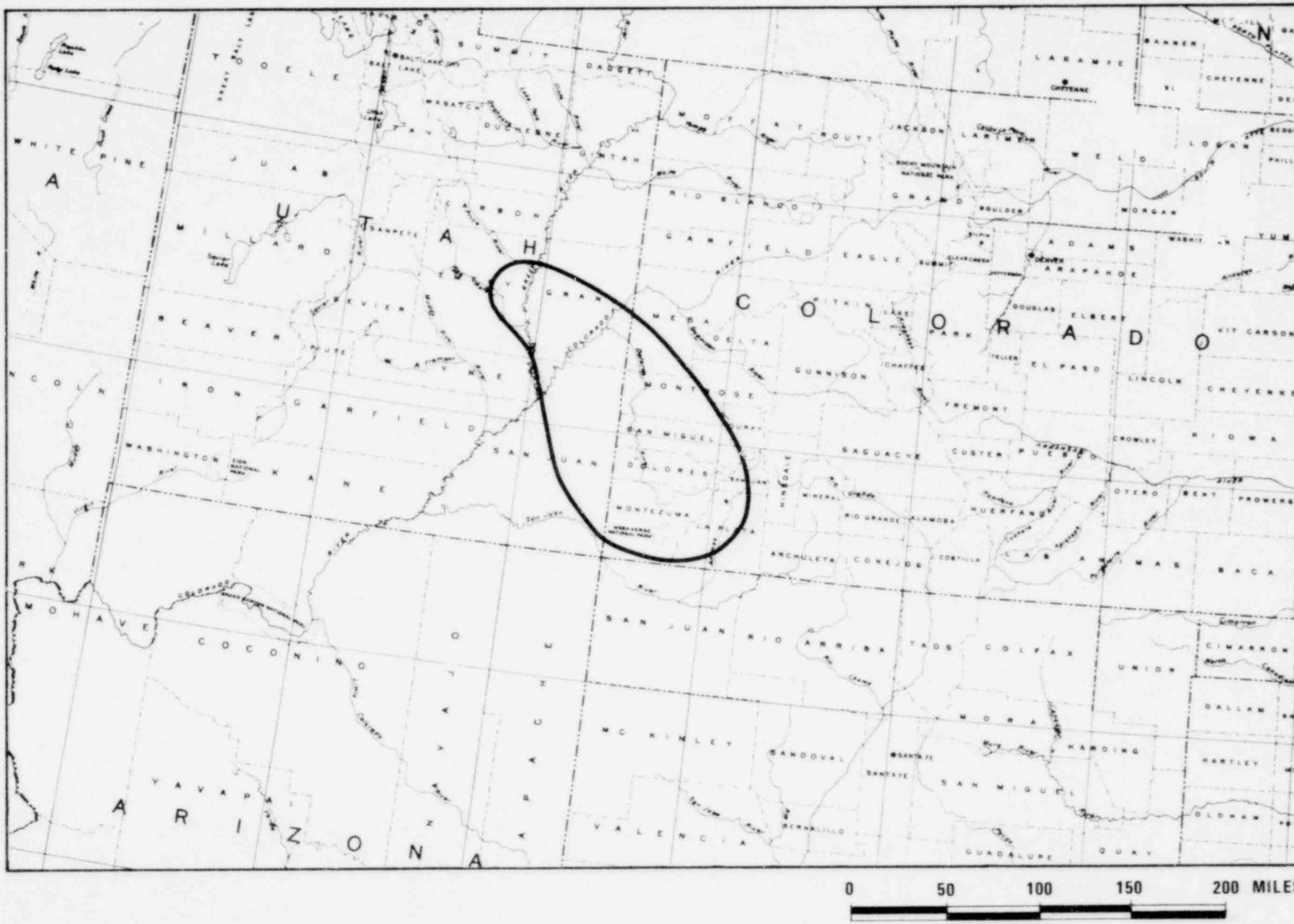


Figure B-3. The Paradox bedded-salt region.

1789 038

The Paradox region is one of low seismic activity. Fifty-four earthquakes with a maximum intensity equal to or greater than 5 on the Modified Mercalli scale of 1931 are known to have occurred in or within 100 miles of the Paradox region from 1853 to 1976.

The tectonic history of the region is eventful. Evidence indicates that the region was under water for a long period of time before the start of the Cambrian period. During the Paleozoic Era much activity occurred, with periods of uplift and erosion alternating with periods of inundation and sedimentation. The formation of the Paradox Basin salt formation occurred during the latter part of this era. By comparison, the Mesozoic Era was relatively quiescent. No major mountain-building activity occurred in the region during the Triassic and Jurassic periods, but the shallow seas moved in and out to deposit occasional layers of marine sediments. The powerful uplifts that raised the Colorado Plateau Province to its present elevation began in the last half of the Cretaceous. During the early Cenozoic Era the mountain building continued until the Rocky Mountains were formed. Volcanism was also widespread and frequent during the Cenozoic Era. Most of the prominent surface features of the region were formed during the era.

The Paradox region and surrounding territory have supplied important energy resources for nearly three decades. Petroleum, natural gas, and uranium from this area have made substantial contributions to the nation's energy needs and have played an important role in the local economy. Energy and mineral production is still increasing. A few metals and industrial minerals are also present in the region, but they have been produced on a small scale compared to exploitation of the energy reserves.

B.6.2 Hydrology

Surface water is a valuable resource in the semiarid Paradox region. The principal rivers in the and surrounding territory of the Upper Colorado Water Resource Region (UCWRR) are the Colorado and the Green, and their major tributaries are the Price, San Rafael, Dolores, and San Juan Rivers. No large natural freshwater lakes or wetlands occur in the region. Precipitation is light and varies with ground elevation. Maximum stream flow occurs in late spring due to snowmelt runoff from mountainous areas. Localized flooding can occur, especially when periods of snowmelt coincide with intense thunderstorms. Areas most prone to flooding are along the floodplains of rivers or streams. Most serious damage occurs in broad floodplains where agricultural or urban developments exist. Flood control is accomplished by watershed management and land-treatment programs in the UCWRR. Flood-control reservoirs are normally multipurpose and may provide power generation, irrigation, and recreational benefits. Surface-water quality is generally good, although high dissolved-solids concentrations pose a problem in some waterways of the UCWRR. Water availability is limited, and demand, especially for good-quality irrigation water, is growing.

Groundwater occurs in the Paradox region under both water-table and artesian conditions, and the quality of this water ranges from fresh to near-saturated brines (in excess of 350,000 mg/l of total dissolved solids). Water-table conditions commonly exist in the shallow alluvial aquifers, in recharge areas, and near the surface in relatively flat-lying rocks that are

1789 039

found over large portions of the region. Most of the groundwater underlying the region has dissolved-solids concentrations in excess of 3000 mg/l and is unsuitable for most uses. Usable fresh water is present only in near-surface aquifers and is seldom found at depths greater than 200 feet. The only source of fresh water is precipitation falling on the region; principal areas of recharge are the highlands of the region and other areas where aquifers crop out.

B.6.3 Climate

The Paradox region is largely a cool, semiarid, mid-latitude steppe with isolated areas classified as mid-latitude deserts or humid continental regimes. The region is very dry, with an average annual precipitation of approximately 8.3 inches. The dry conditions provide the region with a relatively high potential for wind erosion.

Fundamental changes in the climate of the region have occurred during the last million years, apparently resulting from changes in global temperature. Four major glaciations occurred during the Pleistocene Epoch, but the region is located more than 500 kilometers southwest of the southernmost limit of the ice cover and was not glaciated.

The region is relatively free from severe-weather hazards and can expect a maximum 100-year rainfall of only 3 inches in a 24-hour period. It is also in an area of low tornado activity; this part of Utah reported no tornadoes from 1955 to 1967. Similarly, high winds are not frequent; maximum wind speed of about 85 mph has a 100-year mean recurrence interval. However, local channeling effects might alter the maximum speed at specific sites.

Inversions are relatively common in the Paradox region in comparison with the United States as a whole: the region has experienced about 180 episode-days in 5 years. These conditions are related to the terrain of the region, which is a complex system of valleys surrounded by high terrain. This type of terrain allows the formation of frequent temperature inversions that could pose a major problem for the dispersion of emissions from a waste repository. In addition, poor dispersion conditions occur during the frequent stagnation of large-scale high-pressure systems.

With regard to existing air quality (Prevention of Significant Deterioration, all national parks and wilderness areas within the Paradox region are classified as Class I areas. The remainder of the region is a Class II area. The law generally allows no or minimal industrial development in Class I areas and moderate development in Class II areas.

B.6.4 Background Radiation

Virtually no data specific to the Paradox region were available in the sources examined. In general, the mountain states are higher than the national average in both natural terrestrial and cosmic background radiation, although the regional variations appear to be of minor significance.

1789 040

B.6.5 Demographic, Socioeconomic, and Land-Use Systems

The Paradox region is a rural area with many small towns of less than 1000 people scattered along highways. Farmington, New Mexico, and Grand Junction, Colorado, are the only two cities in the areas adjacent to the region with more than 20,000 inhabitants. There are no cities this large within the region. The total population of the region was approximately 240,000 in 1970. Most of the counties in the region showed a 10 to 20% increase in population between 1970 and 1975.

The economy of the region is dependent on the continued long-term development of extractive industries and the processing of petroleum, coal, molybdenum, vanadium, natural gas, and other mineral and energy resources. Growth in these and related support industries will, to a large extent, determine the rate of economic growth for the region, primarily because of their export value.

Agriculture is also important in the region, although productivity is limited by local climatic factors. The low annual rainfall, combined with areas of marginal soil productivity, limits agricultural activities to livestock grazing and local hay and grain production. Livestock is the only major agricultural product exported from the region. Other industries are of lesser importance.

Land uses of interest include Federal and state recreational and natural areas (which occupy 29% of the land area within the region), urban areas (less than 1%), and Indian lands (16%). The bulk of the remaining land is open range, with small areas preempted for transportation networks.

B.6.6 Terrestrial Ecosystems

The Paradox region contains vast areas of relatively undisturbed natural habitat. Fifteen natural vegetation systems occur in the region; these range from pine or fir forests to scrublands, steppes, and barrenlands. Six ecological reserves have been established or proposed for the region; these "natural areas" would insure the preservation of a typical or unusual vegetation type in as near an undisturbed condition as possible. A great variety of wildlife inhabits the region, including many furbearing species, numerous big- and small-game species, and several threatened or endangered species.

Major range types within the region include grasslands, three types of desert shrubs, and pinyon-juniper woodlands. This range is well utilized, and the market value of livestock is normally 50 to 60% of the value of all agricultural products in the region. Lands having good soil on moderate slopes are generally dry-farmed or irrigated. A variety of crops are grown; these typically account for 40 to 50% of the market value of all agricultural products. Although extensive forested areas occur in the region, forest products contribute less than 1% of the total value of all agricultural crops.

B.6.7 Aquatic Ecosystems

Most aquatic habitats in the Paradox region are cold-water trout streams, generally above 5000 feet in elevation. The native game fish, mainly cutthroat trout and whitefish, have been largely replaced by introduced game species, principally rainbow trout. Very little warm-water-stream habitat is found in the region; the warm-water habitats that do exist frequently contain both cold- and warm-water fish species. Although a considerable number of sport fish are taken annually, the fishery resource is relatively poor because of the high sediment load of many streams. Four threatened or endangered fish species have been identified in the region; all are found in the Colorado River or its tributaries.

B.7 GULF INTERIOR SALT-DOME REGION*

B.7.1 Geology

The Gulf interior region of Alabama, Mississippi, Louisiana, and Texas lies within the Gulf Coastal Plain physiographic province (Figure B-4). It includes parts of 11 major physiographic subdivisions.

The basement of the Gulf interior region consists of structurally deformed incipient or weakly metamorphic late Paleozoic and older rocks and crystalline materials of unknown age. These rocks are overlain by a great thickness of Mesozoic and Cenozoic that regionally thickens in successive wedges toward the Gulf. The top of the Paleozoic basement occurs at depths of about 13,000 feet at the northern boundary of the region and reaches almost 30,000 feet in depth at the southern limit. Local structure modifies this general trend.

The region lies within a large structural downwarp known as the Mississippi Embayment, which extends north into southern Illinois, east into Alabama, south to the vicinity of Baton Rouge, Louisiana, and as far west as eastern Texas. A variety of smaller structural elements modifies this general framework and defines the immediate structural parameters of the storage rock unit. These features include basins and domes or uplifts, flexures and faults, and salt domes.

The region is one of low seismicity. Within 100 miles radius of the Gulf interior region there were only 20 earthquakes between 1886 and 1974 whose maximum intensities were equal to or greater than V on the Modified Mercalli scale of 1931.

The early tectonic history of the Gulf Coastal area before Jurassic time is conjectural because of lack of data. Currently, there are two trends of thought concerning the origin of the Gulf. One theory holds that the Gulf in some form existed since late Precambrian; the more popular theory holds that the Gulf was initiated by plate tectonics (sea-floor spreading) during early Mesozoic. By early Jurassic time, marine water had entered the area from the west, and a major evaporite-deposition cycle was initiated. At this time the area was probably landlocked. By the late Cretaceous, the area was open to

---

*Source: Bechtel (1978b).

1789 042

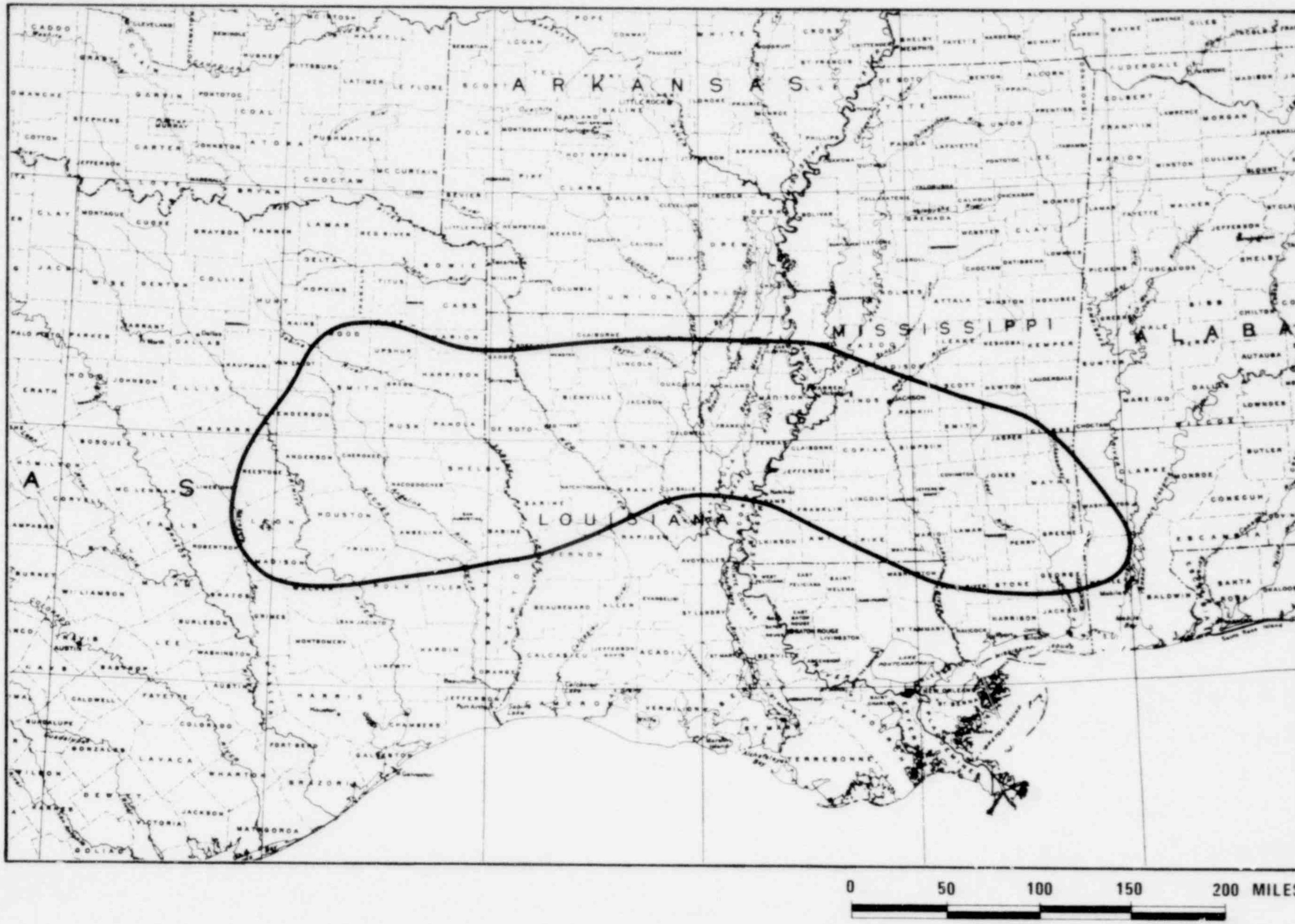


Figure B-4. Gulf interior salt-dome region.

1789 043

the sea, and the salt deposition had ceased. Various episodes of uplift prior to the Recent (Holocene) Epoch have resulted in the deposition of up to as much as 30,000 feet of material.

Oil and natural gas are the chief mineral industries of the area and have been for the past 50 years. However, other industries, based on processing such materials as ceramic and nonceramic clays, iron ore, and salt, are also well developed in relation to available markets.

B.7.2 Hydrology

The surface-water resources of the Gulf interior region can best be summarized by briefly reviewing the surface-water characteristics of each of four Water Resource Regions (WRRS): the Arkansas-White-Red, Texas Gulf, Lower Mississippi, and South Atlantic Gulf Regions. The various surface-water parameters described for each WRR, including precipitation, runoff, flood history, and surface-water quality, availability and demand, may vary significantly between and within WRRs.

The Arkansas-White-Red Region (AWRR), which consists of 265,000 square miles in Oklahoma, Louisiana, Arkansas, Texas, Missouri, Kansas, New Mexico, and Colorado, intersects only a small midwestern portion of the Gulf interior region. Precipitation and runoff decrease greatly from the humid eastern areas to the semiarid western areas of the AWRR. The AWRR averages 3200 113,000 cfs of runoff, with the maximum stream flow generally occurring from April to June. Major rivers include the Arkansas, White, Red, and Canadian. Eastern lowlands of the AWRR are subject to severe rainstorms and recurrent flash flooding; flooding in the western and central portions results from intense and infrequent rainstorms of short duration. Flood-control problems have been reduced, particularly in eastern areas, by the construction of numerous reservoirs along major rivers. Surface-water quality in several major waterways of the AWRR is poor due to widespread natural and man-induced pollution including natural mineralization, mine discharges, erosion, and municipal and industrial effluents. The availability and use of many AWRR surface waters for agricultural, municipal, industrial, and recreational uses are severely limited by the low quantities and qualities of surface waters in some parts of the AWRR. In general, most water supplies are derived from groundwater sources in the western and central AWRR.

The Texas Gulf Region (TGR), which consists of 173,000 square miles in Texas, Louisiana, and New Mexico, intersects roughly one-third of the western Gulf interior region. Precipitation and runoff decrease dramatically from the Texas Gulf Coast northwest to the central and western areas of the TGR. Average runoff is 30 million acre-ft/yr and is principally from the eastern one-fourth of the TGR. Major rivers in the TGR include the Sabine, Neches, Trinity, and Brazos. Flooding in the TGR typically results from tropical storms originating in the Gulf of Mexico; the largest floods have occurred in late summer and early fall from hurricanes. Total-dissolved-solids concentrations in the TGR vary from less than 100 to over 2500 mg/l, with the upper reaches of the Brazos River having the poorest water quality observed. Approximately half the TGR's water needs are met from surface-water sources, and surface-water use is expected to triple by the year 2020. Although the regional supply of surface water is expected to meet that demand, unequal geographic distribution of surface-water supply and demand may pose problems.

The Lower Mississippi Region (LMR) consists of about 102,700 square miles in Louisiana, Mississippi, Arkansas, Missouri, Tennessee, and Kentucky, and intersects the central quarter of the Gulf interior region. Average annual precipitation varies from 64 inches along the Gulf Coast to 44 inches in southern Missouri. Runoff is rather uniform throughout the LMR, decreasing from 26 to 14 inches per year from coastal to central areas, respectively. Roughly 116,380 cfs of annual discharge is generated within the LMR. Major rivers include the Mississippi, St. Francis, White, Arkansas, and Yazoo. Flooding generally results during late winter or spring from heavy rains and rapid snow melt throughout the Ohio and Mississippi River valleys, or in late summer or early fall from tropical storms and hurricanes along the Gulf Coast. Areas subject to flooding are floodplains and adjacent areas of the Mississippi River, its major tributaries, and coastal areas. By 1970, LMR flood-control storage totaled 6,028,000 acre-feet, and over 3780 miles of levees and floodwalls were in place. Surface-water quality throughout the LMR is variable and dependent on location; in general, however, most streams have good natural quality. Varying degrees of man-induced pollution require selective use and some pretreatment of surface waters in some areas of the LMR. The LMR is one of the most water-rich WRRs in the United States, with 85 million acre-feet of runoff generated within the LMR and a total of 485 million acre-feet discharged annually from its waterways into the Gulf of Mexico. Large increases in surface-water demand are projected by the year 2020, and no shortages are expected.

The South Atlantic-Gulf Region (SAGR) consists of 276,000 square miles in South Carolina, Florida, Virginia, North Carolina, Georgia, Alabama, Louisiana, and Mississippi; it encompasses roughly the eastern third of the Gulf interior region. Precipitation is generally plentiful and uniformly distributed throughout the SAGR. Average runoff 305,000 cfs. Seasonal highs in runoff occur from November to April and from June to October, resulting from broad cyclonic disturbances and tropical hurricanes, respectively. Major rivers in the SAGR include the Alabama, Tombigbee, Apalachicola, Santee, and Altamaha. Widespread, disastrous flooding is uncommon, although an estimated (in 1968) additional 3.3 million acres of land require flood protection by 1980. Seasonal flood potential is highest from December to April and from August to October. Areas most prone to flooding include the floodplains of major rivers and coastal areas. Numerous watershed and flood-control projects have been constructed throughout the SAGR for flood protection. Natural surface-water quality is generally excellent, with dissolved-solids concentrations averaging less than 100 mg/l. In some coastal plain streams, high turbidity and high sediment loads are not uncommon. In some localized areas, municipal, industrial, and agricultural sources of pollution have caused restricted use of surface waters and an increased reliance on upstream reservoir storage and groundwater for municipal water supplies. Because of abundant surface-water and groundwater supplies within the SAGR, no current or projected water shortages are expected.

Good-quality groundwater is present throughout the Gulf interior region, and it is used extensively for domestic, municipal, and industrial purposes. Several aquifers or hydrologic units are recognized in the post-Cretaceous coastal plain sediments. They comprise a thick sequence of interbedded sands, clays, and marls in which the more permeable materials provide aquifers confined between the less permeable clays and marls. Important water-bearing units or aquifers in the region include the Wilcox-Carrizo units, the Sparta (Kosciusko) Formation, Miocene sands, and Pleistocene to Recent alluvial

1789 045

valley deposits. The water-bearing formations receive recharge in their out crop areas from precipitation and stream flow, although under present conditions the aquifers are full, and most of the water available for recharge is rejected, moving laterally and discharging to low stream valleys.

B.7.3 Climate

The Gulf interior region lies within a humid temperate zone with moderately high winter temperatures and moderate amounts of rainfall throughout the year. These conditions indicate a relatively low potential for wind erosion.

Although this area has experienced significant temperature decreases (9-28.8°F) in the recent geologic past, indications of glaciation within that period are absent. In fact, the previous glacial boundary appears to be more than 435 miles north of this region.

Severe-weather occurrences in the Gulf interior region generally take the form of high winds and precipitation associated with hurricanes that intrude inland from the Gulf of Mexico. The 100-year-recurrence events for these two meteorological phenomena are 11 inches of precipitation within a 24-hour period and winds of 90 mph. Another severe-weather phenomenon experienced in this region is the occasional tornado (ranging from 6 in a 12-year period on the Louisiana-Mississippi border to 43 or more in portions of northeast Texas during the same period).

Generally moderate mixing levels together with moderate wind speeds and rolling terrain make the Gulf interior region unlikely to experience inversions. Stations within and near this region have reported 13 to 28 episode-days of poor dispersion within a 5-year period.

The region, like most of the country, experiences periods in excess of national ambient air-quality standards (NAAQS) for particulates. Trends in air quality, as evaluated by the Environmental Protection Agency (EPA), indicate a very gradual improvement in this condition in the Gulf interior region, primarily as a result of improved pollution control technology. There are also a number of areas within this region that have been designated by the EPA as areas of concern for the control of photochemical oxidants. In most cases, these areas, consisting of large metropolitan sites and their immediate surroundings, are presently exceeding NAAQS for this pollutant.

With regard to the Prevention of Significant Deterioration, the region lies within a Class II area, which allows for moderate industrial development. The nearest (presently defined) Class I areas are more than 100 miles away.

B.7.4 Background Radiation

Data for approximately 38 locations in the Gulf interior region and surrounding territory indicate that the region is about average in natural terrestrial and cosmic background radiation. The highest reported background radiation values are in Texas, but regional variations appear to be insignificant.

B.7.5 Demographic, Socioeconomic, and Land-Use Systems

In eastern Texas, the Gulf interior region is a rural area with many small towns. The major cities within the area are Tyler and Longview, but large urban areas such as Dallas, Fort Worth, Waco, and Austin are adjacent to the region. Approximately 75% of the population is white; the remaining is black (except for the 0.7% that is Indian, Chinese, Japanese, or other). The total population of the area was 766,154 in 1970, and most of the counties showed a population-growth rate of more than 7% between 1970 and 1975. Per capita income for the region was $3119.

The Gulf interior region in Louisiana encompasses 298 parishes in the northern part of the State and includes the cities of Shreveport, Monroe, and Alexandria. The total population of this area was 1,062,685 in 1970. Population growth was slower in Louisiana than in Texas, and many parishes had a net decline of up to 10% between 1970 and 1975. Annual per capita income in 1974 for the region was $2788.

There are 35 counties in the Gulf interior region in Mississippi. The largest cities in the region are Jackson (166,512), Meridian (46,256), Hattiesburg (38,097), and Vicksburg (29,726). The total population for the area was 778,158 in 1970 and increased to 1,064,217 (estimated) in 1975. Six counties experienced a decline in population between 1970 and 1975, and counties other than those having the major cities mentioned above had a slower growth rate than the rest of the nation and the slowest for all states in the Gulf interior region. Nearly 66% of the 1970 population was white, 34% was black, and less than 1% was of other origin. Per capita income grew by 50 to 70% between 1969 and 1974, and regional average annual per capita income was $2826 in 1974.

The economy of the eastern Texas region is largely resource oriented. Extractive industries such as mining, petroleum, and natural gas extraction, manufacturing based on regional resources, and agriculture comprise the core of the export economic base. In rural counties in eastern Texas, tourism is an important element in the local economy. Mining and manufacturing activities account for 33% of the total employment. Eastern Texas is a producer of agricultural crops and livestock; some counties produce considerable amounts of livestock and poultry for export to other states.

Much of the region in Louisiana is rural and is used for agricultural crops, grazing, or forest. More than 64% of the total employment is located in the Shreveport, Monroe, or Alexandria urban areas. The State is one of the largest producers of natural gas and petroleum. Manufacturing is located near the larger urban areas, and industries based on lumber and wood products, food products, primary metal products, fabricated metal products and appliances, textiles and apparel, and chemicals all have notable employment. In 1970 the agricultural production of crops was centered in the lowland region along the Mississippi River; livestock production was concentrated in upland areas. Total agricultural income in 1974 was $445 million, up 114% from 1969, with approximately 70% attributed to crops and hay.

Manufacturing accounts for 31% of the total employment in the Mississippi Gulf portion of the interior region, and represents the largest single employment sector. Extractive industries (natural gas and petroleum, sand and gravel, and other minerals) employ less than 20% of the labor force. Agriculture is also a significant contributor to the local economy. Lowland counties of the Mississippi River basin are intensively cultivated for field and row crops; upland counties are extensively used for livestock grazing.

The majority of the population in the eastern Texas Gulf interior region lies in the Tyler and Longview urban areas. As much as 10% of the area is in urban uses, and the average population density throughout the area is 0.02 persons per acre. Vast expanses of woodlands and agricultural land characterize the area. Eastern Texas has three national forests totaling 507,012 acres: Angelina, Davy Crockett, and Sabine. Recreational uses of lakes and reservoirs and parks in the area are rapidly growing, and second-home development around some lakes (i.e., the Cedar Creek Reservoir) has occurred recently. The Federal Government maintains and is acquiring jurisdiction over sizable land areas to meet growing demands for various recreational uses. Airports are common throughout eastern Texas; restricted or prohibited airspaces with various altitude and aircraft-operation limitations are also present. Highway and rail systems are extensive throughout the area. One Indian reservation exists in Polk County, Texas.

In Louisiana most urban land in residential, commercial, and industrial uses is around the cities of Shreveport, Monroe, and Alexandria. Outside these urban areas, small towns are numerous, but rural areas are, for the most part, devoted to agriculture or forests. Upland parishes in northwestern Louisiana have less field and row crops and more livestock-grazing land than do lowland parishes along the Mississippi River. The Kisatchie National Forest is distributed in several parcels throughout Louisiana; the total acreage of all parcels is 500,302 acres, or 6.1% of the land in the area. State fish and wildlife management areas and state forests provide abundant recreational uses. Airports of varying size are found throughout the area; restricted and prohibited airspaces with varying limitations are also present. Rail and highway systems are well developed in all of Louisiana. One Indian reservation is located in the area.

The largest cities in the Gulf interior region in Mississippi are Jackson (166,572), Meridian (46,256), Hattiesburg (38,097), and Vicksburg (29,726). Like Louisiana, the area is largely rural, with agricultural lands predominating. Five national forests in the area cover 1.7 million acres, or 15% of the area. Many types of uses are provided, including recreation as well as timber harvesting. Airports of various sizes are found throughout the area, as are restricted airspaces. Rail and highway systems are well developed. One Indian reservation is located in Leake County, outside the Gulf interior region.

B.7.6 Terrestrial Ecosystems

The Gulf interior region and surrounding territory in Texas are made up of nine potential vegetation types, ranging from mixed hardwood-softwood forests to open prairies and savannahs. No ecological reserves have been established in the basin, but a number of locally administered natural areas do insure preservation of habitats in as near an undisturbed condition as possible. Important animal species include approximately 9 fur bearers, several game animals, and 20 protected, threatened, or endangered species.

Major range types in the Texas Gulf interior region include grasslands, shrublands and chaparral, and pinyon-juniper woodlands. The rangeland has a relatively high productivity compared to the typical western range, and livestock and livestock products accounted for the highest portion of all agricultural products sold in the Texas Gulf interior region in 1974 (47%). This was followed by poultry and poultry products (36%), crops and hay (12%), nursery and greenhouse products (3%, and forest products on farms (1%). Harvested hay, sorghum, and cotton were the crops covering the greatest land area in 1974. Commercial forests in counties within the East Texas Piney Woods region cover about 63% of the region. Forest types with the most coverage are loblolly-shortleaf pine, oak-pine, and oak-hickory.

Only four potential vegetation types occur within the Gulf interior region of Louisiana--prairie and three kinds of mixed hardwood-and-softwood forests. However, the variation within these vegetation types, due to man's activities as well as the natural soil and climatic variation, contributes to diverse wildlife habitats. In addition to one ecological reserve, the Bayou Boeuf Natural Area, there are several State, private, and Federal wildlife areas. Important animal species include approximately 13 fur bearers, 11 game mammals, and 6 threatened or endangered species.

Livestock grazing occurs on cultivated pasture as well as in forested lands. Livestock and livestock products represented only 18% of the value of agricultural products sold in 1974. Principal livestock types produced in the area in 1974 were beef and dairy cattle. Livestock productivity varies throughout the area, as does the productivity of agricultural crops and timber resources, the most productive livestock parishes being De Soto, Caddo, Richland, Natchitoches, and Rapides. Agricultural crop production was largest in Morehouse, East Carrol, Madison, and Avoyelles Parishes; crops and hay represented 70% of all agricultural products sold in the Louisiana Gulf interior region in 1974. Cotton was the crop with the largest harvested area, followed by soybeans, rice, corn, sorghum, wheat, and sugarcane. There are three major forest types in Louisiana: southern pine, upland hardwood (oak-hickory), and bottomland hardwood. Commercial southern pine forests are mostly longleaf and slash pines in the southern half of the State and shortleaf and loblolly pines in the north. Bottomland hardwoods include such species as oak, gum, cypress, elm, ash, and cottonwood. Production of timber resources was highest in Ouachita, Caldwell, Winn, Natchitoches, Sabine, and Caddo Parishes.

In Mississippi, as in Louisiana, there are only four potential natural vegetation types, but one, the blackbelt, is limited to the Gulf interior region of Mississippi and Alabama. Six ecological natural areas have been established in the Gulf interior region of Mississippi for the preservation of vegetation types and wildlife habitat. Important animal species include approximately 11 fur bearers, 11 game animals, and 13 species on the Federal list of threatened and endangered species.

In the Mississippi Gulf interior region, poultry and poultry products accounted for the highest portion of all agricultural products sold in 1974 (45%), followed by crops and hay (30%), and livestock and livestock products

(22%). Rangeland and wooded pasture are extensively distributed throughout the area. Soybeans, hay, and cotton were the crops with the largest harvested area in 1974. Commercial forests are extensive, covering about 62% of the land area in Mississippi. Commercial forests with the largest areas are oak-hickory, loblolly-shortleaf pine, oak-pine, and oak-gum-cypress.

B.7.7 Aquatic Ecosystems

The Gulf interior region is noted for its extensive and valuable recreational and commercial warm-water stream and lake fisheries. Stream and lake habitats in the region can be divided into bottomland and upland habitat types. Bottomland habitats are generally in the larger, deeper, slow-moving, and turbid streams and rivers that meander through the interior region. Upland habitats are generally in the smaller, faster-moving creeks and streams that are the tributaries of the major waterways within the region. Six endangered fish species have been identified in the Gulf interior region; all six species are found in the State of Mississippi.

B.8 THE HANFORD SITE*

The Hanford Site is a 600-square-mile tract in the southeastern part of Washington State. It is semiarid, and the closest population center is Richland, 5 kilometers to the south.

B.8.1 Geology

The Hanford Site is in the Columbia Plateau physiographic province, which is characterized by the occurrence of a thick sequence of tholeiitic basalts and varies significantly in topographic expression as well as structure (Figure B-5). The Columbia basin section is a broad geologic and structural basin in the interior of the province; the Hanford Site is located in the Pasco basin, which is one of several subbasins.

The Columbia basin contains the Channeled Scablands formed at the close of Pleistocene glaciation by multiple catastrophic floods. The floods occurred as ice-dammed lakes released torrents of water and ice when the ice dams were breached.

The regional geology is dominated by Cenozoic rocks and structures. During the Cenozoic Era, numerous basalt magma outpourings from extensive fissure systems flowed across the Columbia Plateau and into regional areas of subsidence, such as the Pasco basin, where thick sections of basalt accumulated. The thickness of the basalt sequence is an average of 1800 feet in the Columbia Plateau and is more than 10,000 feet in the Pasco basin. The

---

*Source: Private communication from K. R. Fecht, Rockwell Hanford Operations, December 1978.

frequency and size of the eruptions decreased and then ceased during the late Tertiary period (about 6 million years before the present).

Regional subsidence continued and was accompanied by regional north-south compression, which has resulted in folding of the basalt sequence and in the formation of a number of roughly east-west-trending anticlinal ridges in the central part of the Columbia Plateau. At the Hanford Site, this ridge system is represented by the Rattlesnake Mountains, the Yakima Ridge, and the Umtanum-Gable Mountain Ridge.

Within and on top of the basalt sequence are sedimentary deposits. The interbeds between basalt flows consist of tuffs, tuffaceous sediments, and, in some locations, stream-carried sediments. Interbeds are more prevalent in the upper part of the basalt sequence.

The top of the basalt sequence is covered with fluvial, glaciofluvial, and eolian deposits. In the Pasco basin, the basalt is covered by up to 1000 feet of fluvial sediments (the Ringold Formation) overlain with up to 300 feet of glaciofluvial sediments (informally named the Hanford Formation). Eolian deposits overlie the Ringold Formation in the western part of the Hanford Site. The basement rocks below the basalt sequence are of uncertain composition but are probably sandstones and shale. Granitic rocks are probably below that.

Mineral resources are sand and gravel, basalt, and possibly natural gas. Natural gas has not been detected in recent drilling of deep boreholes.

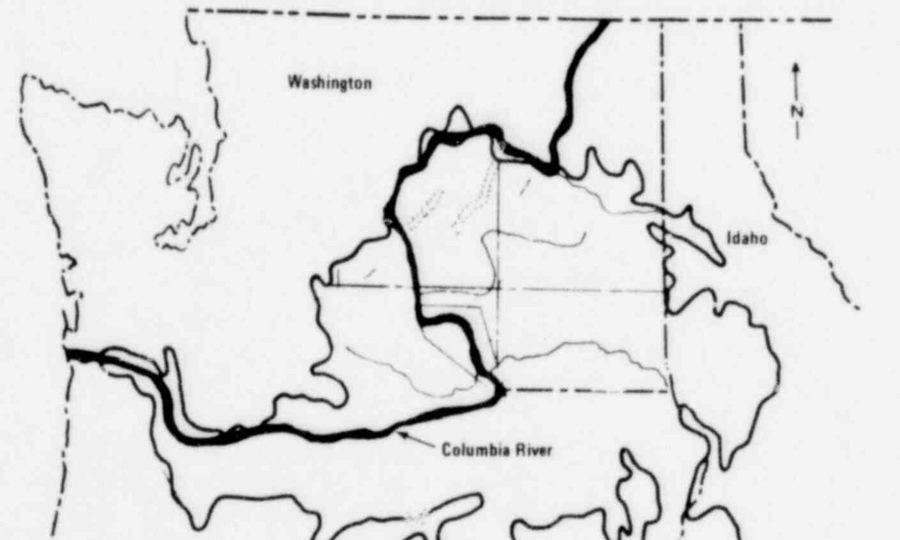


Figure B-5. Location of the Columbia Plateau basalts.

1789 051

The Columbia basin is a region of low seismicity in which moderate earthquakes have occurred. Microseismic activity at the Hanford Site indicates low levels of stress relief, generally shallow focal depths, and no obvious relationship to any geologic structure. The maximum known earthquake intensity in the vicinity of the site was less than IV on the Modified Mercalli scale.

Faults in the region are associated with folds in the basalt and appear to reflect local adjustments to folding. They are relatively short in length (less than 30 miles), with generally small displacements (less than 500 feet).

B.8.2 Hydrology

The Pasco basin is a series of confined aquifers overlain by an unconfined aquifer. The area is bounded by ridges to the north, south, and west and by a broad regional monocline to the east.

The confined aquifers are primarily the permeable interbeds and interflow zones in the basalt sequence. The interflow zones are characterized by vesicular rock or by interconnected fracturing caused by rapid cooling of the basalt magma. There is very little hydraulic interconnection between aquifers since the central volume of the basalt flows is dense and has a very low permeability. Fractures in the basalt have been filled with secondary mineralization products such as montronite. The confined aquifers are recharged by precipitation, stream runoff, and infiltration from the overlying unconfined aquifer or distant recharge points. Discharge of the upper aquifer is to the Columbia River.

The unconfined aquifer occurs above the basalt sequence up to about the top of the Ringold Formation. The groundwater movement is distorted by local geologic structures and has been modified by waste-disposal activities at the Hanford Site.

Between the top of the unconfined aquifer and the land surface is the vadose zone. This unsaturated zone is up to about 300 feet thick and is extremely dry below about 30 feet. In this desiccated zone, there is nearly no downward movement of water.

B.8.3 Climate

The climate of the Columbia basin region is dominated by the Cascade Mountain Range to the west and by the prevalent direction of storm fronts from the Pacific Ocean. Summers are relatively hot and dry, most of the average 6 inches of precipitation falls during the winter, and there are occasional periods of high winds. Prevailing winds are from the northwest.

Tornadoes are infrequent. It has been estimated that the probability of a specific surface structure's being hit by a tornado is only 6 in one million.

Thunderstorm activity is low. The estimated annual lightning strike frequency is 0.022 for a typical Hanford building.

B.8.4 Demography

There are an estimated 250,000 people within 50 miles of the Hanford Site. The estimated mean growth rate to the year 2000 is 0.7%.

B.8.5 Historical and Archaeological Sites

There are five locations listed as historical sites or as natural landmarks within 50 miles of the Hanford Site. None are on the site. There are over 200 Indian archaeological sites in the Hanford area, and many of them are along the Columbia River where it passes through the Hanford Site.

B.8.6 Ecology

The ecological aspects of the Hanford Site are consistent with the semiarid climate. The principal plant community is the sagebrush-cheatgrass-bluegrass association; mammals include the coyote, the rabbit, mule deer, and small rodents; birds include chukar partridge, western meadowlark, migratory ducks and geese, and several species of predatory birds. There are several thousand insect species and about 15 species of snakes and lizards. The aquatic ecosystem consists of the Columbia River and a few ponds and ditches.

Rare, threatened, and endangered species located on the Hanford Site include three plant species and seven bird species. The status of some of the latter has not been determined.

1789 053

REFERENCES

Bechtel, 1978a. Regional Environmental Characterization Report for the Paradox Region and Surrounding Territory, ONWI/Sub/78/512-01600-2, prepared by Bechtel National, Inc., for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

Bechtel, 1978b. Regional Environmental Characterization Report for the Gulf Interior Region and Surrounding Territory, ONWI/Sub/78/512-01600-1, prepared by Bechtel National, Inc., for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

NUS, 1978a. Environmental Characterization of Bedded Salt Formation and Overlying Areas of the Permian Basin (draft), Y/OWI/SUB-78/42505/2, prepared by NUS Corporation for the Office of Waste Isolation, Union Carbide Corporation, Oak Ridge, Tenn.

NUS, 1978b. Environmental Characterization of Bedded Salt Formation and Overlying Areas of the Salina Basin (draft), Y/OWI/SUB-78/42505/1, prepared by NUS Corporation for the Office of Waste Isolation, Union Carbide Corporation, Oak Ridge, Tenn.

DOE (U.S. Department of Energy), 1979. Nuclear Waste Management Program Summary Document, Washington, D.C.

1789 054

Appendix C

FINDINGS AND RECOMMENDATIONS OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

Appendix C

FINDINGS AND RECOMMENDATIONS OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

IRG Discussion of Generic Approach to TRU-Waste Disposal

The discussion by the Interagency Review Group (IRG, 1979. pp. 69-70) of strategies for TRU-waste disposal is extremely relevant to this draft environmental impact statement. It is reproduced in full below.

> As with choosing a strategy for HLW disposal, the choice of a TRU waste disposal strategy must await completion of an appropriate environmental impact statement and its adoption through the NEPA process. In the meantime, Federal actions regarding the management of TRU waste must not prejudice the choice of strategies for their disposal. Nevertheless, an interim strategic planning basis will be necessary to guide the TRU waste management programs and R&D activities before that choice is made.
>
> In laying out the following technical strategies for TRU waste disposal, the IRG assumed that all TRU waste, whether generated by commercial or defense operations, would be disposed of in the same manner because no technical reason exists to treat them differently. The two strategies examined by the IRG are:
>
> Strategy 1. No special action would be taken to pursue TRU waste disposal prior to the opening of a high-level-waste repository. TRU waste would be disposed of in high-level-waste repositories whenever they become available.
>
> Strategy 2. If an opportunity can be found, the program would proceed with an early dedicated TRU repository as soon as a site could be appropriately qualified and NEPA requirements fulfilled.
>
> Enough TRU waste now exists stored above ground to warrant the opening of a repository dedicated to TRU. Such a facility could probably hold all the TRU waste to be generated through the end of this century. Of course, once a high-level-waste repository were available, decisions on the location for disposal of then existing TRU wastes could be made on a case by case basis to maximize convenience and minimize transportation. A second repository dedicated to TRU waste alone would seem to be unnecessary.
>
> Because of the presence in TRU waste of substantial quantities of transuranic radionuclides, issues related to long-term containment (such as the potential for groundwater transport, any possibilities of repository breachment, and concerns about mineral resources or tectonism) are identical for TRU and HLW repositories. However, the problems associated with heat generation and increases in temperature are absent and the TRU wastes are not as difficult to handle as HLW. The operational demands on a disposal system designed for TRU waste alone would be more modest than those associated with a HLW repository. In addition, because of the absence of heat-related

1789 056

considerations, the regulatory review of a dedicated TRU repository would be somewhat simplified compared with that for a HLW repository.

Proceeding with an early, dedicated TRU repository would therefore be consistent with the previously recommended philosophy of conservation and proceeding stepwise into the most difficult disposal problem and would signal the government's determination to proceed in a timely manner with disposal of nuclear wastes. There would, of course, be some additional costs associated with the opening of a dedicated TRU facility.

Having considered these various matters, the IRG recommends adopting, as an interim strategic planning basis pending NEPA review, the concept of proceeding with an early TRU repository if an opportunity exists to do so.

IRG Discussion of the Nature and Benefits of an Intermediate-Scale Facility

As part of its proposal for a near-term interim strategic-planning base for high-level-waste disposal, the IRG put forth the idea of siting one or more intermediate-scale facilities (ISFs). Such facilities were described as licensed facilities in which some hundreds, perhaps as many as a thousand, spent-fuel assemblies or waste canisters would be emplaced in a geologic environment with the possibility of removing them if necessary, but without the expectation of doing so (IRG, 1979, p. 55):

> The functions of an ISF can be divided into (1) acquisition of technical, engineering, and operational data and (2) exercising and learning about licensing and organizational processes. Technical aspects of an intermediate scale facility would include improved understanding of engineering aspects of working in particular host rock and of near field effects of the waste....By emplacing relatively few waste containers or fuel elements, some of this information would be obtained in a short time, perhaps five years. Much of it would apply generically to the type of host rock and the type of waste and packaging used.
>
> Valuable information on intermediate field effects related to heat transfer and rock mechanics could be obtained by monitoring for perhaps 20 or more years. For this purpose, much larger heat loadings would be required than to learn about near field effects. Again, much useful information could be obtained about the particular rocks and environment surrounding the test and existing mathematical models could be tested....
>
> An ISF would also provide valuable experience in constructing, operating, and maintaining facilities and equipment for waste packaging, handling, transporting, emplacement, and retrieval....
>
> Exercising the licensing process for at least one ISF at an early date would be extremely useful preparation for the later licensing proceeding of the first full-scale repository. This would provide an actual proceeding on which the NRC, DOE, and

1789 057

> interested intervenors could focus their attention and exercise their models, analyses, and arguments and from which everyone could learn about the nature of this complex process.

In its revised report, the IRG (1979, pp. 57-58) supplemented these earlier views with the following:

> The IRG agrees that the notion of an ISF as part of the stepwise progression to full repository operations is essentially the same as the retrievable phase of the repository. To avoid further confusion, the IRG now proposes to use the term ISF only for standalone facilities or those colocated with a TRU repository and use the term "the retrievable phase of the repository" to include the notion of adequate instrumentation for purposes of studying the behavior of waste and waste-rock interactions during the interval for which retrievability is possible.
>
> As indicated in the Draft IRG Report, only some of the technical information about geology and waste-rock interactions derived from an ISF could be transferred usefully to another site. However, most of whatever institutional information that is required (including operational experience, logistics, organizational design and licensing) could be transferred. As stated on in Chapter IV of the Draft IRG Report, the IRG considers the resolution of institutional issues to be equally as important as for technical ones. In addition, much of the institutional information will come before and during the construction of an ISF or as it begins operations. This information can be very beneficial to many aspects of the program directed at opening the first full-scale repository. Some of the technical information, if available at the time of repository site selection, could also be utilized, in site selection, but it is by no means essential for that purpose.
>
> The IRG believes that an ISF is not an essential component of a program leading to a full-scale repository. All of the institutional knowledge obtainable from an ISF could also be obtained in the selection, licensing, and construction of the first repository and during its early period of operations. There would therefore be no value in delaying the pace of the program leading to the first repository just to build and operate an ISF.
>
> An ISF is not an essential component of a program leading to a full-scale repository. Nonetheless, if an appropriate opportunity to build an ISF on a schedule significantly prior to the opening of the first full-scale, high-level waste repository were to exist, the opportunity should be taken. From a purely technical perspective, an appropriate opportunity implies technical readiness and the completion of an adequate site characterization program. However, other non-technical factors should also be taken into account. Some agencies believe that an adequate site characterization program must include characterization of a variety of sites, in different geologic environments, and relying on diverse media. All ISF's should be licensed, since these elements will be an important step in the ultimate location and construction of repositories to acquire institutional experience and to protect public health and safety.

1789 058

Some members of the IRG believe that an ISF should only be sited where the possibility of placing a full-scale, high-level-waste repository is recognized from the beginning. Therefore the criteria, standards, and procedures (including appropriate state and local government and public involvement) governing the site selection process for a possible expanded application must be rigorously observed from the initial steps of ISF siting....

Some members of the IRG believe, however, that an ISF should not be colocated with a dedicated TRU repository, but rather that the TRU and HLW activities should proceed at different locations.

Despite this variation in views, the IRG (1979, p. 63) summarized its main finding on ISFs, as one of the key elements of an interim strategic-planning basis for HLW and TRU, as follows:

...If an appropriate opportunity to build an ISF on a schedule significantly prior to the opening of the first full-scale high-level-waste repository were to exist, the opportunity should be taken....All ISFs should be licensed, since these elements will be an important step in the ultimate location and construction of repositories to acquire institutional experience and to protect public health and safety.

IRG Discussion of High-Level-Waste Disposal

The Interagency Review Group defined four technical strategies for high-level-waste disposal (IRG, 1979, pp. 49-50):

- Strategy I provides that only mined repositories would be considered and that only geological environments with salt as the emplacement media would be considered for the first several repositories. As a result of past focusing on salt, there is a large volume of information available. In addition, one body of opinion holds that salt is the best, or at least an acceptable, emplacement medium and that suitable sites can be found where salt is the host rock.

- Strategy II provides that, for the first few facilities, only mined repositories would be considered. A choice of site for the first repository would be made from among whatever types of environments have been adequately characterized at the time of choice. Because generic understanding of engineering features of a salt repository are most advanced, the first choice is expected to be made from environments based on salt geology. Sites from a wider range of geologic environments would be available for selection somewhat later.

- Strategy III provides that, for the first facility only mined repositories would be considered. However, three to five geological environments possessing a wide variety of emplacement media would be examined before a selection was made. Other technological options would be contenders as soon as they had been shown to be technologically sound and economically feasible.

- Strategy IV provides that the choice of technical options and, if appropriate, geological environment be made only after information about a number of environments and other technical options has been obtained.

These strategies were intended to illustrate the range of possible strategic approaches. They were not intended to be a complete list of possible strategies or comprehensive descriptions of a strategic planning basis that might actually be adopted by the waste disposal program. For the latter purpose, they are admittedly incomplete.

IRG Discussion of Key Elements of Interim Strategic-Planning Basis for High-Level Waste

As a result of comments on its draft report, the IRG (1979, pp. 61-62) expanded and clarified its views on the interim strategic-planning basis for high-level waste, restating them as follows:

- The approach to permanent disposal of nuclear waste should proceed on a stepwise basis in a technically conservative manner....

- Near-term R&D and site characterization programs should be designed so that at the earliest date feasible, sites selected for location of a repository can be chosen from among a set with a variety of potential host rock and geohydrological characteristics. To accomplish this, R&D on several potential emplacement media and site characterization work on a variety of geologic environments should be increased promptly.

- A number of potential sites in a variety of geologic environments should be identified and early action should be taken to reserve the option to use them if needed at an appropriate time. In order to avoid working toward and ultimately having a single national repository, near-term options should create the option to have at least two (and possibly three) repositories become operational within this century, ideally and insofar as technical considerations permit, in different regions of the country. In pursuing a regional approach to siting, geologic, hydrologic, tectonic and other technical characteristics of sites must remain the primary basis for selection.

- Construction and operation of a repository should proceed on a stepwise basis and initial emplacement of waste in at least the first repository should be planned to proceed on a technically conservative basis and permit retrievability of the waste for some initial period of time. Further definition of the retrievability concept, the circumstances in which waste would be retrieved and the technical aspects (including development of waste packaging, containers and handling) is necessary.

1789 060

All IRG members agreed with the above elements of the recommended interim strategic-planning basis for high-level waste. They asserted further (IRG, 1979, p. 63) that these elements:

- do not prejudge the NEPA process
- require the Federal government to maintain a technically conservative approach
- call for resolution of uncertainties by increasing the technical and program breadth with respect to the near-term repository characterization program
- do not preclude subsequent adoption of longer term technologies inasmuch as they call for increased R&D to develop selected alternatives
- support a step-wise approach to the development of a HLW repository, while maintaining storage capacity for managing wastes until emplacement and disposal opportunities are available

The IRG did not come to a consensus on the basis for selection of the site for the first HLW repository.

REFERENCE

IRG, 1979. Report to the President by the Interagency Review Group on Nuclear Waste Management, TID-29442, U.S. Department of Energy, Washington, D.C.

Appendix D

SELECTION CRITERIA FOR THE WIPP REFERENCE SITE

CONTENTS

1789 063

Appendix D

SELECTION CRITERIA FOR THE WIPP REFERENCE SITE

This appendix briefly describes how the geologic, hydrologic, and other characteristics of the WIPP reference site in southeastern New Mexico meet site-selection criteria and factors. The criteria and factors given here are from the Geological Characterization Report (Powers et al., 1978, pp. 2-15ff) and are a distillation of criteria suggested earlier by the Oak Ridge National Laboratory (ORNL, 1973), the International Atomic Energy Agency (1977), and Brunton and McClain (1977).

1789 064

D.1 GEOLOGIC CRITERION

The geology of the site will be such that the repository will not be breached by natural phenomena while the waste poses a significant hazard to man. The geology must also permit safe operation of the WIPP reference repository.

Site-Selection Factors

Topography. The terrain must permit access for transportation. Effect on inducing salt flow during excavation must be considered. Surface-water flow and future inundation must be evaluated.

The maximum relief over the WIPP repository is 120 feet. The regional relief is low and easily accommodates the required transportation corridors. The location near a broad surface and groundwater divide will minimize the development of future relief. Differential stress in the salt due to surface relief is not a significant factor in causing deformation in the salt. (See Powers et al., 1978, Sections 3.2 and 4.2).

Depth. Repository horizons should be deeper than 1000 feet to insure that erosion and consequences of surficial phenomena are not a major concern. Depth of suitable horizons will not exceed 3000 feet to limit the rate of salt deformation around the excavations.

The selected repository bed for heat-producing waste varies between depths of 2750 and 2250 feet over the potential excavation area. The bed for TRU waste ranges from 2200 to 1800 feet deep through the repository region. These depths are based on interpretations of seismic reflection data. (See Powers et al., 1978, Sections 3.3, 4.3, and 9.2).

Thickness. The total thickness of the salt deposits should be several hundred feet to buffer thermal and mechanical effects. The desired thickness for the repository bed is 20 feet or more to mitigate the thermal and mechanical effects at nonhalite units.

The halite unit in which the heat-producing waste will be placed is about 100 feet thick. The total thickness of the evaporite section provides about a 1300-foot buffer above and below the repository horizons. This distance to the nearest potential aquifers insures the thermal effects at these aquifers will be insignificant. (See Powers et al., 1978, Sections 4.3.2 and 9.2.)

Lateral extent. The distance to structural or dissolution boundaries must be adequate to provide for future site integrity. For the Los Medanos area a distance of 5 miles to the Capitan reef and 1 mile to regional Salado dissolution has been established.

The selected horizons are believed to extend well beyond the repository site based on seismic data and drill-hole information. The separations from the deformed salt belt parallel to the Capitan reef and from the natural dissolution fronts are adequate to assure the required site integrity. (See Powers et al., 1978, Sections 3.3, 4.3, and 6.3.)

Lithology. Purity of the salt beds is desirable to reduce the brine content of the salt. Pending further investigations, 3% brine is established

1789 065

as a desirable upper limit for the heat-producing waste horizon. Additional geochemical interactions must be considered if significant chemical or mineralogical impurities are present.

The horizon within the lower Salado that will accommodate the heat-producing wastes averages more than 97% halite from the samples analyzed. Brine content averages less than 0.5%. (See Powers et al., 1978, Sections 4.3 and 7.2 through 7.6.)

Stratigraphy. Continuity of beds, character of interbedding and nature of beds overlying and underlying the salt are important considerations in the construction of the facility and in the assessment of possible failure scenarios.

There are no beds of clay or polyhalite near enough to the lower repository horizon to affect repository construction and operation or to cause concern for the repository due to dehydration. The significant nonhalite beds adjacent to the heat-producing waste horizons are principally anhydrite, which has favorable thermal, mechanical, and chemical properties for bounding layers. The upper (TRU) level of the repository can also be located to avoid rock-mechanics instabilities due to interbeds of nonhalite rock. (See Powers et al., 1978, Sections 3.3, 3.4, 4.3, and 4.4.)

Structure. Relatively flat bedding (less than 3 degrees) is desirable for operational purposes. Steep anticlines and major faults are to be avoided.

Seismic reflection data and drill-hole information have been interpreted as showing relatively flat (less than 1 degree) bedding over most of the 3-square-mile repository horizon. Seismic data do show a small anticline at the northern edge of control zone II. Drilling on this anticline (WIPP-12) has shown that the elevation difference of the repository beds, from ERDA-9 at the center of the repository to WIPP-12, is less than 200 feet, an average of about 2 degrees. Photography, satellite imagery, surface mapping, geophysical techniques, and drilling have been used to search for indications of significant faulting. No post-Permian faults are known to exist in the site area. Seismic indications of faulting in older, deeper rocks do not extend through the Permian evaporite section.

The lack of severe structure and recent faulting satisfactorily meets the desired conditions for this factor. (See Powers et al., 1978, Sections 3.4 and 4.4.)

Erosion. While the depth factor reduces concern for erosion, it is desirable to avoid features that would tend to localize and/or accelerate erosion.

The site is located near a broad surface water divide, and the local base level is at an elevation of about 2900 feet. Consequently, future erosion will proceed less rapidly over the site than in the established drainage channels. Anticipated erosion rates will not expose the Salado salt within the required lifetime of the repository. Future climatic changes will not alter this assessment, and glaciation is not expected to be a concern at this location. (See Powers, et al., 1978, Sections 3.2.3, 3.6, 4.2, and 6.2.)

1789 066

Dissolution. Regional and/or local dissolution must not breach the repository while the wastes represent a significant hazard to man. While there are various suggestions for the time a repository should remain isolated from the biosphere, 250,000 years (10 half-lives of plutonium-239) is one period that may be sufficient for evaluating the reference site.

Studies by the U.S. Geological Survey indicate that the maximum rate of horizontal progression of the salt-dissolution front in Nash Draw, averaged over the past 500,000 years, has been 6 to 8 miles per million years and less than 500 feet vertically per million years. The nearest active solution front is to the west, in Nash Draw. This is far enough from the site to provide repository isolation for times in excess of 2 million years. (See Powers et al., 1978, Section 6.3.6.)

Subsidence. Subsidence due to dissolution of salt will be avoided when the subsidence adversely affects the repository beds or unduly accelerates the rate of dissolution to the jeopardy of long-term integrity of the repository.

Subsidence has occurred over the western portion of the reference-site area due to natural removal of salt from the Rustler Formation. Hydrologic data from this region indicate that the major aquifers in the Rustler have different potential heads and thus this regional subsidence has not caused them to be interconnected by permeable fractures. No sinks due to localized solutioning are present in the site.

D.2 HYDROLOGIC CRITERION

The hydrology of the site must provide high confidence that natural dissolution will not breach the site while the waste poses a significant hazard to man. Accidental penetrations should not result in undue hazards to mankind.

Site-Selection Factors

Surface water. Present and future runoff patterns, flooding potential, etc., should not endanger the penetrations into the repository while these openings are unplugged.

Situation of the site near a broad surface water divide, lack of established drainage, and an elevation well above the Pecos River all permit easy construction to prevent flooding of the repository. (See Powers et al., 1978, Section 6.2.)

Aquifers. For WIPP, the overlying and underlying aquifers represent a secondary barrier if the salt is breached. Consequently, low permeability and transmissivity are desirable but not mandatory. Accurate knowledge of aquifer parameters is important to construction, decommissioning, and realistic calculation of the consequences of failure scenarios.

Aquifers above and below the repository have low transmissivity. Consequently, flooding of the repository during its operation through shafts or drill holes is not credible. Thus adequate plugging of these access points on decommissioning will be more readily attained.

The major aquifers above and below the WIPP beds do not produce potable water since they carry too many salts to be useful even if the quantities were adequate for use.

The hydrologic parameters of the aquifers do not permit rapid flow of water. The low permeability would limit the flow even if heads were to be modified in future pluvial cycles. (See Section 9.5 and Powers et al., 1978, Section 6.3.)

Hydrologic transport. For the WIPP, this is a secondary factor that must be evaluated to allow quantitative calculations of the consequences of various failure scenarios. Slow transport of isotopes is acceptable if more critical factors have been satisfied.

Calculation of various postulated failure scenarios indicates that transport of radioactive isotopes through the overlying and underlying aquifers is slow enough that a significant hazard to humans would not exist even if the salt beds were breached. The nearest natural discharge point is the Pecos River, over 14 miles away. Using the maximum measured rates of water movement for intervals between the site and Malaga Bend results in a time interval of about 1700 years after a breach for the first trace of nonretarded isotopes (i.e., iodine-129) to appear at the Pecos. The long-lived transuranic isotopes would be retarded by ion absorption and would not begin to appear at Malaga Bend until 35,000 years after the postulated breach of the salt beds. Concentrations (or possible doses) never reach significant hazard levels in the Pecos River. (See Section 9.5 and Powers et al., 1978, Sections 6.3, 9.3, and 10.6.)

Climatic fluctuations. Possible pluvial cycles must be considered in estimating the effects of the above factors.

The dissolution and erosion rates established as averages over the past 500,000 years integrate the effects of several past pluvial cycles. It is anticipated that future cycles would also be of short duration compared with the isolation time sought for the repository. Transport rates under different climates (rainfall) can be estimated by appropriate boundary conditions on the hydrologic model. The low permeability of the major aquifers above the site will not be significantly altered by the climatic changes anticipated for this area, and the resultant flow in the aquifers will not be grossly altered by changed climatic conditions. (See Powers et al., 1978, Sections 3.6 and 4.5, Chapter 6, and Section 10.3.)

Man-made penetrations. The effect of drill holes and mining operations on the site selection must be evaluated in considerations of dissolution.

The repository and control zone III are free of preexisting boreholes that extend through the salt, shafts, and mining activity. Any existing or future holes in any of the WIPP zones must be adequately plugged when abandoned.

D.3 TECTONIC STABILITY CRITERION

Natural tectonic processes must not result in a breach of the site while the wastes represent a significant hazard to man and should not require extreme precautions during the operational period of the repository.

Site-Selection Factors

Seismic activity. The frequency and magnitude of seismic activity impacts facility design and safety of operation. Low levels of seismicity are desirable, but facility design can accommodate higher levels as well.

The WIPP reference site is in an area of relatively low seismic activity. The nearest seismic activity has been 10 or more miles north of the site and of small magnitude. It is not known whether the three nearest events are tectonic, related to dissolutioning, or a result of man's activity. No faulting has been observed in the area of these seismic events. In any case they, and the potential future events, pose no hazard for a properly constructed repository and are no threat to its long-term integrity. (See Powers et al., 1978, Chapter 5 and Section 10.5.)

Faulting and fracturing. While open faults, fractures, or joints are not expected in salt, the more brittle units within and surrounding the salt may support such features that can enhance dissolution and hydrologic transport. Major faults and pronounced linear structural trends should be avoided.

No major structural trends of recent geologic age are known to exist in the site area. The nearest recent faulting observed is on the west side of the Guadalupe Mountains, some 70 miles away. Seismic reflection data has indicated small faults in deep, old rocks below the Salado Formation. There are no known tectonic faults in post-Permian rocks at the site area. Thousands of miles of drift in the potash mines in the Salado salt have not encountered any open fractures or faults through which groundwater had penetrated.

Salt-flow anticlines. Major deformation of salt beds by flow can fracture brittle rock and create porosity for brine accumulations. Major anticlines resulting from salt flow should be avoided or evaluated to check on brine presence and anhydrite fracturing.

The only anticlines within the reference site are relatively minor features. Both have been drilled, however, and the cores show little fracturing or porosity and no accumulation of fluids. These small anticlines will not hinder repository construction or jeopardize its long-term safety. (See Powers et al., 1978, Section 4.4.)

Diapirism. An extreme result of salt flow, this feature will be avoided for WIPP siting.

There are no known or indicated diapirs (salt domes) in the reference site. (See Powers et al., 1978, Section 4.4.)

Regional stability. Areas of pronounced regional uplift or subsidence should be avoided since such behavior makes anticipation of future dissolution, erosion, and salt flow more uncertain.

Geologic mapping has failed to reveal any indicators of regional instability. Caliche formation and attitude indicate stable conditions in the site region over the last half-million years. Lack of scarps and natural seismicity are consistent with regional stability. (See Powers et al., 1978, Sections 3.4, 4.4, and 10.3.2.)

Igneous activity. Areas of active or recent volcanism or igneous intrusion should be avoided to minimize these hazards to the repository.

No recent igneous activity is known in the region. Geophysical surveys, mining, and drill-hole intercepts have shown that an intrusive dike exists 9 miles northwest of the site. Age dates show it to be 35 million years old. No other intrusive features are known to exist in the region. (See Powers et al., 1978, Section 3.5.)

Geothermal gradient. Abnormally high geothermal gradients should be avoided to allow construction in salt at 3000 feet. High gradients may also be indicative of recent igneous or tectonic activity.

The geothermal gradient as determined in the AEC-8 drill hole shows a normal geothermal gradient averaging about $0.58^{\circ}F/100$ feet. The heat flow is about one heat flow unit. (See Powers et al., 1978, Section 4.4.1.)

D.4 PHYSICOCHEMICAL COMPATIBILITY CRITERION

The repository medium must not interact with the waste in ways that create unacceptable operational or long-term hazards.

Site-Selection Factors

Fluid content. The repository bed containing high-level waste should not contain more than 3% brine. The limit for TRU waste has not been established, but the same value used for HLW is acceptable.

The average brine content of the lower repository is less than 0.5% by weight. The average brine content of the upper repository horizon beds is less than 1% by weight. (See Powers et al., 1978, Sections 7.5 and 10.7.8.)

Thermal properties. No major natural thermal barriers should exist closer than 20 feet to avoid undesirable temperature rises.

This is of significance to the lower horizon, where the halite unit of interest is about 100 feet thick. The adjoining beds are anhydrite, which, even though far enough away, have similar thermal conductivity and do not represent thermal barriers in any case. (See Powers et al., 1978, Section 9.2.3.)

Mechanical properties. The medium must safely support excavation of openings even while thermally loaded. Clay seams and zones of unusual structural weakness should be avoided in the selection of the repository horizon.

The halite bed at the lower level is sufficiently thick and devoid of clay seams that stability of openings will not be a problem for repository operation. Clay seams and polyhalite beds are more common in the area selected for the upper repository level, but construction levels can be located to avoid significant structural stability problems from such nonhalite beds. (See Powers et al., 1978 Section 9.2.4.)

Chemical properties and mineralogy. Beds that are of unusual composition or contain minerals with bound water should not occur within 20 feet of the waste horizon. This will lessen the uncertainties with regard to thermally driven geochemical interactions.

The heat-producing waste horizon is quite pure halite, with more than 97% NaCl. No polyhalite, clay, or other water-bearing minerals occur near this horizon. The upper horizon beds are more than 92% NaCl, with impurities being mostly potassium and magnesium salts and clay. These impurities have no known negative implications for TRU-waste isolation and, in fact, have been shown to absorb radionuclides from brine. (See Powers et al., 1978, Sections 4.3 and 7.2 through 7.5.)

Radiation effects. While no unacceptably deleterious effects are postulated, these phenomena are best quantified in halite, and thus the purer rock salt beds are desired for high-level waste.

No unexpected radiation effects have been detected in samples of WIPP salt. The low brine content will limit the amount and effects of radiolytic disassociation of water. (See Powers et al., 1978, Section 9.3.)

Permeability. Salt has very low permeability, and only the interbeds and surrounding media are considered for siting with respect to this factor. Low permeability is desirable, but quantitative limits need not be specified for site selection. (Salt permeability to gases may be important in establishing waste-acceptance criteria.)

Laboratory measurements on cores indicate very low permeability. On a large scale, measurements at the WIPP horizons have not been made. Experience in other drill holes (absence of aquifers in salt and presence of small, high-pressure gas pockets) would argue for very low in-situ permeability on larger scales. (See Powers et al., 1978, Section 9.2.3.)

Nuclide mobility. This is a secondary factor in siting since confinement by the salt and isolation from water are the basic isolation premises. Ion sorption must be determined to allow quantification of safety analyses and to indicate whether engineered barriers (clay) would be beneficial.

The distributed impurities in the rock salt provide significant ion-absorption capability for many radionuclides. The clay layers in higher salt beds will be still more absorptive. These properties will tend to minimize displacement of radiation due to such local mechanisms as brine migration in thermal gradients. (See Powers et al., 1978, Section 9.3.)

D.5 ECONOMIC AND SOCIAL COMPATIBILITY CRITERION

The site must be operable at reasonable economic cost and should not create unacceptable impacts on natural resources or the biological and sociological environment.

1789 071

Site Selection Factors

Natural resources. Unavoidable conflict of the repository with actual or potential resources will be minimized to the extent possible.

This factor is not well satisfied by the reference site. Both hydrocarbons and potash exist in potentially economic quantities within the site. While salt itself may be considered a valuable mineral, its economic potential at the site is very low. Since both potash and hydrocarbons may be recovered from control zone IV, the amounts that may be restricted from development within zones I, II, and III are the critical amounts. These quantities are not large in terms of national supply (even the langbeinite product is synthesized in quantity from brine lakes). These minerals may prove an enticement for future exploration and exploitation. For this reason, studies are under way to examine the effects of recovering the potash ore from above control zone III. Very little potash exists above the repository (zone II) itself. Similarly, once adequate borehole plugging is demonstrated, drilling in zone III could be permitted or the same zones developed from zone IV by deviated drilling. The expectation, but one that cannot yet be guaranteed, is that these minerals may be recovered in the decades ahead should they be economically attractive. Certainly the time frame for their development would be within the next century, while the repository site is still under administrative control. The small amounts of either resource within zone III would not be of significant interest in the absence of other production in the area. (See Powers et al., 1978, Chapter 8.)

Man-made penetrations. Boreholes or shafts that penetrate through the salt into underlying aquifers shall be avoided within 1 mile of the repository. Existing mining activity, unrelated to the repository, should not be present within 2 miles of the repository. Future, controlled mining will be allowable up to 1 mile from the repository. Future studies may permit still closer mining and drilling if properly controlled.

The present site adequately fulfills this present restriction on man-made penetrations. (See Powers et al., 1978, Section 2.3 and Chapter 4.)

Transportation. Transportation should be capable of ready development. Avoidance of population centers by transportation routes is not a factor in the siting of the repository.

The present site meets this requirement and would utilize a spur line of the Sante Fe Railroad now running to the Duval mine.

Accessibility. The site should be readily accessible for transporation and utilities.

The site presents no problems for access by road, railroad, or utility lines.

Land jurisdiction. Siting will be on federally controlled land to the extent possible.

Of the 18,960 acres to be withdrawn by the DOE if this site is approved, 17,200 are federal land controlled by the Bureau of Land Management, and 1,760 acres belong to the State of New Mexico. There are no private lands within the site.

Population density. Proximity to population centers and rural habitats will be considered in siting. A low population density in the immediate site area is desirable.

There are 13 permanent residents within 10 miles of the site. There is a transient population at potash mines. The nearest town is Loving, New Mexico, with a population of 1,100. Carlsbad is 26 miles west and has a population of 25,000. Low population is not necessary to siting but, all other factors being equal, is desirable.

Ecological effects. Major impacts on ecology due to construction and operation should not occur. Archaeological and historical features of significance should be preserved.

No major or unusual impacts on the environment or ecologic system are anticipated due to construction and operation of the repository. No significant archaeological sites will be destroyed by repository construction. No endangered species are known to occur within the site.

Sociological impacts. Demographic and economic effects should not result in unacceptable sociological impacts.

There was no a priori reason to expect any severe or unacceptable socioeconomic impacts attributable to the site location. This assessment has been substantiated by socioeconomic studies reported in Section 9.4 of this document.

REFERENCES

Brunton, G. D., and W. C. McClain, 1977. Geological Criteria for Radioactive Waste Repositories, Y/OWI/TM-47, Office of Waste Isolation, Union Carbide Corporation, Oak Ridge, Tenn.

International Atomic Energy Agency, 1977. Site Selection Factors for Repositories of Solid High-Level and Alpha-Bearing Waste in Geological Formations, Technical Report Series No. 177, Vienna, Austria.

Oak Ridge National Laboratory (ORNL), 1973. Site Selection Factors for the Bedded Salt Pilot Plant, ORNL-TM-4219.

Powers, D. W., S. J. Lambert, S.-E. Shaffer, L. R. Hill, and W. D. Weart (eds.), 1978. Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, 2 vols., SAND78-1596, Sandia Laboratories, Albuquerque, N.M.

1789 073

Appendix E

DESCRIPTIONS OF WASTE TYPES

CONTENTS

1789 076

Appendix E

DESCRIPTIONS OF WASTE TYPES

This appendix contains five tables that describe the types of waste to be stored at the WIPP reference repository and the containers used for transportation and storage. It also presents a detailed characterization of defense stored transuranic waste, compiled by James E. Dieckhoner of the U.S. Department of Energy. It concludes (Annex 2) with a description of the types of waste stored and the containers used at the Idaho National Engineering Laboratory.

1789 077

Table E-1. Defense Contact-Handled TRU Waste (Drum)[a]

		Remarks
Type of container	DOT-17C 55-gal steel drum	Rocky Flats Plant Standard SX-200
Liner (if used)	0.09-in.-thick, rigid-polyethylene inner liners	Rocky Flats Plant Standard SX-202
Weight of container	640 lb (290 kg)	
Surface-dose rate	≤200 mrem/hr	Interim waste-acceptance criterion
Surface contamination	Limits in 49 CFR 173.397	Interim waste-acceptance criterion
Waste properties	Combustible: paper, cardboard boxes, wooden boxes, plastic bags, rubber scrap, rags, surgical gloves, clothing, etc. Noncombustible: residues or solutions from chemical processing, building rubble, metal, glassware, sludges, and acids	

Radioactive isotope	Expected activity (Ci/drum)	Surface contamination (Ci/drum)
Pu-238	4.1-2[b]	1.28-8
Pu-239	4.8-1	1.49-7
Pu-240	1.2-1	3.63-8
Pu-241 (beta emitter)	2.9	2.00-6
Am-241	7.8-3	2.45-9
TOTAL	3.5	2.20-6
Total fissile content	7.8 g	
Total Pu	8 g	

[a]Data from O'Brien (in press).
[b]4.1-2 = 4.1×10^{-2}.

1789 078

Table E-2. Defense Contact-Handled TRU Waste (Box)[a]

		Remarks
Type of container	DOT-7A 4 x 4 x 7-ft plywood box	Rocky Flats Plant Standards SX-211 (plywood box) and SX-207 (fiberglass-reinforced-polyester coating)
Weight of container	Maximum 10,000 lb (4500 kg); typical 3000 lb (1360 kg)	
Surface-dose rate	≤200 mrem/hr	Interim waste-acceptance criterion
Surface contamination	Limits in 49 CFR 173.397	Interim waste-acceptance criterion
Waste properties	Combustible: paper, cardboard boxes, wooden boxes, plastic bags, rubber scrap, rags, surgical gloves, clothing, etc. Noncombustible: residues or solutions from chemical processing, building rubble, metal, glassware, sludges, and acids Equipment and materials too large for 55-gal drums	

Radioactive isotope	Expected activity (Ci/box)	Surface contamination (Ci/box)
Pu-238	6.5-2[b]	8.66-8
Pu-239	7.5-1	9.94-7
Pu-240	1.8-1	2.41-7
Pu-241 (beta emitter)	4.6	1.34-5
Am-241	1.2-2	1.63-8
TOTAL	5.6	1.47-5
Total fissile content	12.2 g	
Total Pu	13 g	

[a]Data from O'Brien (in press).
[b]$6.5\text{-}2 = 6.5 \times 10^{-2}$.

1789 079

Table E-3. Defense Remotely Handled TRU Waste[a]

		Remarks
Type of container	Steel canister (1200-liter internal volume)	Proposed for WIPP reference repository
Weight of container	10,000 lb (4500 kg)	
Surface-dose rate	≤100 rem/hr	Proposed waste-acceptance criterion
Surface contamination	Limits in 49 CFR 173.397	Proposed waste-acceptance criterion
Waste properties	Primarily noncombustible: concrete, steel, process sludges, etc.	

Radioactive isotope	Activity level (Ci/canister)	Surface contamination (Ci/canister)
Sr-90/Y-90	4.2+2[b]	8.94-6
Co-60	2.6	5.59-8
Ru-106/Rh-106	3.7	7.82-8
Cs-137/Ba-137m	2.1	4.48-8
Eu-152	5.3-1	1.12-8
Eu-154	2.1	4.48-8
Th-232	1.2-3	1.64-10
U-234	9.7-6	1.30-12
U-235	4.1-4	5.51-11
U-238	8.9-3	1.19-9
Pu-238	1.1-1	1.46-8
Pu-239	1.3	1.69-7
Pu-240	3.0-1	4.07-8
Pu-241	7.8	1.64-7
Am-241	2.1-2	2.81-9
Cm-244	5.3	7.04-7
TOTAL	4.5+2	1.03-5
Total fissile content	211.8 g	
Fissile density	0.177 g/l	

[a]Data from O'Brien (in press).
[b]4.2 + 2 = 4.2 x 10^2.

Table E-4. Commmercial High-Level Waste[a]

		Remarks
Type of container	Steel canister (200-liter internal volume)	Proposed for WIPP reference repository
Weight of container	3320 lb (1510 kg)	
Surface-dose rate	>4500 rem/hr	
Surface contamination	Limits in 49 CFR 173.397	
Physical form	Glass (or calcine)	

Radioactive isotope[a]	Activity level (Ci/canister)	Surface contamination (Ci/canister)
Sr-90/Y-90	1.6+5[b]	8.1-7
Ru-106/Rh-106	1.1+3	5.5-9
Cd-113m	1.7+1	8.5-11
Sb-125	9.8+3	8.2-9
Te-125m	6.8+2	3.4-9
Cs-134	1.9+4	9.8-8
Cs-137/Ba-137m	2.3+5	1.2-6
Ce-144/Pr-144	2.7+2	1.4-9
Pm-147	1.9+4	9.3-8
Sm-151	3.1+3	1.5-8
Eu-152	1.8+1	9.3-11
Eu-154	1.2+4	6.0-8
Eu-155	3.7+2	1.9-9
Np-239	4.9+1	2.5-10
Pu-238	2.5+2	1.5-8
Pu-239	4.4	2.6-10
Pu-240	1.2+1	6.9-10
Pu-241	8.6+2	4.3-9
Am-241	4.4+2	2.6-8
Am-242m	2.4+1	1.4-9
Am-243	4.9+1	2.9-9
Cm-242	6.0	3.5-10
Cm-243	8.0	4.7-10
Cm-244	4.4+3	2.6-7
TOTAL	4.6+5	2.6-6
Total fissile content i 10-ft-long canister	93 g	

[a]This is a truncated list of the isotopes present in commercial high-level waste.

[b]$1.6+5 = 1.6 \times 10^5$.

1789 081

Table E-5. Commercial Spent PWR Fuel[a]

		Remarks
Type of container	Steel canister	Proposed for WIPP reference repository
Weight of container (with PWR fuel assembly)	2500 lb (1130 kg)	
Surface-dose rate	$\sim 10^4$ rem/hr (10 years after discharge from reactor)	
Surface contamination	Limits in 49 CFR 173.397	

Radioactivity (10 years after discharge from reactor)

Isotope[b]	Ci	Isotope[b]	Ci
H-3	1.5+2[c]	U-234	3.9-1
Fe-55	2.9+2	U-238	1.4-1
Ni-63	2.2+2	Np-237	1.6-1
Kr-85	2.6+3	Pu-236	1.5-2
Sr-90/Y-90	3.0+4	Pu-238	1.3+3
Ru-106/Rh-106	2.3+2	Pu-239	1.5+2
Cd-113m	9.5+0	Pu-240	2.2+2
Sb-125	3.5+2	Pu-241	3.1+4
I-129	1.5-2	Pu-242	6.7-1
Cs-134	4.3+3	Am-241	6.7+2
Cs-137/Ba-137m	4.0+4	Am-242m	4.0
Ce-144/Pr-144	7.5+1	Am-243	9.1
Pm-147	3.6+3	Cm-242	3.3
Eu-154	2.4+3	Cm-243	1.5
Eu-155	2.7+2	Cm-244	8.8+2
Po-212	5.0-3	Cm-245	1.9-1
Po-216	7.9-3	Cm-246	3.8-2
Th-228	7.9-3		

[a]Data from Sutherland and Bennett (in press).

[b]This is a truncated list of the isotopes present in one 10-year-old spent-fuel assembly. This truncated list was used in the analyses of normal and accidental releases during the operation of the WIPP reference repository (Section 8.6). It was further truncated for the accident analyses presented in Section 9.3.

[c]$1.5+2 = 1.5 \times 10^2$.

1789 082

REFERENCES

Sutherland, S. H., and D. E. Bennett, in press. Defense High-Level Waste and Spent Fuel Characterization for Geologic Waste Repositories, SAND79-0172, Sandia Laboratories, Albuquerque, N.M.

O'Brien, P. D., in press. Waste Characterization for WIPP Safety Analysis, SAND79-0420, Sandia Laboratories, Albuquerque, N.M.

1789 083

REPORT FOR THE WIPP

WASTE ACCEPTANCE CRITERIA STEERING COMMITTEE

DETAILED CHARACTERIZATION

OF DOE STORED TRU WASTE

Compiled by James E. Dieckhoner

Office of Nuclear Waste Management
Division of Waste Products
Operations Branch

June 16, 1978

1789 084

Introduction

This report was prepared in response to a request of the WIPP Waste Acceptance Criteria Steering Committee (WACSC) at their meeting on March 2. All DOE field offices conducting TRU retrievable storage operations were asked to provide the Operations Branch with certain specific information concerning the TRU waste currently on hand and projected for the future. A copy of the request for data is included as Appendix A. Copies of the data supplied are included as Appendices B through G. The remainder of this record is a condensation of these responses and a restructuring of the data into a format where the WACSC can obtain an overall perspective on the DOE-wide situation. The reader is encouraged to consult the individual replies or to contact the respective field offices for more detailed information.

NOTE: Only one of the appendices mentioned above (Appendix F) is included here: the data on wastes stored at the Idaho National Engineering Laboratory (see Annex 1, pp. E-21 through E-36).

1789 085

Section I

Qualitative Description of Available Waste Characterization Information

A. Contact-Handled TRU Waste:

LASL - Waste generators are required to complete a form containing information on the radionuclide content (including error estimates and how the amount was determined), package construction, package radiation level, and waste type. The LASL lists 33 different waste types (see Appendix C [not included in here] for details). In addition, the form also permits the inclusion of additional data. Examples of typically recorded information include the identification of equipment items or types, and of chemical contaminants on or in the waste.

Sandia Lab - The waste will be in the form of glassware, equipment, solidified liquids, ceramic waste, etc., and contains No-239, Pu-238, Pu-239, Pu-241, Am-241, and Cm-244. All waste is packaged in DOT 17-C containers.

Pantex - Data currently available include: container site, volume, weight and type; chemical and physical form of the waste; isotopic composition and curie amount; and surface radiation reading.

ORNL - The computer system contains data by container: data received, source of waste, shipper, location in storage area, estimated amount of combustibles and noncombustibles, and estimated amount of U-233 and transuranics. Essentially all of this waste is from glovebox and hot cell operations. Since no assays were done, the isotopic composition data, if not reported by the generator, can be implied from the source (i.e., building). The package size and construction is well-known, but one precise weight is not. No information on compactibility is available. Although some knowledge of the chemical and physical forms of the waste can be inferred from its source, no specific information has been recorded. No information is available on nonradioactive constituents.

Hanford - Each waste shipment is accompanied by a shipping ticket which physically describes the material content, the source of the waste, any special conditions, the type of radioactivity (specific radionuclides, etc.) quantity (curies or grams), and the radiation level. The TRU waste containers must also be identified as combustible or noncombustible. The locations of the TRU containers are also recorded.

INEL - The following information is recorded for each shipment: waste generator and building number, gross volume, gross weight, curie content, type and number of containers, unit container volume, waste description, nuclide identification and storage location. No data are currently available on nonradioactive toxic constituents in the TRU waste. Some may be contained from a records search, although initial indications are that any such information would be very limited and superficial. Compilations of some of these data can be found in Appendix F [reproduced here as Annex 1, pp. E-21 through E-36].

NTS - For retrievably stored, contact-handled TRU waste the gram content, curie content, isotopic composition, package site with weight and construction, and combustibility information are available.

SR - Early records contain only waste volumes and activities. However, since July 1, 1974, combustibles and noncombustibles are segregated and placed in separate drums and marked accordingly. The material composition of the waste can only be inferred from sample observations of the waste packaging operations and estimation by the production personnel. Results of such a survey can be found in Appendix B [not included here].

B. Remote-Handled TRU Waste:

LASL - The same type of information will be available as previously indicated for contact-handled TRU waste.

Sandia Lab - The same type of information would be available as previously indicated for contact-handled TRU waste.

Pantex - No waste of this type is stored at Pantex.

ORNL - Essentially all of this type waste is from hot cells (90 percent from one facility) and gloveboxes. It includes plastics, paper, wipes, various kinds of equipment, equipment racks, etc. No assays of waste to determine isotopic composition were made but the source and knowledge of the process may give some indication. The package site weight and construction are well-known. An estimate of the combustibility is available, but there is no information on its compactibility, nor on the presence of nonradioactive toxic constituents. The chemical form varies--nitrides, chlorides, oxides, and others.

Hanford - The same type of information is available as previously indicated for contact-handled TRU waste.

INEL - The same type of information is available as previously indicated for contact-handled TRU waste.

NTS - No waste of this type is stored at NTS.

SR - No waste of this type is stored at SR.

C. TRU Waste Disposed of by Shallow Land Burial:

LASL - Waste management personnel have kept logbook-type records on all waste disposed of since the late 1940's. Work is underway to convert the pre-1971 records into the current computer system. The major problem with these old records will be the actual identification of which wastes contain 10 nCi/gm. Where buried TRU wastes can be identified, information as to waste matrix, packaging, radiation level, TRU content, and burial location should be available.

Sandia Lab - The waste is in the form of glassware, equipment, paper products, contaminated experiments, etc., and contains about 1 gram of Pu-239.

1789 087

Pantex - The same type of information is available as previously indicated for contact-handled TRU waste.

ORNL - Due to an accidental loss of records, no detailed information is available for the pre-1969 buried TRU waste, estimated to be about 200,000 ft^3 in volume. Since field separation of TRU waste began in 1970, about 63 containers of equipment were buried, in an essentially nonretrievable fashion, that were judged to be contaminated marginally above the 10 nCi/gm level. About 90 percent contained hoods and gloveboxes. No assays were made and the data is based on the judgment of the generator. The site and composition of the containers are known, the weights are estimates based on actual weights of a few. An estimate of the combustibility is available, but no information on the compactibility or on the presence of nonradioactive toxic constituents is available.

Hanford - The same general type of information is available as previously indicated for contact-handled TRU waste, except for knowledge of where the buried TRU-contaminated (>10 nCi/gm) waste is located among the non-TRU-contaminated waste.

INEL - The data available at the present time on the subsurface disposed TRU are limited to hand tabulations of quantities shipped from Rocky Flats plant and estimates of Pu quantities.

NTS - No waste of this type is buried at NTS.

SR - Much of the waste sent to the burial ground was contained in cardboard cartons which were dumped into the waste trenches and covered with soil. Bulky waste was wrapped in plastic and buried, or wrapped waste was placed in wooden boxes. Test retrievals indicate that the waste package in plastic will be well preserved; however, the cellulosic materials in contact with the soil will be degraded. Because early records are lacking, activity content and volume of waste buried before 1961 can only be estimated.

NOTE: The preceding are only brief synopses of the lengthier information submitted by the field. The reader is encouraged to consult the Appendices [in the original report] for more details, and to directly contact the field organizations to resolve difficulties in interpretation or to obtain specific additional information.

Section II

Inventory Data

All of the field offices were asked to present estimates of the approximate volumes of TRU waste in the following three categories (i.e., retrievably stored, contact-handled, retrievably stored, remote-handled, and TRU waste disposed of by shallow land burial) as of the start of FY 1978 and expected to have been accumulated as of the start of FY 1986. Estimates of the accuracy of these data were also requested. A compilation of the site submitted data is presented in Table 1, and a summary of the DOE-wide situation in Table 2.

1789 089

TABLE 1

APPROXIMATE VOLUMES OF DOE TRU WASTE AND ESTIMATES OF THEIR ACCURACY

Waste Category	Site	As of 10/1/77 Volume (ft^3)	As of 10/1/77 Accuracy	As of 10/1/84 Volume (ft^3)	As of 10/1/84 Accuracy
Stored, Contact-Handled TRU Waste	LASL	54,020	± 5%	200,000	± 25%
	SLA	0	-	3,500	± 30%
	Pantex	38	± 10%	57	± 15%
	ORNL	9,600	- 5% (4)	18,750 (4)	± 25% (4)
	Hanford	247,000	± 10%	770,000	± 30%
	INEL	1,201,917	± 10%	2,036,682	± 30%
	NTS	6,116	± 10% (3)	35,314	+200% - 50% (3)
	SRP	56,168	± 5% (1)	95,100	± 25% (1)
		1,574,859 ft^3	± (5-10)%	3,195,403 ft^3	± 30%
Stored, Remote-Handled TRU Waste	LASL	0	-	8,000	± 50%
	SLA	0	-	50	± 30%
	Pantex	0	-	0	-
	ORNL	26,550	± 5%	47,350 (4)	± 25% (4)
	Hanford	2,940	± 5%	7,900	+100% - 50%
	INEL	304	± 10%	14,442	± 50%
	NTS	0	-	0	-
	SRP	0	-	0	-
		29,794 ft^3	± (5%)	77,742 ft^3	± 50%
Buried TRU Waste	LASL	580,045	± 50%	580,045 (2)	± 50%
	SLA	60	± 50%	60	± 50%
	Pantex	1,143	± 10%	1,143	± 10%
	ORNL	200,000 (5)	± 50% (5)	200,000 (5)	± 50% (5)
		15,000	± 10% (4)	22,000	± 25% (4)
	Hanford	5,483,000	+200% - 50%	5,483,000	+200% - 50%
	INEL	2,102,000	± 30%	2,102,000	+200% - 50%
	NTS	0	-	- (3)	-
	SRP	1,084,740	± 5% (1)	1,084,740	± 5% (1)
		9,465,988 ft^3	+125% - 40%	9,472,988 ft^3	+125% - 40%

(1) Telecon with J. Covell, SR, 6/6/78.

(2) Telecon with J. Warren, LASL, 6/6/78. The figure in Appendix C was reduced since no burial of 10 nCi/gm is planned.

(3) Telecon with B. Church and P. Fitzsimmons, NV, 6/6/78. The figure in Appendix G was reduced since no burial of 10 nCi/gm waste is planned. The 1 x 10^4 m^3 referred to 10 nci/gm waste.

(4) Telecon with B. Brockelsby, OR, 6/6/78. The changes in Appendix D reflect re-estimates by ORNL for 1984 and the accuracy values. These buried TRU volumes refer to bulky equipment.

(5) This buried TRU volume refers to waste buried prior to the initiation of TRU retrievable storage operations at ORNL. Confirmed by telecon with B. Brockelsy, OR, 6/6/78.

Table 2

Summary of DOE TRU Waste Volumes

Waste Category	As of 10/1/77 Volume (ft^3)	As of 10/1/77 Accuracy	As of 10/1/84 Volume (ft^3)	As of 10/1/84 Accuracy
Stored Contact-Handled	1.6×10^6	$\pm$ (5-10)%	3.2×10^6	$\pm$ 30%
Stored Remote-Handled	3.0×10^4	$\pm$ 5%	7.8×10^4	$\pm$ 50%
Buried (1) (2)	9.5×10^6	+ 125% − 40%	9.5×10^6	+ 125% − 40%

(1) An unknown fraction of the buried TRU waste may be in concentrations less than the 10 nCi/gm level, and therefore may be incorrectly included as "TRU" waste.

(2) Due to the degradation of the original container, the total volume of material resulting from any operations to recover this material may be a factor of 2 to 3 larger than the original waste volume. In addition, such recovery operations would also generate an additional waste volume.

1789 092

Section III

Obtaining More Detailed Waste Characterization Data

The estimated time and funding required at the TRU waste retrievable storage sites to obtain significantly better data varied from site to site. Following is a synopsis of the individual replies:

LASL - For the retrievably stored waste, very little, if anything, can be done to improve signficantly the available data.

Pantex - It was estimated that it would require 80 man-days and $6,400 to obtain more detailed waste characterization data. This would not include opening of the containers, only verification with instruments. It would also not lead to the establishment of an actual weight of TRU material, since it is mixed with non-TRU materials and processing would be required.

ORNL - For the contact-handled TRU waste there might be two possible methods:

- The firm would require the development of an instrument system that can detect and quantify a variety of radionuclides through the wall of a storage drum. Employment of such a system would cost about $100/drum. This method would not, however, give any additional information on percent combustibles, compactibility, the presence of nonradioactive toxic materials, etc.

- The second method would involve construction of a facility where the drums would be opened and the contents analyzed and repackaged. Construction cost would be about $1M and operating costs about $1K/drum.

For the remote-handled TRU waste, improvement of the isotopic composition data is essentially not possible. The waste is heavily shielded so it would have to be removed from the casks in hot cells for further study, after being excavated. Construction would cost about $2M, excavation about $0.6K/cask and operation about $3K/cask. It would take about two to four years.

Hanford - It is estimated that rough estimates for the missing data for 300 Area burial grounds could be obtained in about one year and cost about $75K. The cost to improve the quality of the available data would take about one to two years and cost $250-$500K.

INEL - If the timing of additional waste characterization studies could be arranged to coincide with the ongoing program, it is anticipated that it could be done in four months for about $375K. If the timing could not be arranged, it would take two more months and cost an additional $100-$125K. An additional $100K would be needed to characterize the Pu in the soil surrounding the buried waste.

NTS - Estimates of the funding and time required to obtain significantly more detailed waste characterization data appear to be minimal.

1789 093

SR - A more detailed waste characterization study of retrievably stored waste would cost about $160K and take about one year. It would characterize, in detail, current waste as it is prepared for storage. Sampling waste now in storage would be more difficult and costly.

1789 094

Section IV

References

The following published reports contain specific additional data on the DOE stored and buried TRU waste. Additional data is contained in internal memos, burial records and shipping records.

1. "History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas, A, B, C, D, E, F, G, and T). A Source Document," LA-6848-MS, Vol. I and II, Margaret Anne Rogers, June 1977.

2. "Radioactive Waste Management Site Plan, Los Alamos Scientific Laboratory," updated June 1977 (available from AL).

3. "Radioactive Waste Management Site Plan, Sandia Laboratories--Albuquerque," updated 1977 (available from AL).

4. "Radioactive Waste Management Site Plan, Pantex Plant, Amarillo, Texas," updated 1977 (available from AL).

5. "ORNL Solid Waste Disposal Log," ORNL Computer Report, PCS-0673.

6. "Radioactive Waste Management Site Plan - ORNL," updated 1977 (available from OR).

7. ERDA-1538, "Final Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington," December 1975.

8. BNWL-MA-88, "Resource Book - Disposition (D&O) of Retired Contaminated Facilities at Hanford," August 1975.

9. RHO-CD-27-3Q, "Summary of Radioactive Solid Waste Burials in the 200 Areas During the First Three Quarters of 1977," J. D. Anderson and B. E. Porcurba, December 7, 1977.

10. "Radioactive Waste Management Site Plan - Hanford," updated 1977 (available from RL).

11. ERDA-1536, "Final Environmental Statement, Waste Management Operations, Idaho National Engineering Laboratory, Idaho," September 1977.

12. IDO-10054(77), "Radioactive Waste Information 1977, Summary and Record to Date."

13. IDO-10055(77), "Radioactive Waste Management Information for 1977."

14. WMP-77-3, "History of Buried Transuranic Waste at INEL," D.H. Card, March 1977.

15. "Radioactive Waste Management Site Plan - INEL," updated 1977 (available from ID).

1789 095

16. "Reports of the DOE Solid Waste Information Management System (SWIMS) (available from ID).

17. E. L. Albenesius, H. E. Hootman, "Characterize TRU Waste Inventories and Relate Characterization to Proposed Criteria," TRU Waste Form and Package Criteria Meeting, pp. 49-60, SAND 77-1178, August 1977.

18. E. L. Albenesius, W. C. Reinig, "Long Range Management of Transuranium-Contaminated Solid Wastes at Savannah River," Proceeding of the Seminar on the Management of Plutonium-Contaminated Solid Wastes, Marcoule, France, 1974, OECD, 1976.

19. M. O. Boersma, H. E. Hootman, P. H. Permar, "Development of an Integrated Facility for Processing TRU Wastes at the Savannah River Plant," paper presented at NEA-IAEA Technical Seminar on the Treatment, Conditioning and Storage of Solid Alpha-Bearing Wastes and Cladding Hulls, Paris, France, December 6-7, 1977.

20. J. W. Fenimore, R. L. Hooker, "The Assessment of Solid Low-Level Waste Management at the Savannah River Plant," DPST-77-300, August 1977.

21. J. H. Horton, J. C. Corey, "Storing Solid Radioactive Wastes at the Savannah River Plant," DP-1366, June 1976.

22. SRO-TWM-77-1, "Integrated Radioactive Defense Waste Management Plan," Savannah River Plant, Aiken, S.C., July 1977.

Annex 1

DATA ON WASTES STORED AT
THE IDAHO NATIONAL ENGINEERING LABORATORY

1789 099

April 23, 1978

Mr. J. B. Whitsett, Chief
Radioactive Waste Programs Branch
Idaho Operations Office - DOE
Idaho Falls, ID 83401

TRU WASTE DATA - Duf-73-78

Ref.: J. P. Hamric ltr to L. P. Duffy, same subject, Mar. 22, 1978

Dear Mr. Whitsett:

The referenced letter requested that TRU waste data be furnished for the WIPP Steering Committee. The following information and attached tables fulfill that request. The data are furnished in the same sequences as requested in the referenced letter.

(1) The information presently available on TRU waste is provided by the Waste Management Information System (WMIS) and the Transuranic Contaminated Waste Container Information System (TCWCIS). The start of the WMIS data file presently coincides with the initiation of retrievable storage at INEL (10//0) and the TCWCIS started in September 1971.

The WMIS data base includes the following data for each solid waste shipment: waste generator and building number, gross volume, gross weight, curie content, type and number of containers, unit container volume, waste description, nuclide identification and storage or disposal location. Routine monthly reports include disposed waste by nuclides, stored waste by nuclides, waste compaction data, number of stored or disposed containers, and detailed and summary reports by generator or disposal/storage location.

All retrievably stored waste, both contact and remote-handled, are included in the WMIS. The first year of data for retrievable storage is not available in the TCWCIS. The data available at the present time on the subsurface disposed TRU are limited to hand tabulations of quantities shipped from Rocky Flats plant and estimations of Plutonium quantities.

(2) Table I lists the quantities of TRU waste in each of the three requested categories. The retrievable storage data are derived from the WMIS data bank. The subsurface volume data are based on the information published in IDO-10055 (77) and have been modified to reflect the retrieval operations through 12-31-77. The quantity

listed for the Transuranic Disposal Area reflects the 10 nCi/gm TRU portion of the total waste disposed on Pad-A. Table II lists the volume projections for TRU waste through 10-1-84, based on the waste generator's forecasts. There is no projected subsurface disposal of TRU.

(3) The data for TRU waste presently in retrievable storage are the container volumes and are considered to be accurate within ± 10%. The projected container volumes for contact-handled TRU is ± 30% based on generator forecasts. For remote-handled TRU (ILTSF), the projected volume may vary ± 50%. This projection includes the first years waste from SAREF. The subsurface disposed TRU quantities are container volumes, based on tabulations of containers shipped, and do not reflect a review of waste shipment records. The disposed volume probably is accurate within ± 30%. However, due to container degradation, the mixing of waste with soil along with the TRU waste generation associated with retrieval operations; the total TRU retrieved volume may be a factor of 2 to 3 larger than the original waste volume.

(4) The WMIS data are published annually by DOE-ID. The documents are:
IDO-10054 (77) Radioactive Waste Management Information 1977 Summary and Record to Date.
IDO-10055 (77) Radioactive Waste Management Information for 1977.

The TCWCIS data are not published formally; however, several tabulations from this system are attached. Another information source is "History of Buried Transuranic Waste at INEL," WMP-77-3, March 1977, J.H. Card. A review of available past data records has been initiated with the objective of producing a WMIS type data base for all solid waste prior to October 1970. Also some additional Rocky Flats drum logs may allow the TCWCIS data base to be extended back to include the TRU waste of 1969-1971.

(5) The time and costs required to obtain significantly more detailed waste characterization data are dependent upon the scheduling of the project relative to the current waste retrieval operations. It is anticipated that upon completion of the Initial Drum Retrieval (IDR) project, the TSA-1 will be opened for a visual inspection of the exterior surfaces of the waste containers. This operation could also be the first step in obtaining retrievable containers for waste characterization. Also the Early Waste Retrieval (EWR) project, currently scheduled through December 1973 provides the basic containment structure and equipment for the characterization project. If the waste characterization project could be scheduled to operate concurrently with the final portion of the EWR project or directly afterwards, the costs of reactivating a mothballed EWR facility would be circumvented.

Utilizing the TSA-1 container inspection program to obtain the drums and an active EWR facility as a basic containment facility, it is anticipated that the costs of the waste characterization program would be 375,000 dollars and require 4 months of operation. A separate entry into the TSA to obtain the drums and reactivation of the EWR facility to conduct the waste characterization would add 2 months and 100-125,000 dollars to the program.

Another area of investigation which is very critical to the waste volume shipped to WIPP is the amount and degree of Plutonium soil contamination surrounding the subsurface waste. It is proposed that core samples be obtained in and around the early waste pits and trenches to better quantify the soil volume that will have to be processed. It is estimated that such a project could be accomplished for approximately 100,000 dollars.

The specifications for current waste packages are given in Appendix A. These specifications are applicable to drummed waste received after December 1972 and boxed waste received after June 1972. Consequently, it is estimated that TSA-1 and TSA-4 contain 1262 boxes which were not fiberglassed and 60,119 drums without liners.

Table III lists the isotopic composition by weight percent for the TRU nuclides in the contact-handled TRU waste. Table IV gives the average weight for the boxes and drums in the contact-handled TRU waste by year of storage. The increase in drum weight for the period of 1970-1977 is very significant and probably the result of better package utilization. Table V lists the combustibility and compactibility for the contact-handled TRU waste. Utilizing normal compaction and incinerating techniques, about 71% of the waste is not treatable. Table VI gives the plutonium loading in the Rocky Flats boxes and runs by year of storage. Again, the drums show a significant increase in Plutonium content in the latest waste (1970-1977).

A sampling of the contact-handled TRU waste by container content is given in Table VII. This table contains the data from several waste generators. Consequently, duplicate or near duplicate content descriptions may be encountered.

No data are currently available on nonradioactive toxic constituents in the TRU waste. Some information may be obtained from our record search.

1789 100

However, the initial indications are that any information of this type will be very limited and superficial.

Very truly yours,

L. P. Duffy, Manager
Waste Management Program

HMB:lf

Attachment - Appendix A

cc: R. W. Kiehn, EG&G Idaho

1789 101.

TABLE I

TRU WASTE AT INEL
AS OF 12/31/77

Storage Area	Volume m^3	Volume Cu. ft.	Curies	Box	Barrel	Bin	Grams PU	Grams Am-241	Grams U-233
Retrievably Stored - Contact-Handled TRU									
TSA #1 (1) 10/70-10/75	27,450	969,260	120,900	4,241	64,519	83	148,400	11,290	40,590
TSA #2 10/75-12/77	4,583	161,825	44,390	787	8,728	78	49,480	2,230	15,040
TSARI (2) 1/77-12/77	2,006	70,832	9,469	-	9,378	11	12,140	946	-
TOTALS	34,039	1,201,917	174,759	5,028	82,625	172	210,020	14,466	55,630
Retrievably Stored - Remote-Handled TRU									
11 TSF (3) 11/76-12/77	9	304	54	-	76	-	19	-	-
Subsurface Disposal TRU						Cartons			
SDA (4) 1954-10/70	59,522	2,102,000	191,000	6,042	182,250	12,783	344,000	-	-
TDA (5)	7,190	253,800	3,494	1,243	15,000	-	11	-	-

(1) Transuranic Storage Area - 20 year retrievable storage
(2) Transuranic Storage Area - Retrieved waste from subsurface disposal
(3) Intermediate Level Transuranic Storage Area - Intermediate gamma TRU waste
(4) Subsurface Disposal Area - Shallow land burial TRU wastes
(5) Transuranic Disposal Area - Pad disposal of 10nCi/gm TRU

TABLE II

TRU WASTE AT INEL

As of 10/1/84

Retrievably Stored - Contact-Handled TRU

As of 12/31/77	34,039 m^3	or	1,201,917 cu. ft.
Projection thru 1984	23,641 m^3	or	834,766 cu. ft.
Totals	57,680 m^3	or	2,036,682 cu. ft.

Retrievably Stored - Remote-Handled TRU

As of 12/31/77	9 m^3	or	318 cu. ft.
Projection thru 1984	400 m^3	or	14,124 cu. ft.
Totals	409 m^3	or	14,442 cu. ft.

Subsurface Disposal TRU

As of 12/31/77	59,522 m^3	or	2,102,000 cu. ft.
Projection thru 1984	0		0
Totals	59,522 m^3	or	2,102,000 cu. ft.

TABLE III
ISOTOPIC COMPOSITION OF TRU NUCLIDES IN TSA WASTE

Nuclide	Weight%
Am-241	5.15
Pu-238	0.34
Pu-239	69.57
Pu-240	4.36
Pu-241	.30
Pu-242	<0.01
U-233	20.27

TABLE III

ISOTOPIC COMPOSITION OF TRU NUCLIDES IN TSA WASTE

Nuclide	Weight %
Am-241	5.15
Pu-238	0.34
Pu-239	69.57
Pu-240	4.36
Pu-241	.30
Pu-242	0.01
U-233	20.27

TABLE IV

AVERAGE WEIGHT TRU WASTE CONTAINERS

Drums

	# Drums	Weight (lbs)	Average Weight
1970*	9,378	1,787,825	190.6
1971*	2,726	871,646	319.6
1972	15,690	5,641,154	363.2
1973	9,097	3,000,723	329.9
1974	6,860	2,444,782	356.9
1975	8,782	3,261,068	371.3
1976	4,279	1,596,536	372.4
1977	3,464	1,471,801	424.9
	60,266	19,975,565	331.5 (45 lbs/ft^3)

Boxes

	# Boxes	Weight (lbs)	Average Weight
1971*	562	1,205,060	2183.1
1972	975	3,063,110	3141.7
1973	944	2,813,612	2980.0
1974	774	2,006,220	2692.0
1975	613	1,316,289	2566.9
1976	492	1,359,950	2764.1
1977	514	1,415,634	2754.2
	4,764	13,179,875	2766.6 (25 lbs/ft^2)

*Partial year's data.

1789 105

TABLE V

COMBUSTIBILITY AND COMPACTIBILITY - TSA WASTE

9/71 - 12/77*

Unit Count	Total	Comp Comb	Comp NComb	NComp Comb	NComp NComb
Drums	48,917	15,677	1,190	408	31,842
Boxes	4,766	404	423	205	3,734
Bins	161	160	1	-	-
Volume (m^2)					
Drums	10,374	3,325	252	87	6,710
Boxes	14,849	1,259	1,318	639	11,633
Bins	547	544	3	-	-
Total	25,770	5,128	1,573	726	18,343
%		19.9	6.1	2.8	71.2

*Does not include retrieved wastes.

TABLE VI

AVERAGE PLUTONIUM LOADING ROCKY FLATS WASTE

Drums

Year	# of Units	Weight (gms)	Gms Pu/ Container
1971*	2,726	2,555	0.94
1972	15,690	27,744	1.76
1973	8,978	12,705	1.42
1974	6,119	28,595	4.67
1975	3,556	30,894	8.69
1976	2,765	15,519	5.61
1977	2,660	27,198	10.2
TOTAL	48,494	145,210	3.42 (Ave.)

Boxes

Year	# of Units	Weight (gms)	Gms Pu/ Container
1971*	552	769	1.39
1972	975	5,383	5.52
1973	944	11,554	12.24
1974	776	6,612	8.39
1975	302	1,047	3.47
1976	492	1,858	3.78
1977	466	4,993	10.71
TOTAL	4,507	32,116	7.13 (Ave.)

*Partial year's data.

1789 107

TABLE VII

TRANSURANIC STORAGE AREA DATA
9/71 thru 12/76
TABULATED BY CONTENT CODE

Content Description	Drums	Volume Cu. Ft.	Boxes	Volume Cu. Ft.	Weight lbs.	PU Grams	AH Grams
Not Recorded - Unknown	1,903	21,088			392,805	3,241	32
First Stage Sludge	4,957	37,821			2,537,489	26,224	10,249
Second Stage Sludge	6,472	48,842			3,469,429	1,523	16
Organic Set Ups (Oil Solids)	3,366	27,581			1,784,055	1,837	0
Special Set Ups (Cement)	851	6,812			508,472	910	7
Evaporated Salts	12	107	1	112	10,692	6	7
Combustibles (Rags, Gloves, Poly)	865	6,623			164,845	-0-	-0-
Non-compressible, Non-combust.	777	5,762			184,474	-0-	-0-
Solidified Grinding Sludge, Etc.	41	305			9,880	-0-	-0-
Solid Binary Scrap Powder, Etc.	12	88			2,950	-0-	-0-
Dirt	135	993			83,535	-0-	-0-
Sludge	23	169			6,800	-0-	-0-
Alpha Hot Cell Waste	40	160			3,674	16	-0-
American Process Residue	120	897			43,997	150	-0-
Sludge, Filter	1	7			145	14	-0-
Cemented Sludge	73	537			19,072	1,061	-0-
Graphite	758	5,619			197,179	6,274	-0-
Graphite Cores	32	235			8,327	405	-0-
Benelex and Plexiglas	16	118	16	1,792	63,728	67	-0-
Graphite Scarfings	16	118			3,827	81	-0-
Graphite Heels	4	41	1	112	3,500	783	-0-
Tantalum	192	1,412			48,365	2,372	18
Paper and Rags - Dry	4,945	36,835	323	36,176	1,576,644	2,662	91
Filters, Absolute (8x8)	110	809			16,912	215	7
Paper and Rags - Moist	7,293	53,738	8	896	1,455,248	2,212	11
Plastics, Teflon, Hash, Pvc	1,832	13,625	9	1,000	333,056	1,145	39
Insulation & CWS Filter Media	253	1,860	78	8,736	195,774	6,501	0
Leaded Rubber Gloves & Aprons	509	3,743			172,042	14,025	16
Insulation	239	1,761	1	112	36,138	217	0
Insulation Heel	1	11			411	199	0
Crucible, Lead	30	221			11,448	91	0
Brick, Fire	886	6,519	24	2,688	387,140	2,789	0
Grit	5	37			2,220	21	0
Blacktop Concrete Dirt and Sand	937	6,890	81	9,072	669,417	647	0

TABLE VII (Continued)

Content Description	Drums	Volume Cu. Ft.	Boxes	Volume Cu. Ft.	Weight lbs.	PU Grams	AH Grams
Oil Dirt Residues From Incinerator	11	81			4,209	10	0
Cement Insul. & Filter Media	206	1,515	2	224	56,971	5,253	17
Crucible and Sand	1	7			282	35	0
Sand, Slag and Crucibles	6	67			2,700	1,164	0
Sand, Slag, and Crucible Heels	8	59			1,707	1,468	0
Electrorefining Salt	2	15			476	24	0
Ash, Incinerated (Virgin)	8	59			3,212	359	0
Soot	13	96			2,826	702	0
Resin, Ion Column Unleached	29	266			11,528	2,716	0
Resin, Leached	6	59			2,389	263	0
Resin, Leached and Cemented	139	1,022			40,500	2,964	21
Glass	761	5,881	1	112	190,594	3,841	16
Raschig Rings, Unleached	1,096	8,060			215,924	11,562	0
Raschig Rings, Leached	22	166			6,545	46	0
Washables, Rubber, Plastics	6	67			2,813	81	0
Gloves, Drybox	53	510			19,533	759	0
Plexiglass and Benelex	48	364			12,971	90	0
Metal Scrap (Non SS)	1,669	12,718	2,589	289,702	7,981,075	27,319	43
Metal, Leached (Non SS)	457	3,361	1	112	141,841	13,531	3
Filters CWS	58	460	466	52,192	886,546	5,548	13
Equipment Boxes			12	1,344	12,687	88	0
High Level Acid	235	1,728			75,815	17	0
High Level Caustic	691	5,081			229,878	20	0
High Level Sludge/Cement	1,998	14,692			1,260,952	7	0
16 nCi/gm Non-Combustible	1	7			335	0	0
Contaminated Soil			36	4,032	160,002	1	0
LSA 100 nCi/gm Combustible	103	757			23,168	0	0
LSA 100 nCi/gm Non-Combustible	110	609			22,782	0	0
LSA Paper, plastics, Etc.	352	2,611	6	672	82,244	1	0
LSA Metal, Glass, Etc.	110	809	334	37,492	918,936	68	0
Concrete, Asphalt, Etc.	704	5,233	171	10,426	1,022,373	326	0
Wood	24	176	54	6,055	123,892	467	0
Bldg. 776 Process Sludge	5	37	19	2,128	89,887	23	0
Laundry Sludge			11	1,232	46,980	43	0
Equipment	1	7			178	11	0
Dirt	470	3,456			255,463	0	0
Sludge	296	2,177	8	896	176,751	64	0
TOTALS	47,404	363,658	4,252	467,323	28,492,732	154,559	10,606

NUCLIDE DISTRIBUTION - TSA STORED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Ac-227	-0-	-0-	-0-	-0-	7.290E-02	-0-	-0-	7.290E-02	4.273E-07	-
Am-241	6.630E+03	1.193E+04	7.351E+03	4.574E+03	5.600E+03	3.722E+03	5.936E+03	4.574E+04	2.681E-01	26.8
Am-243	-0-	1.000E-04	-0-	-0-	9.250E-04	6.117E-05	-0-	1.086E-03	6.366E-09	-
Ce-144	-0-	-0-	-0-	-0-	-0-	4.200E-01	-0-	4.200E-01	2.462E-06	-
Cf-252	-0-	-0-	-0-	-0-	1.342E-04	-0-	-0-	1.342E-04	7.866E-10	-
Cm-244	-0-	6.000E-01	1.112E+03	-0-	4.854E-01	3.640E-02	-0-	1.113E+03	6.524E-03	.6
Co-58	-0-	-0-	8.300E-01	-0-	-0-	-0-	-0-	8.300E-01	4.865E-06	-
Co-60	-0-	-0-	6.200E+00	-0-	-0-	-0-	-0-	6.200E+00	3.634E-05	-
Cr-51	-0-	-0-	1.450E+00	-0-	-0-	-0-	-0-	1.450E+00	8.499E-06	-
Cs-137	2.468E+00	-0-	3.000E+00	-0-	1.882E-01	4.200E-01	-0-	6.076E+00	3.562E-05	-
Eu-152	-0-	-0-	-0-	-0-	1.690E-01	-0-	-0-	1.690E-01	9.906E-07	-
H-3	-0-	-0-	-0-	-0-	-0-	8.541E-06	-0-	8.541E-06	5.006E-11	-
MAP	-0-	-0-	8.495E-02	-0-	-0-	-0-	-0-	8.495E-02	4.979E-07	-
MFP	2.743E-01	1.000E-01	3.750E-01	2.160E+01	1.717E+01	1.897E+01	1.626E+01	7.475E+01	4.382E-04	-
Mn-54	-0-	-0-	1.400E-01	-0-	-0-	-0-	-0-	1.400E-01	8.206E-07	-
Np-237	-0-	6.445E-04	-0-	-0-	1.206E-04	-0-	7.050E-06	7.732E-04	4.532E-09	-
Pm-147	-0-	-0-	-0-	-0-	4.640E+02	-0-	-0-	4.640E+02	2.720E-03	-
Pu-238	2.334E+01	4.219E+01	5.030E+01	5.797E+01	2.462E+03	4.712E+02	1.301E+04	1.612E+04	9.449E-02	9.4
Pu-239	7.747E+02	1.641E+03	1.726E+03	1.921E+03	2.534E+03	8.995E+02	2.220E+03	1.172E+04	6.870E-02	6.9

1789 110

NUCLIDE DISTRIBUTION - TSA STORED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Pu-240	1.902E+02	4.029E+02	4.252E+02	4.718E+02	6.185E+02	2.144E+02	5.331E+02	2.856E+03	1.674E-02	1.6
Pu-241	6.294E+03	1.367E+04	1.390E+04	1.639E+04	2.068E+04	5.611E+03	1.539E+04	9.194E+04	5.389E-01	53.9
Pu-242	1.075E-02	2.213E-02	2.341E-02	3.858E-02	4.702E-02	1.743E-02	4.643E-02	2.058E-01	1.206E-06	-
Ra-228	-0-	-0-	-0-	-0-	2.750E-01	-0-	-0-	2.750E-01	1.612E-06	-
Ru-106	-0-	-0-	-0-	8.000E-01	-0-	-0-	-0-	8.000E-01	4.689E-06	-
Sr-90	-0-	-0-	-0-	-0-	-0-	3.000E-01	-0-	3.000E-01	1.758E-06	-
Tc-99	-0-	-0-	-0-	-0-	1.390E-03	-0-	-0-	1.390E-03	8.148E-09	-
Th-232	-0-	-0-	1.202E-03	5.665E-02	6.123E-02	4.201E-02	5.886E-03	1.670E-01	9.789E-07	-
U-232	-0-	-0-	-0-	3.483E+00	3.537E+00	1.999E+00	2.604E-01	9.279E+00	5.439E-05	-
U-233	-0-	1.000E-02	2.562E+00	2.003E+02	1.959E+02	1.132E+02	1.475E+01	5.267E+02	3.037E-03	.3
U-234	-0-	-0-	1.098E-04	1.658E+00	1.674E+00	-0-	-0-	3.332E+00	1.953E-05	-
U-235	1.778E-05	-0-	2.390E-04	1.141E-04	1.076E-04	1.446E-04	5.902E-04	1.293E-03	7.579E-09	-
U-236	-0-	-0-	1.750E-06	2.639E-04	2.666E-04	-0-	-0-	5.323E-04	3.120E-09	-
U-238	1.332E-06	1.465E-05	4.040E-05	3.433E-05	1.363E-03	2.740E-04	2.423E-04	1.970E-03	1.155E-08	-
Un-Id-B & G	-0-	-0-	1.400E+00	-0-	-0-	-0-	-0-	1.400E+00	8.206E-06	-
TOTAL	1.392E+04	2.769E+04	2.458E+04	2.365E+04	3.258E+04	1.105E+04	3.712E+04	1.706E+05		

1789 111

NUCLIDE DISTRIBUTION - DISPO. WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Pu-240	9.060E-04	1.775E-03	6.975E-02	1.312E-01	9.430E-03	1.360E-03	1.026E-02	2.247E-01	1.148E-07	-
Pu-241	1.000E-04	6.062E-02	3.199E-01	4.646E+00	3.227E-03	3.564E-02	2.885E-02	5.414E+00	2.734E-06	-
Pu-242	-0-	9.777E-08	5.557E-07	1.088E-05	7.709E-07	1.065E-07	6.979E-08	1.248E-05	6.303E-12	-
Ra-226	5.576E+00	1.250E+00	2.293E-01	1.000E+00	3.382E-08	2.021E-01	-0-	8.258E+00	4.171E-06	-
Rb-86	-0-	4.210E+00	4.160E+00	6.322E+01	5.851E+00	-0-	-0-	7.744E+01	3.911E-05	-
Ru-103	2.570E-02	9.558E+03	1.076E+00	9.644E-02	2.033E+00	8.026E-02	2.980E-02	9.561E+03	4.829E-03	.5
Ru-106	8.307E+00	1.093E+01	1.989E+02	3.379E+02	2.614E+02	1.358E+02	1.530E+02	1.106E+03	5.586E-04	-
Sb-125	1.931E+01	1.915E+00	8.932E+01	1.074E+02	7.397E+01	6.260E+01	6.833E+01	4.288E+02	2.166E-04	-
Sc-46	4.948E+00	3.121E+00	-0-	-0-	-0-	-0-	-0-	8.069E+00	4.075E-06	-
Sm-153	-0-	-0-	-0-	-0-	-0-	3.302E+00	-0-	3.302E+00	1.677E-06	-
Sr-89	-0-	-0-	-0-	-0-	-0-	1.008E-01	-0-	1.008E-01	5.091E-08	-
Sr-90	1.678E+01	2.103E+01	1.872E+02	1.579E+03	1.764E+03	2.817E+02	2.546E+02	4.104E+03	2.073E-03	.2
Ta-182	-0-	-0-	-0-	-0-	-0-	7.310E-02	-0-	7.319E-02	3.692E-08	-
Tc-99	-0-	-0-	-0-	-0-	-0-	3.961E-07	3.200E-09	3.993E-07	2.017E-13	-
Th-230	-0-	-0-	-0-	-0-	5.405E-09	-0-	-0-	5.405E-09	2.730E-15	-
Th-232	2.180E-04	1.090E-07	5.450E-05	4.695E-05	1.091E-02	9.610E-08	3.646E-04	1.159E-02	5.854E-09	-
U-232	-0-	-0-	-0-	-0-	8.360E+00	-0-	-0-	8.360E+00	4.222E-06	-
U-233	-0-	6.000E-06	-0-	1.040E-08	-0-	9.527E-03	-0-	9.533E-03	4.815E-09	-
U-234	3.710E-04	-0-	1.857E-05	1.123E-05	1.760E-04	6.178E-04	2.782E-02	2.901E-02	1.465E-08	-

1789.112

NUCLIDE DISTRIBUTION - DISPOSED WASTE (CURIES)

'uclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
J-235	1.018E-01	1.072E-01	6.434E-02	6.481E-02	7.012E-02	2.764E-02	4.606E-02	4.820E-01	2.434E-07	-
J-236	1.584E-06	-0-	-0-	-0-	2.280E-06	3.170E-05	2.049E-04	2.405E-04	1.215E-10	-
J-238	7.735E+00	8.274E+00	4.723E+00	4.875E+00	5.211E+00	1.788E+00	3.147E+00	3.575E+01	1.806E-05	-
Jn-Id-Alpha	-0-	3.020E-01	4.360E-01	1.604E-02	1.791E-03	-0-	-0-	7.566E-01	3.821E-07	-
Jn-Id-B & G	2.864E+03	1.762E+04	8.048E+01	2.882E+01	1.056E+01	1.318E+02	8.995E+00	2.094E+04	1.058E-02	1.0
i-107	5.298E+00	-0-	-0-	-0-	-0-	-0-	-0-	5.298E+00	2.676E-06	-
Zn-65	4.272E+00	-0-	-0-	3.665E+02	4.000E-01	1.701E+00	5.960E-02	3.669E+02	1.853E-04	-
Zr-95	5.130E-02	1.374E+05	1.458E+01	-0-	2.318E+00	3.199E+00	5.295E+01	1.375E+05	6.944E-02	6.9
Zr-Nb-95	3.554E+04	2.736E+00	1.237E+02	1.536E+02	1.142E+02	8.912E+01	1.088E+01	3.603E+04	1.820E-02	1.8
TOTAL CURIES	3.509E+05	2.147E+05	3.399E+05	1.832E+04	1.319E+04	2.188E+05	8.241E+05	1.980E+05		

1789 113

NUCLIDE DISTRIBUTION - ILTSF (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
MFP *	-0-	-0-	-0-	-0-	-0-	1.890E+01	2.843E+01	4.733E+01	9.443E-01	94.4
Pu-238	-0-	-0-	-0-	-0-	-0-	-0-	5.193E-02	5.193E-02	1.036E-03	.1
Pu-239	-0-	-0-	-0-	-0-	-0-	2.526E+00	1.479E-01	2.674E+00	5.335E-02	5.3
Pu-240	-0-	-0-	-0-	-0-	-0-	-0-	6.135E-04	6.135E-04	1.224E-05	-
Pu-241	-0-	-0-	-0-	-0-	-0-	-0-	5.975E-02	5.975E-02	1.192E-03	.1
Pu-242	-0-	-0-	-0-	-0-	-0-	-0-	4.477E-06	4.477E-06	8.933E-08	-
U-233	-0-	-0-	-0-	-0-	-0-	-0-	1.733E-04	1.733E-04	3.458E-06	-
U-235	-0-	-0-	-0-	-0-	-0-	-0-	4.247E-05	4.247E-05	8.474E-07	-
TOTAL	-0-	-0-	-0-	-0-	-0-	2.143E+01	2.869E+01	5.012E+01		

1789 114

NUCLIDE DISTRIBUTION - ILTSF (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Eu-155	-0-	-0-	-0-	2.422E+01	2.154E+01	9.000E-02	2.001E+01	6.586E+01	3.326E-05	-
Fe-59	2.935E+04	6.701E+02	5.918E+02	1.440E+03	5.630E+02	1.865E+04	6.319E+04	1.145E+05	5.783E-02	5.8
H-3	5.000E-01	-0-	2.300E-01	-0-	-0-	-0-	-0-	7.300E-01	3.687E-07	-
Hf-181	2.805E-01	-0-	-0-	-0-	4.882E-02	7.310E-02	5.960E-02	4.620E-01	2.333E-07	-
I-131	1.569E+00	-0-	-0-	-0-	8.167E-03	8.800E-01	5.500E+00	7.957E+00	4.019E-06	-
La-140	3.533E-01	3.775E-01	-0-	-0-	2.053E+00	5.890E+01	-0-	6.168E+01	3.115E-05	-
MAP	2.219E+00	1.083E+01	2.309E+04	9.224E+01	1.367E+01	3.074E+01	1.009E+02	2.334E+04	1.179E-02	1.2
MFP	6.709E+01	3.037E+01	1.292E+02	7.614E+02	2.866E+02	2.133E+02	2.613E+02	1.750E+03	8.838E-04	-
Mn-54	1.241E+00	4.370E+00	2.081E+04	7.201E+01	3.669E+02	2.973E+01	7.391E+04	9.519E+04	4.808E-02	4.8
Mn-56	1.485E+00	2.600E+01	-0-	-0-	5.538E+02	-0-	-0-	5.813E+02	2.936E-04	-
Na-22	-0-	-0-	-0-	-0-	-0-	-0-	1.160E-06	1.160E-06	5.859E-13	-
Na-24	3.537E+00	-0-	-0-	-0-	-0-	2.499E+01	-0-	2.855E+01	1.441E-05	-
Nb-95	3.724E+00	-0-	-0-	3.196E-01	3.096E-01	2.671E+00	5.503E+01	6.205E+01	3.134E-05	-
Ni-59	5.000E+02	1.299E+01	9.931E+02	3.200E+03	-0-	-0-	-0-	5.992E+03	3.026E-03	.3
Np-237	-0-	-0-	6.345E-07	-0-	-0-	4.200E-06	-0-	4.835E-06	2.442E-12	-
Pm-147	-0-	-0-	7.400E-01	-0-	-0-	-0-	-0-	7.400E-01	3.737E-07	-
Po-210	1.100E-01	-0-	-0-	-0-	-0-	-0-	-0-	1.100E-01	5.556E-08	-
Pu-238	-0-	2.181E-04	1.231E-03	1.679E-02	1.183E-03	1.052E-03	2.287E-01	2.492E-01	1.259E-07	-
Pu-239	1.842E-01	8.807E-03	2.467E-01	5.355E-01	1.275E-01	8.660E-03	1.555E-01	1.267E+00	6.494E-07	-

NUCLIDE DISTRIBUTION - DISPOSED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Ag-110M	2.338E-02	-0-	-0-	-0-	-0-	2.180E-01	5.960E-02	3.010E-01	1.520E-07	-
Am-241	-0-	1.000E-05	-0-	-0-	1.850E-07	-0-	3.240E-07	1.051E-05	5.308E-12	-
Ba-133	-0-	-0-	-0-	-0-	-0-	4.000E-07	3.400E-08	4.340E-07	2.192E-13	-
Ba-La-140	2.022E+00	8.629E+00	-0-	-0-	1.430E+00	4.368E+01	-0-	5.576E+01	2.816E-05	-
Be-10	4.290E+00	-0-	1.000E+01	-0-	-0-	-0-	-0-	1.429E+01	7.217E-06	-
Bi-210	-0-	-0-	-0-	-0-	-0-	3.930E-08	-0-	3.930E-08	1.985E-14	-
C-14	-0-	-0-	-0-	-0-	-0-	2.870E-07	-0-	2.870E-07	1.449E-13	-
Cd-109	-0-	-0-	-0-	-0-	-0-	-0-	1.180E-06	1.180E-06	5.960E-13	-
Ce-141	2.944E+01	2.789E+04	2.954E+00	1.717E+00	1.895E+00	2.889E+01	1.316E+01	2.797E+04	1.413E-02	1.4
Ce-144	5.465E+01	1.093E+01	4.130E+02	8.047E+02	9.517E+02	3.98[illegible]E+02	2.092E+03	4.725E+03	2.386E-03	0.2
Cl-35	-0-	-0-	-0-	-0-	-0-	3.970E-08	-0-	3.970E-08	2.005E-14	-
Co-57	-0-	-0-	-0-	-0-	-0-	-0-	1.110E-06	1.110E-06	5.555E-13	-
Co-58	8.477E+00	6.108E+00	3.900E+03	2.079E+00	3.154E-01	3.086E+01	1.061E+05	1.100E+05	5.556E-02	5.5
Co-60	4.610E+04	1.444E+04	2.082E+05	7.662E+03	7.289E+03	4.689E+04	6.217E+04	3.928E+05	1.984E-01	19.8
Cr-51	2.359E+05	5.163E+03	8.003E+04	8.170E+01	2.233E+02	1.512E+05	5.147E+05	9.873E+05	4.986E-01	49.9
Cs-1	2.119E+00	3.288E+00	5.243E+01	6.636E+01	4.619E+01	5.713E+00	1.706E+01	1.932E+02	9.758E-05	-
Cs-137	4.005E+02	2.700E+02	8.947E+02	1.424E+03	5.697E+02	4.726E+02	6.683E+02	4.760E+03	2.374E-03	.2
Eu-152	-0-	-0-	-0-	-0-	1.060E+00	4.308E-01	1.630E+02	1.645E+02	8.308E-05	-
Eu-154	-0-	-0-	-0-	4.199E+01	3.521E+01	5.008E-01	7.656E+01	1.543E+02	7.793E-05	-

1789 116

Annex 2

INEL CONTAINERS FOR TRU WASTE

STANDARD CONTAINERS

Standardized containers are used at the INEL Radioactive Waste Management Complex (RWMC). These containers are designed to provide safety, integrity, and improved space utilization of the RWMC. The following containers are approved by the Department of Transportation (DOT) and by DOE-10 for use at INEL. DOE-ID will provide the procurement specifications, noted below, upon request.

(1) The DOT 17C 55-gallon drum, per procurements specification, S72001, is standard steel drum, constructed of 16-gauge materials, with a removable head (see Figure 1).

(2) The DOT 6M packaging consist of a DOT 17C 55-gallon drum with fiberboard centering media and a DOT spec 2R inner containment vessel (see Figure 2). DOT 6M packaging is acceptable at the INEL for storage only when the drums have no mechanism for venting. This requires the generator to obtain approval for modification to the DOT 6M packaging which may be obtained when the 6M package is shipped inside another DOT approved transport device.

The DOT specification 2R, or equivalent, containment vessel must be made of stainless steel, malleable iron, brass or other material having equivalent physical strength. The vessel shall be less than 25 3/4 inches overall length and have a maximum outside vessel diameter of 5 inches. Ends of the vessel must be fitted with a screw-type closure, flanges of welded or brazed plate. The waste generator must submit the details of the 6M packaging, including 2R containment vessel to DOE-ID and EG&G WMPO for information prior to usage.

(3) The DOT 1/H 30-gallon drum, per procurement specification 572006, is a standard steel drum constructed of 18-gauge material with a removable head (see Figure 3).

(4) Two styles of DOT 7A boxes are acceptable (see Figures 4 and 5). Packaging of transuranic waste per Section V, Table II, requires the box to be coated with 1/8" of fiberglass per procurement specification 572013 as shown on Figure 4.

(a) The DOT 7A wooden box, per procurement specification 572016, is an externally cleated plywood box, normally 4' x 4' x 7' long (see Figure 5). These boxes are being replaced by the box shown in Figure 6.

(b) The DOT 7A wooden box, per procurement specification 572011, is a plywood box with internal stiffeners, normally 4' x 4' x 7' (see Figure 6).

(5) The DOT 7A steel box, per procurement specification 572010, is a rectangular steel box of dimensions 50 3/8" x 58 3/8" x 72 3/8" (see Figure 7). When used as an overpack it will hold eight (8) 17C 55-gallon drums in two (2) layers of four (4) drums each or twelve

1789 118

(12) 17M 30-gallon drums in two (2) layers of six (6) drums each. This box does not require a security seal when it is used as an overpack, provided each of the DOT approved inner containers is properly sealed.

(6) See Section VIII Exceptions of Special Shipment Requirements for use of containers that do not meet the above criteria.

DOT SPEC. 17C STEEL DRUM (55 gallon)

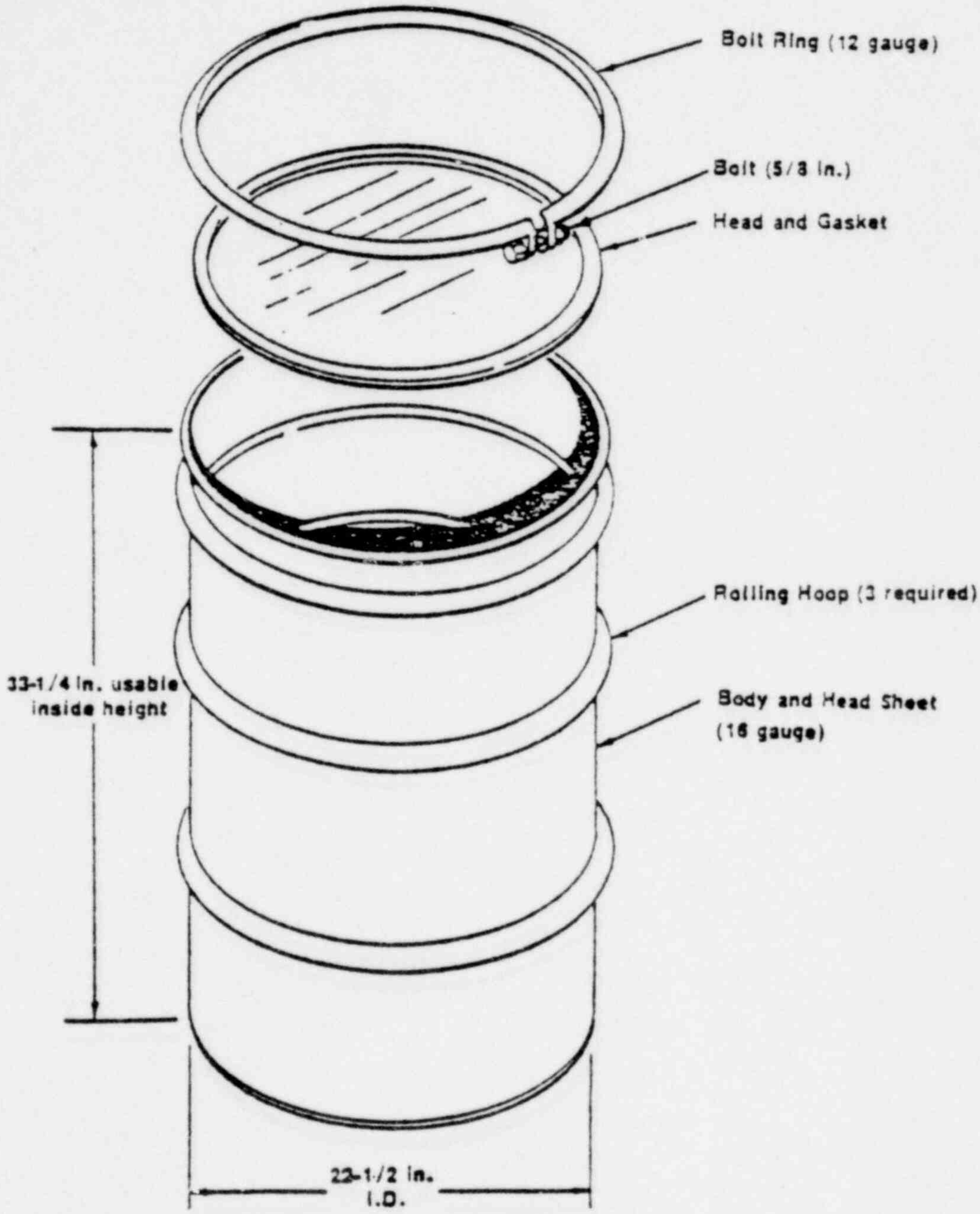


Figure 1

1789 120

DOT SPEC. 6M Packaging

(CFR 49 § 178.104)

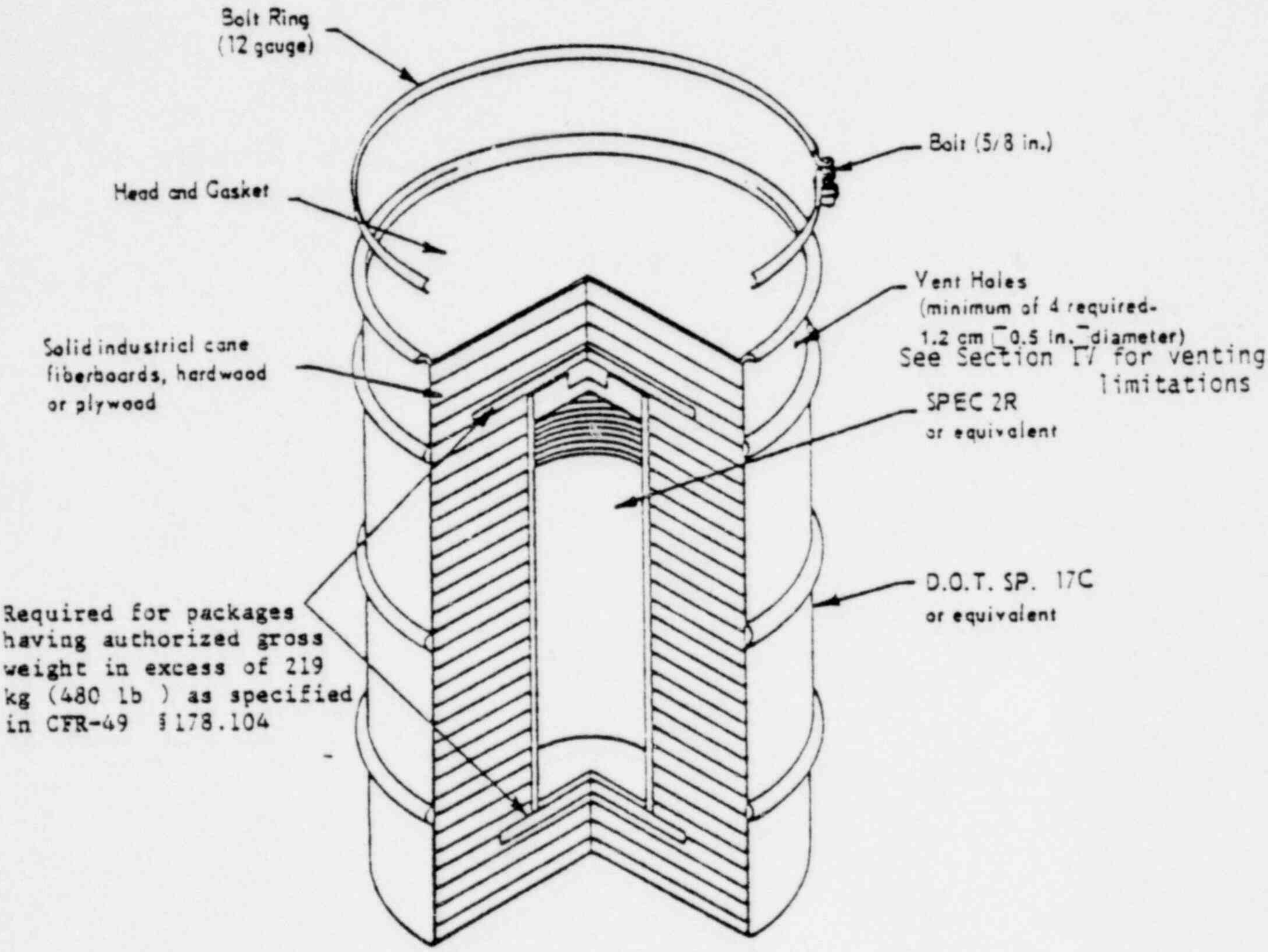


Figure 2

1789 121

DOT SPEC. 17H STEEL DRUM (30 gallon)

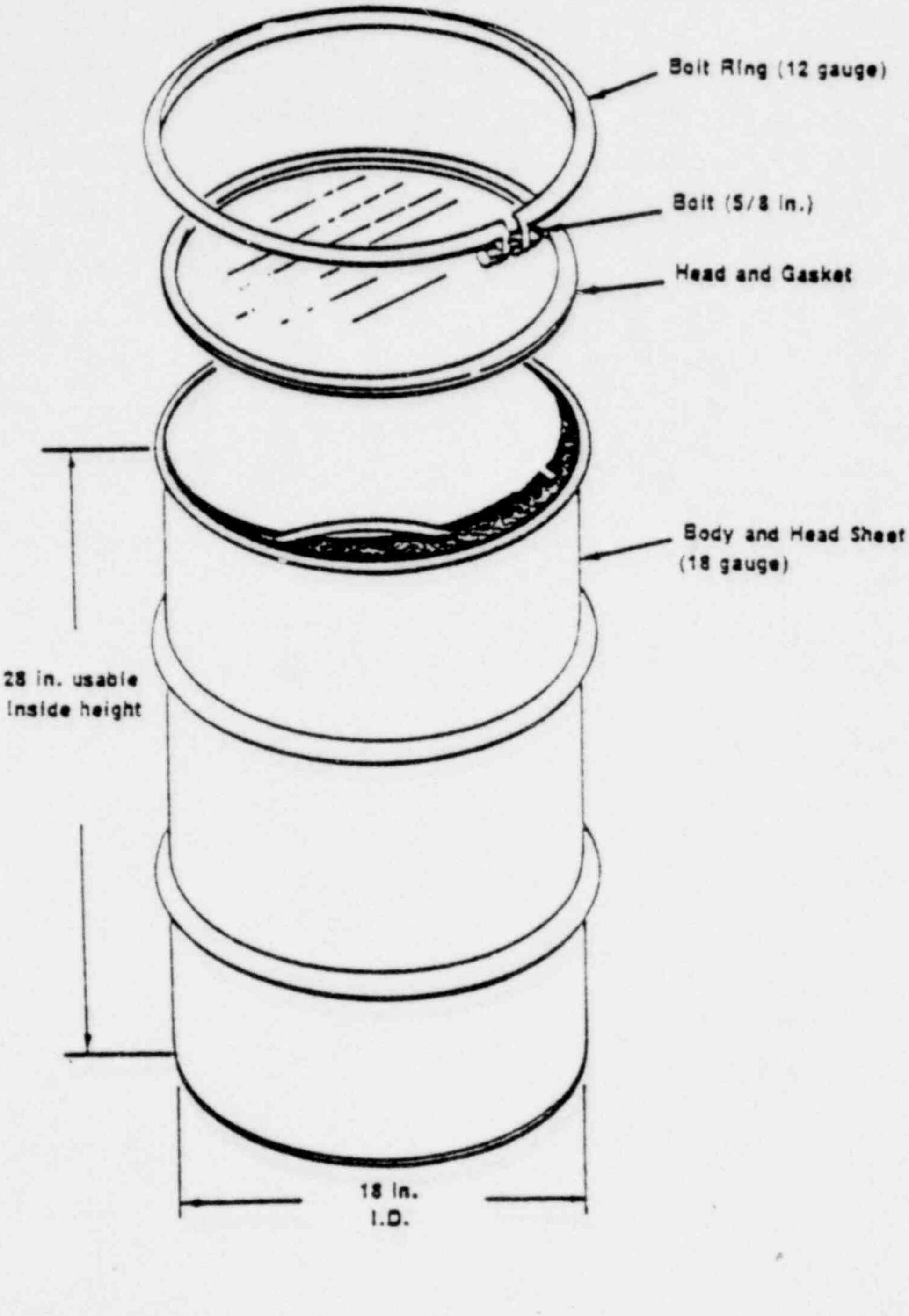
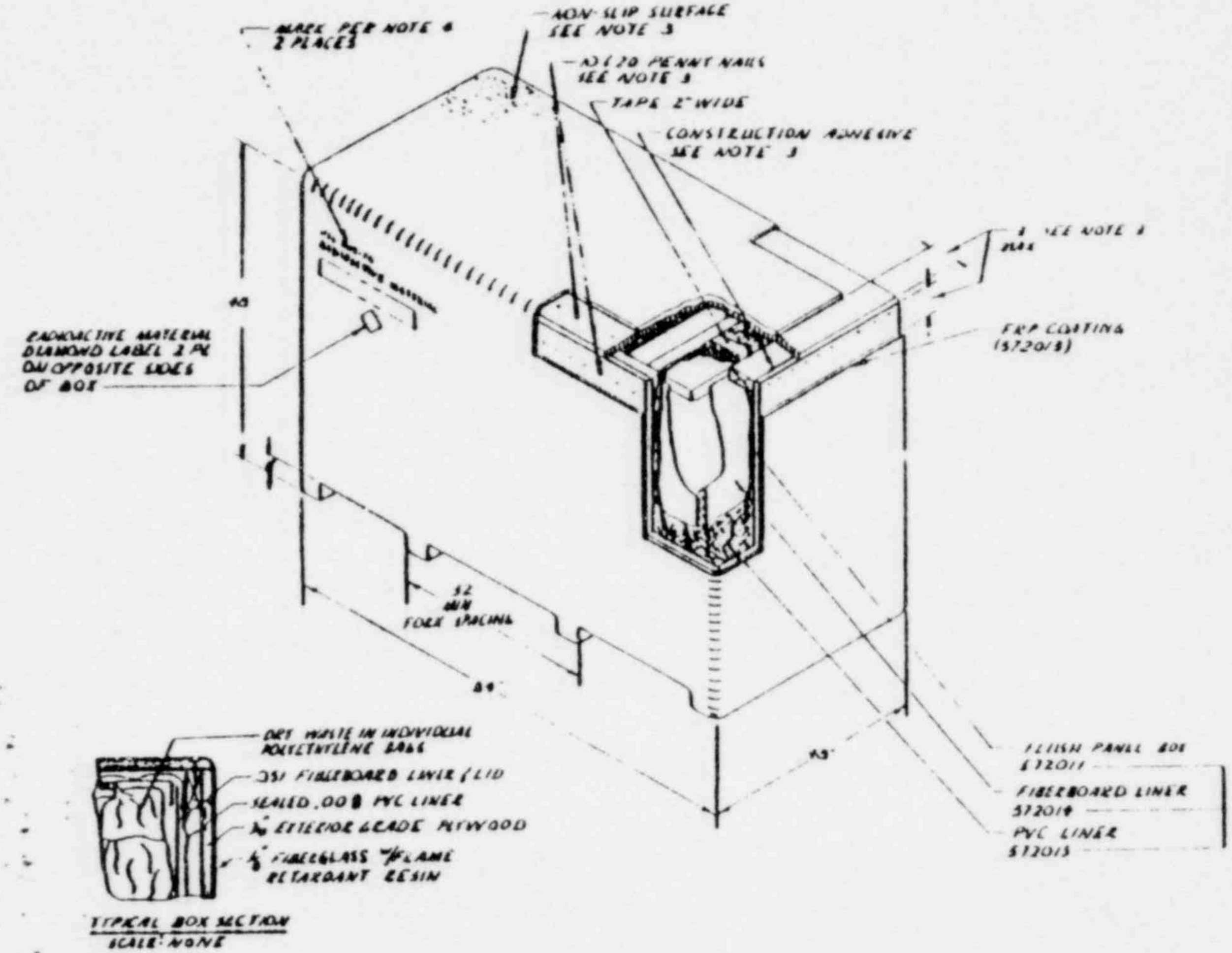


Figure 3

1789 122

DOT 7A FIBERGLASS REINFORCED FLUSH PANEL
OR CLEATED PLYWOOD BOX ASSEMBLY



CLEATED PLYWOOD BOX
572016
FIBERBOARD LINER
572017
PVC LINER
572018

NOTES.

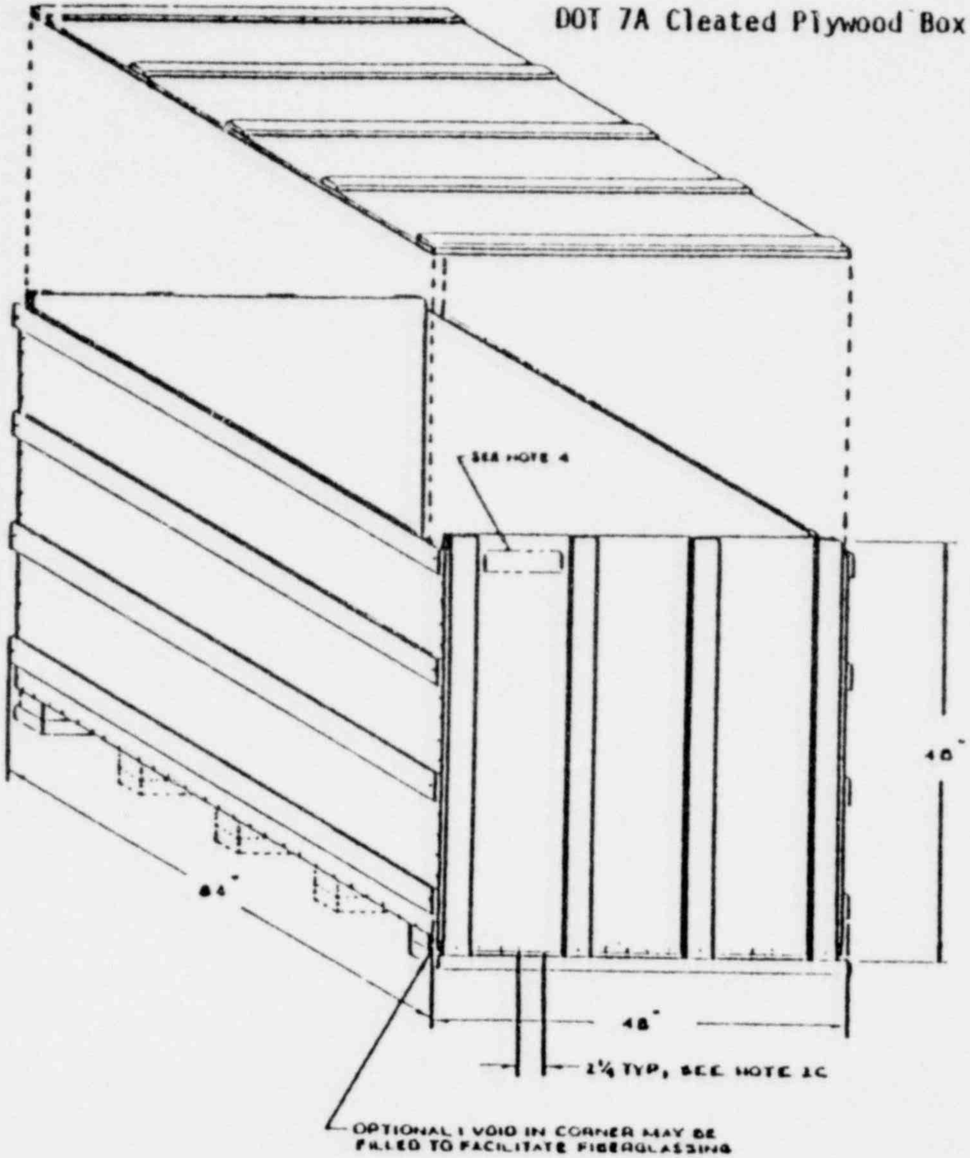
1. SECURELY BLOCK LARGE, HEAVY ITEMS WITHIN THE BOX TO PREVENT MOVEMENT. TIGHTLY PACK OTHER MATERIAL IN INDIVIDUAL PLASTIC BAGS AS APPROPRIATE. ALL MATERIAL SHALL BE FREE OF LIQUID.
2. PLACE LID ON FIBERBOARD LINER, FOLD OVER PVC LINER AND SEAL WITH TAPE.
3. FASTEN LID ON BOX USING CONSTRUCTION ADHESIVE AND CEMENT-COATED NAILS PER THE APPLICABLE BOX ASSEMBLY DRAWING. ADD FRP COATING PER 572013 IN AREA THREE INCHES EITHER SIDE OF JOINT TO SEAL BOX. SPRAY TOP OF BOX WITH A LIGHT COAT OF RESIN AND DISTRIBUTE ABOUT ONE QUART OF FINE GRAVEL INTO WET RESIN TO PROVIDE A NON SLIP SURFACE.
4. DURABLY AND LEGIBLY MARK "USA DOT-7A", "RADIOACTIVE MATERIAL", NAME AND ADDRESS OF USER, AND GROSS WEIGHT USING CHARACTERS AT LEAST 1.0 INCH HIGH, 2 PLACES, ON OPPOSITE SIDES OF BOX.
5. ALL DIMENSIONS ARE IN INCHES AND ARE GIVEN FOR REFERENCE ONLY. SEE THE APPLICABLE BOX ENGINEERING DRAWING FOR DETAILS. FLUSH PANEL BOX SHOWN. BOXES MAY BE ORDERED IN TWO HEIGHTS. SEE TABLE FOR SIZES.
6. WHEN USING 24x48x84 BOX, CUT FIBERBOARD AND PVC LINERS TO FIT.

NOMINAL BOX SIZE	OVERALL HEIGHT
48x48x84	52
24x48x84	25

Figure 4

1789 123

DOT 7A Cleated Plywood Box Assembly



NOTES:

1. BOX DIMENSIONS BEFORE FIBERGLASSING.

   OUTSIDE: 84L x 48W x 49-1/2D = 115 FT³
   INSIDE: 81L x 45W x 42-1/2D = 90 FT³

2. ASSEMBLE BOX WITH THREE WAY CORNERS AS FOLLOWS:

   A. APPLY ELASTOMERIC CONSTRUCTION ADHESIVE (B.F. GOODRICH PL 200 OR APPROVED EQUIVALENT) IN A CONTINUOUS BEAD OF 1/4 INCH MINIMUM DIAMETER ALONG EACH PLYWOOD TO PLYWOOD JOINT. REMOVE EXCESS ADHESIVE FROM OUTSIDE OF BOX.

   B. EACH END OF EACH CLEAT SHALL BE FASTENED WITH AT LEAST ONE 16 PENNY CEMENT COATED BOX NAIL.

   C. APPLY 8 PENNY CEMENT COATED BOX NAILS OR 2 INCH PLASTIC COATED STAPLES THRU THE PLYWOOD INTO THE APPROPRIATE CLEAT OR STRINGER AS SHOWN. FASTENERS SHALL BE FLUSH TO 1/16 MAXIMUM BELOW SURFACE. STAPLE CROWNS SHALL CROSS GRAIN OF FIRST PLY AT NOT LESS THAN A 40° ANGLE. INTERIOR OF BOX SHALL BE FREE OF PROTRUDING FASTENERS.

3. FIBERGLASS BOX AND ASSEMBLE SKIDS PER S72013. COATING MAY BE DONE ON INDIVIDUAL PANELS OR ON ASSEMBLED BOX.

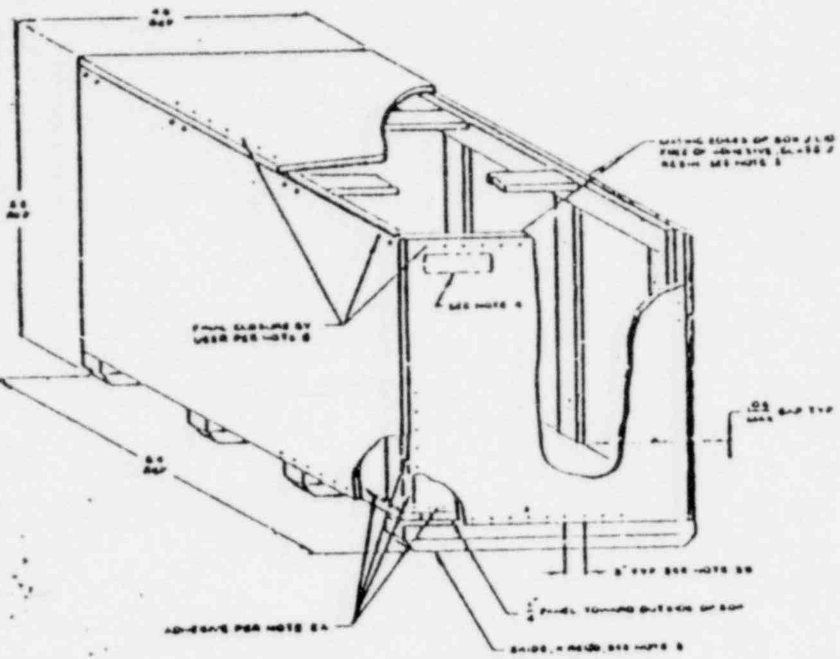
4. DURABLY AND LEGIBLY MARK MANUFACTURER'S NAME OR SYMBOL AND DATE OF MANUFACTURE 2 PLACES ON OPPOSITE ENDS OF BOX, USING CHARACTERS AT LEAST 1/4 INCH HIGH. A PAPER LABEL WITH RESIN OVERCOAT ACCEPTABLE.

5. WHEN THE PURCHASE ORDER SPECIFIES A NON FIBERGLASSED BOX, OMIT ASSEMBLY STEPS PER NOTE 3. ATTACH SKIDS PER SHEET 2 OF THIS DRAWING SERIES. TEMPORARILY SECURE LID WITH DOUBLE HEADED NAILS OR OTHER SUITABLE FASTENERS TO RESIST BLOWING IN HIGH WINDS DURING STORAGE OR TRANSPORATION.

6. FINAL LID CLOSURE BY USER SHALL BE MADE USING CONSTRUCTION ADHESIVE AND 8 PENNY CEMENT COATED NAILS OR 2 INCH PLASTIC COATED STAPLES.

Figure 5.

DOT 7A Flush Panel Plywood Box Assembly



NOTES:

1. NOMINAL BOX SIZE: 1"

   TYPE 1 - 48 x 48 x 84: OVERALL HEIGHT 52
   TYPE 2 - 24 x 48 x 84: OVERALL HEIGHT 28

   ALL DIMENSIONS ARE IN INCHES, EXCEPT AS NOTED

2. ASSEMBLE BOX AS FOLLOWS:

   A. APPLY ELASTOMERIC CONSTRUCTION ADHESIVE (B.F. GOODRICH PL-200 OR APPROVED EQUIVALENT) IN A CONTINUOUS BEAD OF 1/4 INCH MINIMUM DIAMETER ALL AROUND 3/4 INCH BOTTOM PANEL AND ON BOTH SIDE EDGES OF END PANELS. APPLY A BEAD OF ADHESIVE BETWEEN VERTICAL END STRUTS AND END PANELS. REMOVE EXCESS ADHESIVE FROM OUTSIDE OF BOX.

   B. FASTEN PANELS USING 10 PENNY CEMENT COATED BOX NAILS OR 2 INCH PLASTIC COATED STAPLES WITH 3 INCH MAXIMUM SPACING. FASTENERS SHALL BE DRIVEN FLUSH TO 1/16 MAXIMUM BELOW SURFACE. STAPLE CROWNS SHALL CROSS GRAIN OF FIRST PLY AT NOT LESS THAN A 40° ANGLE. INTERIOR OF BOX SHALL BE FREE OF PROTRUDING FASTENERS AND SPLIT LUMBER.

   C. EDGES OF SIDE AND END PANELS SHALL BE FLUSH TO 1/16 MAXIMUM ABOVE BOTTOM OF BOX.

3. FIBERGLASS BOX AND ASSEMBLE SKIDS PER S72013. COATING MAY BE DONE ON INDIVIDUAL PANELS OR ON ASSEMBLED BOX. MATING EDGES OF BODY AND LID SHALL BE FREE OF GLASS AND MEASURABLE RESIN OVER SPRAY. BOX EDGES MAY BE BROKEN 3/4 MAXIMUM RADIUS OR CHAMFER TO FACILITATE FIBERGLASSING.

4. DURABLY AND LEGIBLY MARK MANUFACTURER'S NAME OR SYMBOL, DATE OF MANUFACTURE, 2 PLACES ON OPPOSITE ENDS OF BOX USING CHARACTERS AT LEAST 3/4 INCH HIGH (MAY BE PAPER LABEL WITH RESIN OVERCOAT.)

5. USER SHALL MAKE FINAL BOX CLOSURE WITH THE MATERIALS SPECIFIED IN NOTE 2. APPLY ADHESIVE ALL AROUND TOP EDGES OF VERTICAL 3/4 INCH PANELS. IN ADDITION TO 10 PENNY NAILS ON 3 INCH CENTERS, DRIVE TWO 20 PENNY CEMENT-COATED NAILS THROUGH SIDE PANEL INTO EACH 2x4 ON TOP PANEL (8 PLACES).

6. WHEN THE PURCHASE ORDER SPECIFIES A NON-FIBERGLASSED BOX, OMIT ASSEMBLY STEPS IN NOTE 3. ATTACH SKIDS PER SHEET 2 OF THIS DRAWING SERIES. TEMPORARILY SECURE LID WITH DOUBLE-HEADED NAILS OR OTHER SUITABLE FASTENERS TO RESIST BLOWING OFF IN HIGH WINDS DURING STORAGE OR TRANSPORTATION.

Figure 6

1789 125

DOT SPEC. 7A STEEL BOX

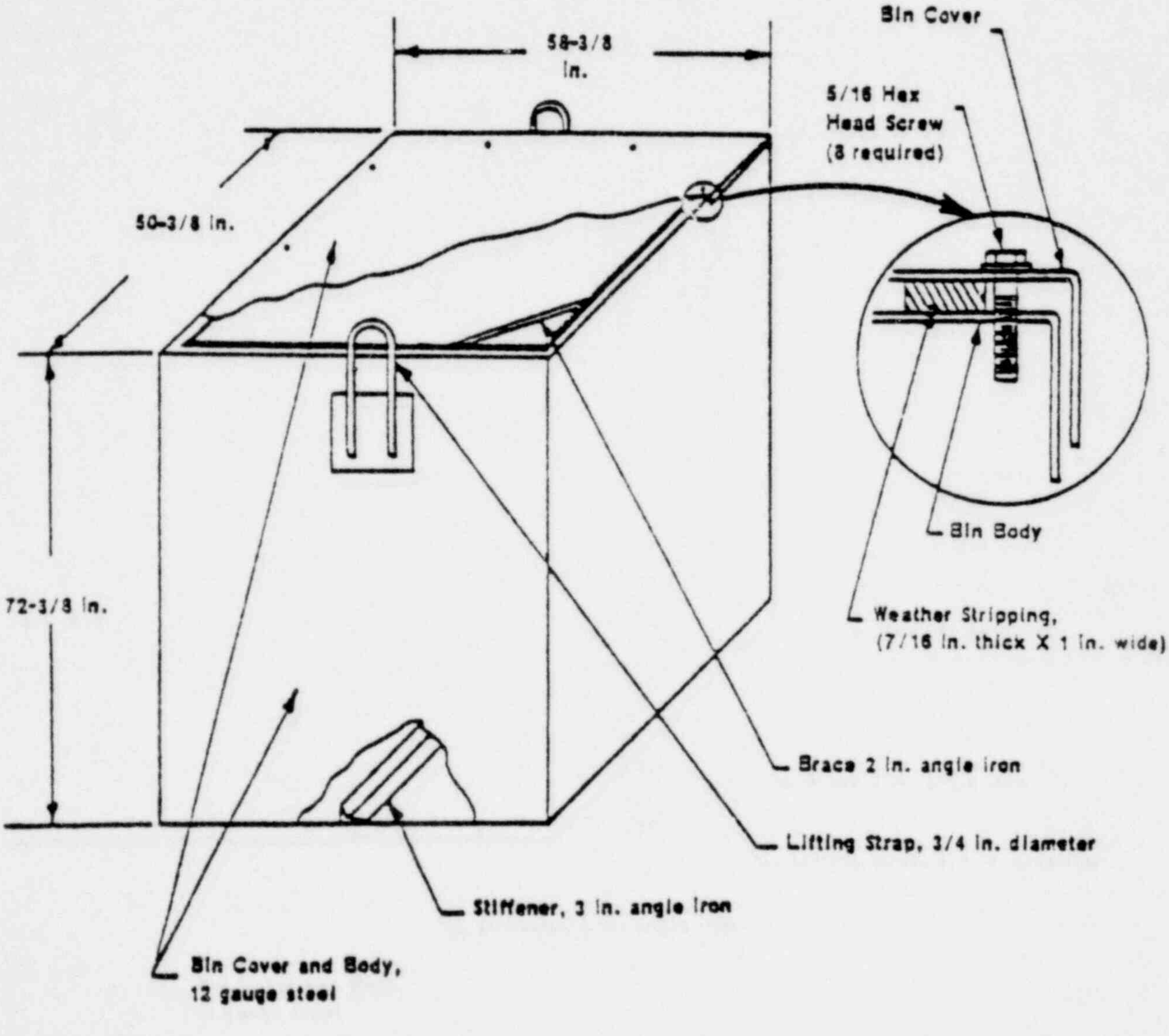


Figure 7

1789 126

Appendix F

IMMOBILIZATION AND INCINERATION PROCESSES

CONTENTS

Appendix F

INCINERATION AND IMMOBILIZATION PROCESSES

As explained in Section 5.3.1, numerous studies of the processing of transuranic waste have been carried out at the Idaho National Engineering Laboratory. The first analysis, performed by the FMC Corporation (1977), evaluated 17 incineration processes (nine for radioactive waste and eight for municipal or commercial waste) and 11 immobilization processes. This appendix briefly describes these processes.

F.1 INCINERATION PROCESSES

F.1.1 Processes for Radioactive-Waste Incineration

An acid digestion process is being developed at the Westinghouse Hanford Company, Richland, Washington. This system treats combustibles with sulfuric and nitric acids at about 240°C. The residue from this process consists of inorganic sulfates and oxides in a salt-cake form.

An agitated hearth is an adaptation of a commercial incinerator. This operation is being developed by Rockwell International at Rocky Flats, Colorado. In this process a batch of contaminated combustible material is charged into a primary chamber where rotating rabble arms agitate the combustible material to improve the burning. The output of this process is a dry ash.

A controlled air incinerator, also a modification of commercially available equipment, is under construction at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico. This incinerator uses a starved-air primary chamber with an oxygen-rich secondary chamber. The offgas is scrubbed with a wet process. The output of this process is also a dry ash.

A cyclone-drum incinerator is being operated at the Monsanto Mound Laboratory, Miamisburg, Ohio. Contaminated laboratory waste is burned in a vortex-type incineration process inside a 55-gallon drum. The contaminated waste may be handled both in and out of the incinerator in the 55-gallon drums. The residue from the combustible portion of this process is almost completely oxidized.

A fluidized-bed incinerator is being developed by Rockwell International at Rocky Flats, Colorado. This process feeds combustible material into a hot fluidized bed of sodium carbonate. The hot air that fluidizes the bed provides immediate ignition for combustibles, which are burned. The ash is separated in a cyclone. A second fluidized bed is used for complete oxidation. The residue is an ash collected in the cyclone separator. The sodium carbonate provides in-situ neutralization of the hydrogen chloride and other acidic gases formed during the oxidation.

The molten-salt incinerator was developed by Atomics International for the Idaho National Engineering Laboratory, Idaho Falls, Idaho. This process feeds finely divided combustibles and noncombustibles, including metals, into a molten-salt bath. The combustibles immediately oxidize within the bath, and the ash is captured there along with the metal oxides and other noncombustibles. When the bath is fully loaded with noncombustible material, it is drained along with the captured incinerator residue. The sodium carbonate in the molten bath provides in-situ neutralization of the acid gases formed during the oxidation process.

A pyrolysis-controlled-air incinerator is being developed by E. I. du Pont de Nemours & Company, Inc., at Savannah River, South Carolina. This process moves combustible material into a refractory-lined chamber heated to 1000°C by electric heaters. The oxygen is maintained below stoichiometric levels to obtain flameless incineration. Under these conditions the volatile materials are driven off and oxidized in an oxygen-rich secondary chamber. The principal residue of this process is a char relatively high in carbon.

A commercial rotary-kiln incinerator, adapted for radioactive waste, is under construction for Rockwell International at Rocky Flats, Colorado. The contaminated waste material is fed into the upper end of the rotary kiln and oxidized as the kiln rotates. The dry ash is continuously removed from the bottom of the kiln. The offgases are burned in an afterburner.

A slagging-process incinerator, installed at the CEN-SCK Waste facility in Mol, Belgium, is a commercial incinerator adapted for radioactive-waste disposal. The waste material is shredded before being fed into a waste hopper that surrounds the incineration chamber. As the waste material feeds into the incineration chamber, it is oxidized, and the noncombustible materials are melted into a slag at 1600°C. The slag output material drips continuously from the hearth into a water quench tank below the incinerator. The output material is a basaltlike glassy slag.

F.1.2 Processes for Commercial Municipal-Waste Incineration

The commercial controlled-air incinerator is similar to the radioactive-waste unit; it uses a "starved-air" primary combustion chamber process to produce a low level of turbulence that minimizes the transfer of particulate matter to the offgas. An oxygen-enriched secondary chamber with vigorous air turbulence is used to completely oxidize the offgas.

Commercial fluidized-bed incinerators (FBI), although similar in principle to the Rocky Flats FBI, are quite different. All commercial FBIs operate at high temperatures and consequently use refractory linings. Physical sizes and capacities are much larger. Usually the feed material they process can be in much larger chunks that need not be shredded as fine.

Commercial application of molten-salt incinerators is in the development stage. The molten-salt incinerator developmental programs are in the areas of coal gasification, flue-gas purification, etc. Production rates vary from 1 to 3 metric tons per hour.

1789 130

The commercial moving grate is a common type of municipal solid-waste incinerator or combustion system for waste-heat boilers, etc. This incinerator requires finely shredded combustible feed material with little foreign noncombustible material. The maximum capacities of these units in tons per hour are large.

The commercial multiple-hearth combustor is used frequently for incinerating municipal and industrial sludges, shredded solid wastes, etc. An advantage of the multiple hearth is long residence time in the incinerator and varying temperature ranges for the individual hearths so that the top hearths may be drying the waste, the middle hearths pyrolyzing the waste, the lower hearths oxidizing the waste, and the bottom hearth cooling the waste. Because the individual hearths are vertically above each other, the units are efficient in operation, utilizing all the waste heat of combustion. The maximum capacities of multiple-hearth units can be more than 100 tons per hour.

The commercial versions of the pyrolysis incinerators are operated more nearly as a controlled-air process than as a pure pyrolysis process. These units completely oxidize the pyrolysis char residue in the primary chamber to provide a dry inert ash. A secondary combustion chamber oxidizes the tars and other volatile pyrolysis products.

The rotary kiln is another large-capacity, standard commercial/municipal waste incinerator. Rotary kilns are also used for hazardous-waste incineration in which 55-gallon drums of material are directly fed into the rotating kiln with little deleterious effect on the kiln lining.

The slagging-pyrolysis process is a relatively new form of municipal-waste incinerator. The original objective of this process was to generate gas from a pyrolysis zone that could be used as fuel for industrial or municipal operations. In this process waste material is loaded into a vertical shaft chamber. As the material descends, it passes through a drying zone, a pyrolysis zone, an oxidation zone, and, finally, a slagging zone in the bottom of the chamber. The hot gases driven off each zone rise and form the fuel for the upper zones. In the pyrolysis zone, the volatile gases are collected; they may be used as fuel in a steam boiler or oxidized in an afterburner with the hot gases running to heat exchangers. The output of this process is a basalt-like glassy slag that entraps the ash along with metals and noncombustibles in the waste material.

F.2 IMMOBILIZATION PROCESSES

Bitumen. Any form of waste residue may be encapsulated in bitumen (asphalt) that can be handled by the bitumen mixer. This process has been used primarily for waste residues that are to be disposed of in the sea.

Cement. Hydraulic cement may be used to stabilize ash, salt, or even small pieces of metal and other noncombustibles, so long as these materials can be handled by the mixer. The cement with embedded waste materials may be cast into any desired form for handling. Steel reinforcements are used to increase the strength of the packages.

1789 131

Ceramic. In this process, the waste material in the form of a calcine is combined with glass frit to produce glass ceramics. For immobilizing high-level waste, the output ceramic is embedded in a metal matrix for heat dispersion.

Clay. Radioactive waste in the form of sodium-salt solutions combine chemically with clays to immobilize the waste. The clay may be formed into bricks, which are fired at 700 to 900°C; this firing decreases the leach rate.

Glass (solution). Various waste materials may be combined with glass-forming materials and melted at high temperatures. When the forms of the output materials are finely ground ash, salts, oxides, or calcines, they dissolve and are dissolved in the glass matrix.

Glass (encapsulation). Small pieces of metals and other noncombustible materials are encapsulated in molten glass poured over them.

Metal matrix. Metals are used to stabilize the radioactive-waste materials that are in the form of vitrified pellets or beads or in some other calcined form. The principal advantages of the metal matrices are high impact strength and high thermal conductivity.

Pellets. The radioactive material and ash are ground very finely and mixed with high-alumina cement. This powder is then pressed into pellets and sintered. The principal advantage of this process is that the concentration of radioactive waste in the pellets (80%) is higher than with other techniques. For example, in the glass-solution process the radioactive-waste concentration is 50% at a maximum.

Plastic materials. A variety of resins and plastic materials have been used as matrices to immobilize ash, salts, and oxides. These materials could be used to stabilize small pieces of metal and noncombustibles. The primary disadvantage is that these resins are combustible.

Salt cake. The cast salt cake taken directly from the output of the molten-salt incinerator or the acid-digestion process adequately immobilizes the fine ash material. However, the salt cake exhibits a very high leach rate and thus will not meet stabilization requirements.

Slag. The product of the slagging incinerator is a granular basaltlike glassy slag. It is expected that this product will be acceptable to the WIPP reference repository. Glass formers may be added to the waste-material feed in the incinerator to improve the vitrified output.

REFERENCE

FMC Corporation, 1977. Selection of Waste Treatment Process for Retrieved TRU Waste at Idaho National Engineering Laboratory, R-3689.

Appendix G

METHODS USED TO DETERMINE DOSES

CONTENTS

1789 134

Appendix G

METHODS USED TO CALCULATE RADIATION DOSES FROM RADIONUCLIDE RELEASES

G.1 INTRODUCTION

The dose calculations were performed with a modified version of the AIRDOS-II computer code. Since excellent documentation describing the code and its input instructions is available (Moore, 1977), this appendix only highlights the major features of the code and outlines modifications made to the code.

Generally, AIRDOS-II, a code that calculates the radiation dose to man from a radionuclide release, is primarily intended to calculate doses from a continuous release of radionuclides, but, with the proper adjustments of input parameters, it can be used for a pulse release--that is, a release over a short time that would resemble a release resulting from an accident. The unmodified code calculates atmospheric dilution factors (χ/Q values), and hence, in order to input χ/Q values calculated with other codes, it was necessary to write another subroutine. This subroutine allows direct input of χ/Q values into AIRDOS-II. In its modified form, AIRDOS-II was used for assessing the doses for both normal and accidental releases from the repository. Site-specific χ/Q values were obtained by using the integrated-puff model, MESODIF, as described in Appendix H, Section H.4. The unmodified form was used to calculate doses from transportation-accident releases.

The general flow of information in the code is indicated in Figure G-1. The MAIN subroutine drives the code as it differentiates between user options and directs the logical calculation process. MAIN first calls either CONCEN or COMPAG. CONCEN estimates ground-level air concentrations and surface-deposition rates. CONCEN calls QX, which accounts for plume depletion over the study area. COMPAG inputs previously calculated χ/Q values and then calculates surface-deposition rates. Once the concentrations and deposition rates are calculated, MAIN calls DOSE to compute the dose to man. DOSE then calls DOSMIC, which simply provides a structured output of DOSE results.

G.2 METEOROLOGICAL ROUTINE

The AIRDOS-II code consists of two major calculation routines: the meteorological routine and the dose routine. The meteorological routine is based on a dispersion model that considers plume rise, plume depletion, and an inversion lid. The equation used to estimate plume dispersion is the Gaussian plume equation of Pasquill, as modified by Gifford (1972):

$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

where

χ = concentration in air at x meters downwind, y meters crosswind, and z meters above the ground (pCi/m^3)

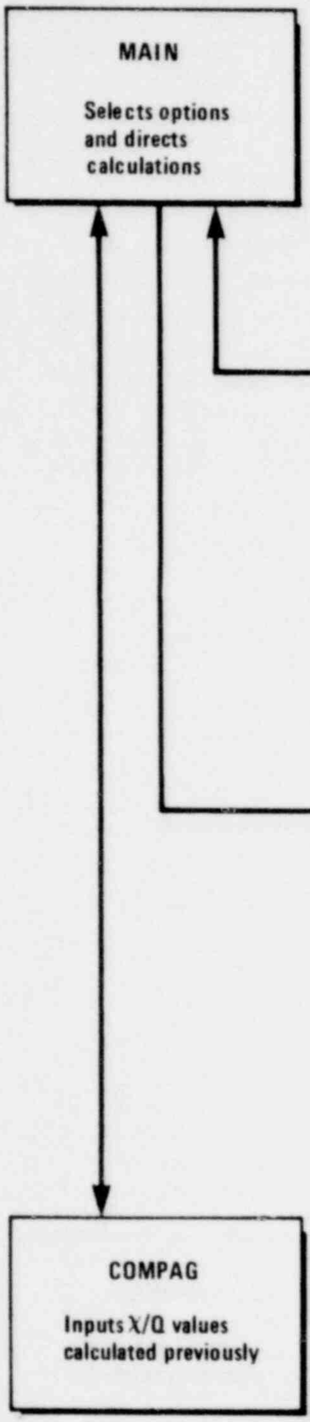


Figure G-1.

1789 136

Q = uniform emission rate from the stack (pCi/sec)
u = mean wind speed (m/sec)
σ_y = horizontal dispersion coefficient (m)
σ_z = vertical dispersion coefficient (m)
H = effective stack height (physical stack height h plus the plume rise Δh) (m)
y = crosswind distance (m)
z = vertical distance (m)

For calculating ground-level concentrations, this equation may be reduced to the following:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

The values of the dispersion coefficients are calculated from equations developed by G. A. Briggs of the National Oceanic and Atmospheric Administration. They are described in Table G-1 for each Pasquill category.

Table G-1. Formulas Recommended by Briggs[a] for σ_y and σ_z for Open-Country Conditions[b]

Pasquill category	σ_y (meters)	σ_z (meters)
A	$0.22d\ (1 + 0.0001d)^{-1/2}$	$0.20d$
B	$0.16d\ (1 + 0.0001d)^{-1/2}$	$0.12d$
C	$0.11d\ (1 + 0.0001d)^{-1/2}$	$0.08d\ (1 + 0.0002d)^{-1/2}$
D	$0.08d\ (1 + 0.0001d)^{-1/2}$	$0.06d\ (1 + 0.0015d)^{-1/2}$
E	$0.06d\ (1 + 0.0001d)^{-1/2}$	$0.03d\ (1 + 0.0003d)^{-1}$
F	$0.04d\ (1 + 0.0001d)^{-1/2}$	$0.016d\ (1 + 0.0003d)^{-1}$

[a]G. A. Briggs, Air Resources Atmospheric Turbulence and Diffusion Laboratory, National Oceanic and Atmospheric Administration, Oak Ridge, Tennessee.

[b]The quantity d is the downwind distance in meters.

The Rupp model for momentum-dominated plume rise is used. The Rupp equation for momentum-dominated plumes is

$$\Delta h = 1.5vd/u$$

where

Δh = plume rise (m)
v = effluent stack-gas velocity (m/sec)
d = inside stack diameter (m)
u = wind speed (m/sec)

1789 137

As the plume extends in size, particles will deposit on the ground or on water surfaces by dry deposition or by scavenging. Dry deposition is a process by which particles are removed from the plume at the ground surface by impingement, electrostatic attraction, or chemical interaction with the ground cover or ground surface. The rate of dry deposition is determined by the following equation:

$$R_d = V_d \chi$$

where

R_d = surface-deposition rate (pCi/cm^2-sec)
χ = ground-level concentration in air (pCi/cm^3)
V_d = deposition velocity (cm/sec)

Rain or snow scavenges particles in a plume by depositing them on the ground. The rate of scavenging deposition is defined by

$$R_s = L\phi\chi_{va}$$

where

L = lid height (cm)
R_s = surface-deposition rate (pCi/cm^2-sec)
ϕ = scavenging coefficient (sec^{-1})
χ_{va} = average concentration in vertical column up to lid height (pCi/cm^3)

The AIRDOS-II code accounts for the effect of these depletion processes by calculating a reduced release rate (source term) at each downwind distance and by using this reduced release rate in place of the input source term. Additional plume depletion is accounted for by radionuclide decay within the plume.

Often throughout a typical year, a stable air mass will reside above an unstable one. This condition, commonly referred to as an atmospheric inversion, produces a ceiling, or lid, above which a plume will not disperse. Consequently, above the lid altitude no vertical dispersion will occur. AIRDOS-II accounts for the increase in ground-level concentration by allowing the user to input an inversion-lid altitude. The average concentration of particulates is adjusted by means of this input parameter as is the surface-deposition rate.

For releases from the reference site, atmospheric dilution factors (χ/Q values) were calculated by another code. Consequently, it was not necessary to use the CONCEN subroutine. CONCEN was circumvented by writing COMPAG, which is a subroutine that allows direct input of concentrations into DOSE.

G.3 DOSE ROUTINE

The dose routine calculates the dose to man via several major pathways. It considers internal exposure resulting from the inhalation and ingestion of radionuclides and external exposure resulting from air immersion, water immersion, and contaminated surfaces. The dose from the inhalation of radionuclides is estimated from the following equation:

$$D_{inh} = (1.0 \times 10^{-6})(8760) \chi B_r C_{inh}$$

where

D_{inh} = inhalation dose (rem/yr)
χ = ground-level concentration of the radionuclide in air (pCi/cm^3)
B_r = breathing rate (cm^3/hr)
C_{inh} = dose-conversion factor for inhalation (rem/μCi)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr

The only parameter that is calculated by the code is the ground-level concentration; the other values are user inputs.

The dose from ingestion is calculated by using the terrestrial model of Booth et al. (1971). The code only considers radionuclide intake through the ingestion of vegetables, beef, and milk. The radionuclides deposited both on the vegetable surfaces and absorbed through the root systems are considered. This is also true for the grass intake in the beef- and milk-intake pathways. General agricultural and demographic information must be input by the user for ingestion-dose calculations.

External doses from gamma radiation emitted by the radionuclides in the plume are calculated as follows:

$$D_{imm} = (1.0 \times 10^{-6})(8760) \chi C_{imm}$$

where

D_{imm} = air-immersion dose (rem/yr)
χ = ground-level concentration of the radionuclide in air (pCi/m^3)
C_{imm} = dose-conversion factor for immersion in an infinite cloud ($rem\text{-}cm^3/\mu Ci\text{-}hr$)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr

Once again, the code used calculated concentrations and user-input dose-conversion factors.

A similar treatment is used for estimating doses that result from immersion in water on which radionuclides have been allowed to deposit. This is seldom a significant exposure pathway, but the dose contribution is calculated from the equation

$$D_{wimm} = (1.0 \times 10^{-6})(8760) \frac{R_t}{d} \frac{1 - e^{-\lambda_T t}}{\lambda_T} (3600)(24) C_{wimm}$$

1789 139

where

D_{wimm} = water-immersion dose (rem/yr)
R_t = surface-deposition rate (pCi/cm^2-sec)
d = depth of water (cm)
λ_T = radioactive decay constant + environmental decay constant for water (day^{-1})
t = time allotted for buildup in water (days)
C_{wimm} = dose-conversion factor for immersion in a body of water of infinite dimensions (rem-$cm^3/\mu Ci$-hr)
1.0×10^{-6} = $\mu Ci/pCi$
8760 = hr/yr
3600 = sec/hr
24 = hr/day

As can be seen in the equation, a shallow body of water makes the most significant contribution to the resultant dose.

The deposition rate is calculated by the code; the other parameters are input. The final pathway--exposure resulting from standing on a contaminated surface--is evaluated by using the following equation:

$$D_{surf} = (1.0 \times 10^{-6})(8760)R_t \frac{1 - e^{-\lambda_T t}}{\lambda_T}(3600)(24)C_{surf}$$

where

D_{surf} = dose from surface exposure (rem/yr)
R_t = surface-deposition rate (pCi/cm^2-sec)
λ_T = radioactive decay constant + environmental decay constant (day^{-1})
t = time allotted for surface buildup (days)
C_{surf} = dose-conversion factor for surface exposure to an infinite plane at a point 1 m above ground (rem-$cm^2/\mu Ci$-hr)
1.0×10^{-6} = $\mu Ci/pCi$
8760 = hr/yr
3600 = sec/hr
24 = hr/day

The expression

$$R_t \frac{1 - e^{-\lambda_T t}}{\lambda_T}(3600)(24)$$

represents the surface concentration after time t in days. The value of t used in analyses for the reference case was a conservative 15 years. The deposition rate is calculated by the code, and the other parameters are input by the user.

1789 140

G.4 INPUT DATA

Input data for AIRDOS-II were obtained from various references. The references for data used in analyses for the reference case are listed in Table G-2.

Table G-2. Sources of Input Data for the Reference-Case Analyses

Category	Source
Meteorological data	Appendix H, Section H.4
Scavenging coefficients	Moore, 1977
	NCRP, 1975
Physical and dimensional data	Chapter 8 and the WIPP conceptual design (as of December 1978)
Radiological data	
Decay constants	Lederer, 1967
Biological decay constants	Ng, 1968; NRC, 1977a
Dose-conversion factors	
External exposure	Killough, 1976
Internal exposure	Moore, 1977
	NRC, 1977a
Biological data	NRC, 1977b
	Wolfe. 1977
	Killough, 1976
	Ng, 1968
	Discussions with
	Lea County Agent, R. Henard, January 25, 1978, and January 18, 1979
	Eddy County Agent, D. Liesner, January 26, 1978, and January 19, 1979
Living patterns	NRC, 1977
	Discussions with
	Lea County Agent, R. Henard, January 25, 1978, and January 18, 1979
	Eddy County Agent, D. Liesner, January 26, 1978, and January 19, 1979

REFERENCES

Booth, R. S., et al., 1971. "A Systems Analysis Methodology for Predicting Dose to Man from a Radioactively Contaminated Terrestrial Environment," in Proceedings of the Third National Symposium on Radioecology, May 10-12, 1971, D. J. Nelson, ed., CONF-710501, pp. 877-893.

Gifford, F. A., Jr., 1972. "Atmospheric Transport and Dispersion Over Cities," Nuclear Safety, 13(5), 391.

Killough, G. G., et al., 1976. Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment, ORNL-4992, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Lederer, C. M., 1967. Table of Isotopes, John Wiley and Sons, Inc., New York.

Moore, R. E., 1977. The AIRDOS-II Computer Code for Estimating Radiation Dose to Man from Airborne Radionuclides in Areas Surrounding Nuclear Facilities, ORNL-5245, Oak Ridge National Laboratory, Oak Ridge, Tenn.

NCRP, 1975. Krypton-85 in the Atompshere--Accumulation, Biological Significance, and Control Technology, Report No. 44, National Council on Radiation Protection and Measurements, Bethesda, Md.

Ng, Y. C., et al., 1968. "Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices," Part IV, Handbook for Estimating the Maximum Internal Doses from Radionuclides Released to the Environment, UCRL-50163 Lawrence Livermore Laboratory, Livermore, Calif.

NRC, 1977a. Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake, prepared by Battelle Pacific Northwest Laboratories for the U.S. Nuclear Regulatory Commission.

NRC, 1977b. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I," U.S. Nuclear Regulatory Commission, Washington, D.C.

Wolfe, H. G., et al. (eds.), 1977. An Environmental Baseline Study of the Los Medanos Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report (Addendum), SAND77-7018, Sandia Laboratories, Albuquerque, N.M.

1789 142

Appendix H

DESCRIPTION OF THE REFERENCE SITE

CONTENTS

1789 144

CONTENTS (continued)

178 5

LIST OF TABLES

1789 146

LIST OF TABLES

1789 147

LIST OF TABLES

1789 148

LIST OF FIGURES

Appendix H

DESCRIPTION OF THE REFERENCE SITE

H.1 SCENIC, HISTORIC, AND CULTURAL RESOURCES*

H.1.1 General Appearance

The WIPP reference site in Eddy County, New Mexico, is monotonous in aspect and covered with desert vegetation. Ranching is the characteristic activity, and cattle are often to be seen. Ranch buildings are many miles apart; in between one sees an occasional windmill, stock-watering tank, drilling rig, or grasshopper pump. There are many roads in the area, the better ones surfaced with caliche, the poorer ones often little more than tracks in the sand. The most noticeable features are the potash-mining operations, especially the processing plants with their very large buildings and stacks. Their emissions often create a haze heavy enough to block the view of the mountains 40 to 60 miles to the west.

The overall scenic quality of the study area was evaluated in April 1975 by the Bureau of Land Management (BLM) for an environmental analysis related to potash leasing (BLM, 1975). The Bureau has a standard quality-evaluation scoring system that takes into account landform, color, water, vegetation, uniqueness, and intrusions. On a scale of 1 to 24, with 24 high, the scores from 16 observation points about the study area averaged 8.3 ± 2.9. (The same BLM scoring system applied to the center of the WIPP site resulted in a score of 8.) Only one of the 16 observation points received a rating as high as 15; it was a view from New Mexico highway 31 of a salt lake in the lower end of Nash Draw. This observation point is 13 miles west-southwest of the site.

H.1.2 History

The State of New Mexico has an extensive history of Spanish exploration and settlement, dating from the reconnaissance of Marcos de Niza in 1539, which was sparked by reports brought to Mexico by Cabeza de Vaca, telling of enormous wealth in the land to the north. De Vaca himself probably passed through New Mexico near present-day Carlsbad in 1534 or 1535. However, most Spanish exploration and settlement took place in the Rio Grande Valley in the northeastern part of the State. The next entry of Spaniards into southeastern New Mexico was in 1583, when an expedition led by Antonio de Espejo traveled down the Pecos River on the way back from the north. In 1590, an expedition led by Gaspar Castano de Sosa traveled north up the Pecos to the village of Pecos and then turned west to the Rio Grande.

For almost three centuries after de Sosa passed through the area, there were only two significant recorded entries by white men. The first was in

*The archaeological resources at the reference site are described in Section 7.4.

1775, when Commandant-General Hugh O'Conor conducted military campaigns against the Apaches in the Pecos Valley. The second occurred in 1854, when Brevet Captain John Pope conducted a survey of a possible route for a railroad to the Pacific through southern New Mexico.

H.1.3 Registered Historic Sites

The WIPP reference site contains no sites listed by the National or the State Register of Historic Sites. However, at the instance of Thomas S. Merlan, State Historic Preservation Officer, the site has been declared eligible for nomination as an archaeological district (Appendix I) because the 33 archaeological sites located, when taken together, are likely to yield significant information on prehistoric occupation.

There are, however, historic sites in the vicinity of the site. Nine miles south-southwest is the Project Gnome site, which is presently undergoing the nomination procedure. It was the site of the first underground nuclear detonation (December 1961) of the Plowshare program, the AEC's program of search for nonmilitary uses of nuclear explosions. North of the site two areas believed to be of National Register quality are also undergoing the nomination procedure: Laguna Plata, 15 miles north, and Maroon Cliffs, 11.5 miles northwest of the center of the site. Another site being nominated is Pope's Wells, near the State line to the south.

Nearby sites now on the State Register include Rattlesnake Draw, Monument Springs, the Lusk Ranch, and Boot Hill (listed as Red Tank Archaeological Site), all on private land. Rattlesnake Draw is said to contain the best stratigraphic sequences found to date in southeastern New Mexico. Monument Springs consists of pit-house ruins and a large midden. The Lusk Ranch is the site of a mammoth-bison kill dating from 9000 B.C. Boot Hill dates from 900-1300 A.D. and contains a series of Jornada Mogollon pit houses.

H.1.4 Settlement

Aboriginally, the study area was inhabited by wandering bands of American Indians, predominantly Lipan Apaches. Occasional parties of Mescalero Apaches, Comanches, and Kiowas probably crossed the area on hunting or raiding forays. With the coming of the cattlemen, there were occasional encounters between white men and Indians, but these were infrequent, and by the 1880s Indians were no longer a significant presence in the area.

Ownership of New Mexico changed from Spain to the Republic of Mexico in 1821 and from Mexico to the United States in 1848. Southeastern New Mexico played no part in these changes other than being a small portion of large tracts of land changing hands.

It was the coming of the cattlemen, led by Charles Goodnight and Oliver Loving in 1866, that started the modern development of southeastern New Mexico. When the Army and the Indian Bureau called for bids to furnish beef for the Navajos and Mescalero Apaches who had been forced onto a reservation at Fort Sumner, New Mexico, local ranchers and farmers could not meet the demand. Goodnight and Loving drove a mixed herd of Texas cattle across the southern part of the Llano Estacado and up the Pecos River to Fort Sumner. In the next year John Simpson Chisum followed the Goodnight-Loving trail with another herd. When the contractors would not accept cows with calves, Chisum placed these unacceptable cattle on the range south of Fort Sumner. Eventually, with the addition of unacceptable cattle from subsequent drives, Chisum had cattle grazing along the Pecos River all the way to the Texas border. Trading posts catering to the needs of the cowboys were established, and settlement of southeastern New Mexico was begun. One such trading post was located near the present-day town of Malaga, south of Carlsbad.

In 1888, another cattleman, Charles Bishop Eddy, founded the Pecos Valley Land and Ditch Company to build irrigation ditches and canals. Carlsbad was founded in 1889 as the town of Eddy.

The twentieth century in southeastern New Mexico has seen the development of other industries. The Hammond well, and later the Brown well, produced oil near Artesia in 1909; oil and gas development started in earnest in Lea County and adjacent Texas in 1934. Oil drilling led to the discovery of potash in 1925, and the commercial exploitation of these resources began in 1931. Mining is now the principal industry of Eddy County.

H.2 POPULATION

H.2.1 Population Trends and Distribution

In 1912, when New Mexico became a state, Eddy County contained approximately 9600 people. Between 1920 and 1930 the population grew to 15,842. After the start of potash mining in 1931, the population increased again (24,311 persons in 1940) and continued to grow from 1940 to 1960, principally because of the mining operations. By 1960 the population had reached 50,783 (BBER, 1962). After 1960 the potash industry in the area became severely depressed, and the population dropped to 41,119 by 1970. Since 1970 the economy of the area has improved, and the population has again increased. The 1976 estimate released by the Bureau of the Census showed that Eddy County had grown to 45,300, an increase of approximately 4200 people over the 1970 Census figure (USDC, 1977a). Since 1931, the population has increased and fluctuated with the potash-mining industry, with 50,783 inhabitants in 1960 (BBER, 1962), 41,119 in 1970, and 45,300 in 1976 (USDC, 1977a). The county contains four municipalities: Artesia, Carlsbad, Loving, and Hope (Table H-1). Carlsbad, the largest, had 26,600 inhabitants in mid-1977, up slightly from the 25,541 in 1960.

Lea County was organized in 1917 from parts of Chaves and Eddy Counties and had 3545 residents in 1920. Oil exploration, begun in southeastern New Mexico in 1924, brought substantial growth: by 1930 the population had increased to 6144 and by 1940 had more than tripled to 21,154. Continued growth brought a population of 53,429 in 1960 (BBER, 1962). Between 1960 and 1970 Lea County sustained a population decrease of approximately 7.3% owing mainly to decreased oil and gas exploration or production (USDC, 1970c). After 1970 the population increased from 49,554 to 54,400 in mid-1976 (USDC, 1977b). Most of the growth was related to increased activity in the oil and gas industry after 1973. Lea County has five municipalities: Hobbs, Lovington, Eunice, Jal, and Tatum (Table H-1). Hobbs, the largest incorporated place in the county, had an estimated 1977 population of 32,200.

Both counties are fairly homogeneous racially and ethnically (Table H-2), with a relatively small Spanish-origin ethnic group (speaking population) (statewide average 30.3%). The American Indian population is also relatively low: 0.3%, or 258 individuals in 1970 (statewide average 7.2%) (USDC, 1970a).

Table H-1. Population in Eddy and Lea Counties: 1960-1976

Location	Distance from site[a] (miles)	Population		
		1960[b]	1970[b]	1976[c]
Eddy County	N/A	50,783	41,119	45,300
Artesia	47	12,000	10,315	10,400
Carlsbad	26	25,541	21,297	25,500
Loving	18	1,646	1,192	1,100
Hope	62	108	90	120
Lea County	N/A	53,429	49,554	54,400
Eunice	35	3,531	2,641	2,500
Hobbs	41	26,275	26,025	31,300
Jal	37	4,133	3,241	2,700
Lovington	45	9,660	8,915	9,450
Tatum	65	1,168	982	850

[a]Distance rounded to the nearest mile; N/A = not applicable.
[b]USDC (1970b).
[c]Larry Adcock and Associates (1977-1978).

Table H-2. Characteristics of the Population in Eddy and Lea Counties[a]

Characteristic	Percentage of population[b]	
	Eddy County	Lea County
Race		
White	97.1	93.7
Black	2.2	5.3
Other	0.7	1.1
Spanish origin or descent	25.4	10.9
Residence		
Urban	76.9	81.1
Rural, nonfarm	18.1	15.1
Rural, farm	5.0	3.8

[a]Data from USDC (1970a).
[b]Percentages may not add to 100.00% because of rounding errors.

The age distribution of the population in the two-county area differs slightly between the counties, as well as between New Mexico as a whole and the United States (Table H-3). In both Lea and Eddy Counties the median age is below that of the United States as a whole but significantly above New Mexico's median age of only 23.9 years in 1970. The population of Carlsbad has a relatively low percentage in the less-than-20 age group and a relatively high percentage in the over-50 age group. The number of residents who are 65 or older is significantly higher in Carlsbad than the statewide average and the average for either Lea or Eddy County. An active program to attract retirees is supported by the Carlsbad area. The age distribution in Hobbs indicates a younger population (25.5 years) than that in Carlsbad (29.4 years).

Net-population-migration figures indicate significant changes during the last few years. In the 1960-70 period the two-county area was somewhat depressed because of reduced hydrocarbon exploration and potash mining. As a result, Eddy County experienced a net loss of more than 11,000 individuals during a 5-year period and Lea County a loss of approximately 5200. Since the Census, however, there has been a significant change in the net migration trend, with both counties showing a reversal: Eddy County received a net gain of 2000 during 1970-76 and Lea County a net gain of 600 (USDC, 1977b).

Although net migration during the last 6 years has been positive, major growth in the two counties has been caused by natural increase (births minus deaths): about 2200 persons in Eddy County and 4300 persons in Lea County, or about 2.5 times the growth caused by in-migration.

Population densities in the two counties are relatively low but slightly higher than the statewide average of about 9.9 persons per square mile. The population density in Eddy County was 9.9 in 1970 and is now approximately 11.4 persons per square mile. The population density in Lea County was 11.3 in 1970 and is now estimated at 12.9 persons per square mile. It should be noted that the density figures are somewhat misleading because most of the

Table H-3. Percentage Age Distribution of Population (1970 Census)[a]

	Percentage age distribution					
Age	United States	New Mexico	Eddy County	Lea County	Carlsbad	Hobbs
Under 5	8.5	9.5	8.2	9.0	8.2	9.4
5-14	20.1	23.8	22.3	22.8	20.8	22.8
15-19	9.4	10.4	10.9	10.7	10.4	10.5
20-29	14.5	14.6	11.3	12.5	11.2	13.0
30-39	11.1	11.6	10.5	12.7	9.9	12.9
40-49	11.8	11.0	12.0	13.4	12.6	12.9
50-59	10.4	8.9	11.3	9.9	12.1	9.6
60-64	4.3	3.4	4.5	3.6	4.9	3.6
65+	9.9	6.9	8.8	5.4	9.7	5.3
Median age	28.1	23.9	27.2	25.9	29.4	25.5

[a]Data from USDC (1970c).

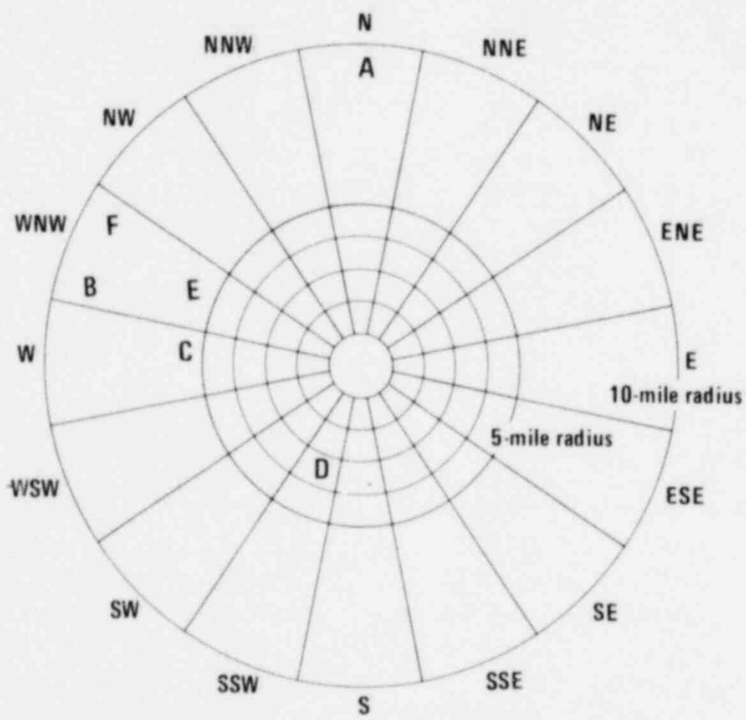
1789 154

population in Eddy County live in Carlsbad and Artesia. In Lea County slightly fewer than 85% of the total population live in four urban places. Thus, except for the six urban places, the two-county area is very sparsely populated.

Within a radius of 10 miles from the site, there are currently 16 permanent residents and three commercial mining operations (Figure H-1) with a total daytime employment of nearly 650 persons (Adcock, 1977-1978) and considerably smaller swing shifts and night shifts.

Within a radius of 50 miles from the site (Figure H-2) there were more than 94,000 inhabitants in 1976 (Table H-4). The major population centers are listed in Table H-1.

Population projections to the year 2010 are presented in Appendix M. From 1978 to 2010 Eddy County is projected to grow at a compound annual rate of 1.7% and Carlsbad at an annual rate of just more than 1.8%. Lea County growth for the 22-year period is 2.0% per year, and the projected annual growth rate for Hobbs is 2.2%.



A Kerr-McGee plant and mine: 151 employees (maximum), day shift

B International Minerals and Chemical Corporation: 450 employees (maximum), day shift

C Duval Corporation (Nash Draw Mine): 46 employees (maximum), day shift

D James Ranch: six permanent residents (six seasonal part-time employees)

E Smith (Crawford) Ranch: seven permanent residents (18 seasonal part-time)

F Pue's Store: three permanent residents

Figure H-1. Population within a 10-mile radius of the site.

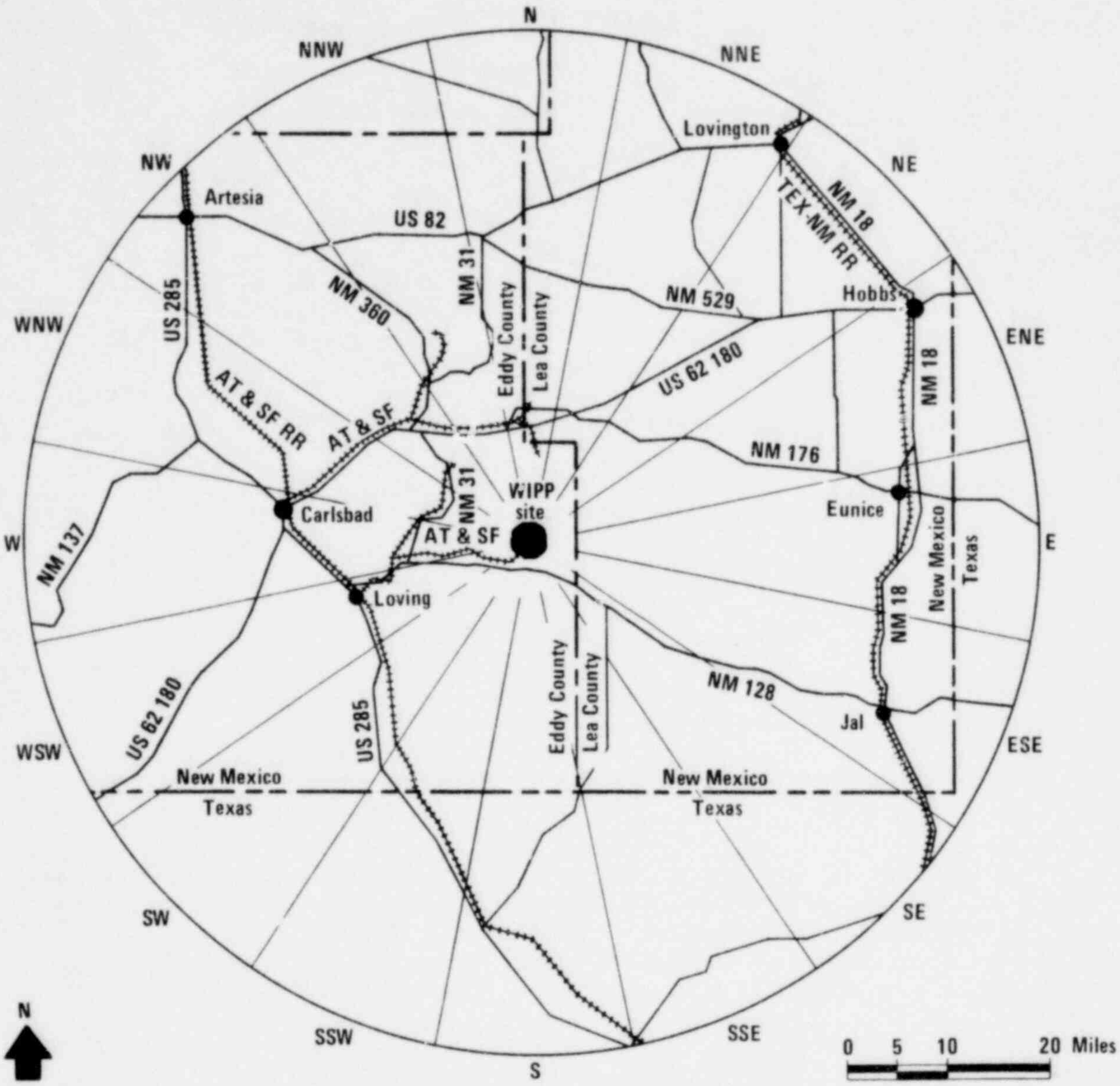


Figure H-2. Area covered by a 50-mile radius of the site.

Demographic changes

Few demographic changes are expected within 10 miles from the site in the foreseeable future. Interviews with ranch owners and managers indicate that one ranch house is expected to be built in the next 5 years, at the Mobley ranch just south of NM 128, approximately 8 miles west-southwest of the center of the site.

One other demographic change may occur just outside the 10-mile radius. A small trailer park (fewer than 20 units) is being built in and around the commercial establishment now known as Halfway Bar. Future plans for further trailer-park development are reported to be partially contingent on the construction of the reference repository.

1789 156

Table H-4. 1976 Resident Population Within 50 Miles of the Site[a,b]

Sector	Distance from site (miles)						
	0-5	5-10	10-20	20-30	30-40	40-50	Total
N	0	0	35	25	175	25	260
NNE	0	0	25	5	55	5,585	5,670
NE	0	0	0	25	75	6,735	6,835
ENE	0	0	15	70	185	30,595	30,865
E	0	0	5	15	3,190	155	3,365
ESE	0	0	5	10	3,035	295	3,345
SE	0	0	5	15	25	30	75
SSE	0	0	0	25	10	40	75
S	0	0	5	15	60	15	95
SSW	6	0	5	30	90	15	145
SW	0	0	55	15	10	45	125
WSW	0	0	1495	185	50	65	1,795
W	0	0	70	29,045	40	35	29,190
WNW	0	10	5	190	55	50	310
NW	0	0	30	20	65	11,505	11,620
NNW	0	0	15	5	250	10	280
Radius total	6	10	1770	29,695	7,370	55,200	94,050
Cumulative total	6	16	1785	31,480	38,850	94,050	---

[a]Data collected by Adcock and Associates (1977-1978).

[b]Figures for all areas beyond the 10-mile radius have been rounded to the nearest "5."

The population of workers at various mining operations in the 10-mile radius may vary from one period to another. During 1960-1970, it dropped significantly because of a decreased demand for potash from the Carlsbad area. Potash production now appears to have stabilized, at least for the near future. This work force is not expected to change significantly in the next few years.

Maintenance workers for oil and gas wells are transients in the area. The number of active oil and gas wells in Eddy County has been increasing during the past few years, and there are many active wells within the 10-mile radius (Figure H-1). Although the average number of workers in the area is not known, it is not expected to increase significantly during the next few years.

H.2.2 Social Characteristics

Employment structure and unions

In 1970, nearly 90% of the employed in Eddy County were wage and salary workers (74% in the private sector, 16% in the government sector), about 10% were self-employed, and 1% were unpaid family workers (USDC, 1970b, 1975-1978). In Lea County a slightly larger proportion of wage and salary workers were in the private sector and a correspondingly smaller proportion (12%) were in the government sector.

Table H-5. Median Earnings by Occupation, Ethnic Group, and Sex, Eddy and Lea Counties, 1969

Occupation	Median earnings					
	Eddy County			Lea County		
	All groups	Spanish	Black	All groups	Spanish	Black
Males 16 and older with earnings	$7068	$4286	$4820	$7695	$4883	$4225
Professional, manager	9158	4808	--	9909	8000	--
Crafts, foreman	8050	6667	4375	8127	6085	5211
Operatives	7244	5019	7078	7629	4477	4853
Nonfarm labor	4297	3306	5469	3793	3800	3500
Farmers and managers	6729	5533	--	4944	--	--
Farm laborers and foremen	2960	2871	--	3608	3350	--
Females 16 and older with earnings	$2810	$1596	$ 994	$2707	$1435	$1066
Clerical	3551	2575	--	3551	1875	--
Operatives	1241	830	--	2079	848	875

Table H-6. Income and Poverty Status of Families by Ethnic Group and Sex of Household Head, Eddy and Lea Counties, 1969[a]

Families with income below poverty level	Percentage of all families	
	Eddy County	Lea County
All families	17.8	12.5
Spanish	41.5	31.5
Black	24.4	50.7
Families with female head	50.0	47.0

[a]Data from USDC (1970a).

A large proportion of employed workers are blue collar (craftsmen and foremen, operatives, nonfarm laborers, and farm laborers): with 45% in Eddy County workers and 49% in Lea County workers falling into this class in 1970 (USDC, 1970b). Data on earnings, poverty and employment are given in Tables H-5, H-6, and H-7.

Eddy County has four unions with local headquarters in the county; the largest is the United Steelworkers Union. Lea County has none (Table H-8).

Churches and community organizations

Carlsbad has 60 churches and 1 synagogue, while Hobbs has 70 churches and 1 synagogue. Of the churches, two in Carlsbad and one in Hobbs are Catholic. Many of the remaining churches are Baptist.

There are 20 major civic and community organizations in Hobbs and 13 in Carlsbad. Most of these are fraternal organizations, with membership in many restricted to men, although many have auxiliaries for wives.

Table H-7. Employed Persons by Industry, Sex, and Ethnic Group, Eddy and Lea Counties, 1969[a]

Total employed, 16 and older	Eddy County					Lea County				
	Total	Male	Female	Spanish	Black	Total	Male	Female	Spanish	Black
Number	14,145	9374	4771	3046	364	18,255	12,745	5510	1571	729
Percent of total										
Agriculture	7	9	1	17	4	5	6	1	10	3
Mining	21	38	3	11	12	27	45	6	19	7
Construction	6			6	2	6			14	12
Manufacturing	5	6	3	6	7	5	6	3	4	1
TC & PU	7	8	4	6	6	7	8	5	4	5
Wholesale trade	3	4	1	2	--	3	4	1	2	2
Food, bakery, dairy stores	2	2	4	3	--	3	2	4	3	2
Eating and drinking establishments	3	1	6	3	2	4	1	11	7	5
Other retail	11	10	13	12	9	12	10	16	14	6
Finance, insurance, and real estate	3	3	5	1	4	3	2	5	2	2
Business and repairs	2	3	2	2	--	4	4	3	3	3
Personal and other services	7	3	16	10	32	5	2	14	8	32
Entertainment and recreation	1	1	1	1	3	1	1	1	1	6
Health services and hospitals	6	2	13	4	2	3	1	8	2	3
Education	9	5	18	10	5	7	3	14	3	6
Other professions	4	3	6	3	5	3	2	5	2	4
Public administration	4	4	4	3	7	3	3	3	1	1

[a]Data from the 1970 Census of Population.

Community planning capabilities

Both Carlsbad and Hobbs are experiencing considerable population and housing growth, which is expected to continue into the mid-1980s and probably into the year 2000. Both communities presently have planning agencies and various other city agencies that analyze and assist in growth management.

Table H-8. Unions Represented in Eddy and Lea Counties, 1978[a]

Name of union	Number of members	Local office	Area and firms covered
Carpenters' Local 1245	240	Carlsbad	Carlsbad, Hobbs, Roswell, Portales, Clovis, Tucumcari; construction contractors
International Brotherhood of Electrical Workers	259	Carlsbad	Electrical workers at Duval Corp., Potash Company of America, and Mississippi Chemical potash mines; 4 out of 5 local construction contractors
Iron Workers Local 775	Not known	Carlsbad	Not known
Retail Clerks Local 462	Not known	Las Cruces	Not known
United Steel Workers Locals 177, 178A, 181, 183, 187, 188A, 8507	1500	Carlsbad	Potash mines, Carlsbad city employees, school custodial and maintenance workers

[a]Data from Adcock and Associates (1977-1978).

H.3 ECONOMIC SETTING

H.3.1 General Economic Characteristics

As defined by standard economic-base theory, there are three basic economic sectors in Eddy and Lea Counties: mining, manufacturing, and agriculture. Although government is a basic industry* in many parts of New Mexico because of heavy Federal activity (statewide location quotient** of 2.1), most of the governmental activity in Eddy and Lea Counties is only a supportive function (two-county location quotient of 0.23) (USDC, 1975-1978). The

*Basic industries are those whose level of activity is not closely tied to the level of economic activity in the local community (Tiebout, 1962, p. 74).

**For an explanation of "location quotient," see Appendix L.

1789 160

nonbasic sectors in the two counties include contract construction; transportation, communications, and utilities; trade; finance, insurance, and real estate; and services. Certain activities in the retail-and-services sector are larger than might be expected because of heavy tourist traffic (Carlsbad Caverns). Transportation facilities and the transportation sector in the area are well developed because of the heavy industry there.

Basic industries

Mining, which includes oil and gas extraction, is the major industry in both counties. In 1977 mining employed about 3700 persons in Eddy County and about 5800 in Lea County. In both counties employment in mining was substantially higher than in any other industrial sector (ESCNM, 1975-1978). In Eddy County potash mining employs more than nine out of ten persons working in this sector. Figures for 1977 showed that New Mexico (Lea and Eddy Counties) supplied 93% of the total potash mined in the United States (USBM, 1978). In Lea County mining is centered on oil and gas (5500 employees); mining in potash, sand and gravel, rock salt, and caliche employed fewer than 200 people in 1977.

Personal income from mining in Eddy County was more than 22.2% of the total personal income generated there in 1976. In Lea County this figure was just more than 27.3%. Moreover, the impact of mining is increasing: personal income from mining rose 108.6% from 1970 through 1976 (USDC, 1975-1978).

At the beginning of 1977, there were 36 manufacturing companies with approximately 1050 employees in Eddy County and 48 manufacturing companies with 1065 employees in Lea County (ESCNM, 1975-1978). In 1976 manufacturing was second in income generated by a basic industry. However, the total personal income from manufacturing was only 5.2% of all personal income generated in the two-county area.

In 1975 the principal subsector of agriculture in the two-county area was meat animals and livestock. In the immediate area of the reference site, (10-mile radius), agriculture is restricted to cattle grazing. Personal income from agriculture in 1975 was less than 5% of the total personal income derived in the two-county area.

Trade and services

The 1972 Census of Business shows 454 retail outlets in Eddy County and 614 in Lea County, for a total of 1068. In Eddy County the majority, 281, are located in Carlsbad. The total sales volume in 1972 was about $185.9 million, or just over 8% of the statewide total of more than $2.[illegible] billion. Although little sales-volume information is available after 1972, etail sales in the area have increased substantially. Employment in both wholesale and retail trade has increased from an average of 2500 in 1972 to approximately 3300 in 1977 in Eddy County and from just less than 3600 to nearly 4700 in Lea County (ESCNM, 1975-1978).

The Rand-McNally 1978 Commercial Atlas and Marketing Guide shows both Eddy and Lea Counties as basic trade areas, which are defined as areas in which normal retail-trade purchases are made. Rand-McNally defines 50 major trade areas with a major central city from which substantial retailing and wholesaling operations are conducted. The Carlsbad basic trade area, Eddy County, is in the major trade area of El Paso; the Hobbs trade area, Lea County, is in the major trade area of Dallas. It is important to note that the basic trade areas for both Carlsbad and Hobbs do not extend beyond their respective county limits to any significant degree. Therefore, Rand-McNally notes few leakages in normal retail purchases from the two-county area. However, for major retail purchases and wholesaling there is substantial leakage out of the State into El Paso and Dallas.

There were 835 service establishments (e.g., hotels, motels, barber shops, advertisers, business services, repair shops) at the time of the 1972 Census of Business. Activity in this sector has increased substantially since 1972, with service-sector employment in Eddy County rising from slightly less than 1900 to about 2600 in 1977 (preliminary estimates) and from slightly less than 1800 to 2300 in Lea County (ESCNM, 1975-1978).

Tourism

Tourism contributes substantially to economic activity in the two-county area, particularly in Eddy County. The main tourist attraction in the area is Carlsbad Caverns National Park, which is approximately 22 miles southwest of Carlsbad and 41 miles west-southwest of the site. In 1977 it received 862,790 visitors, or nearly 44% of the visitors to all 11 national parks and monuments throughout the State (USDI, 1970-1978). Nearby parks (Guadalupe Mountains National Park, Living Desert State Park, the Presidents' Park in Carlsbad, and others) also attract local residents and tourists. Outdoor recreation centers around hunting, four-wheel-vehicle driving, and camping.

The effects of tourism in the area can be readily seen in employment statistics, with retail trade and selected services being most affected. For example, employment in eating and drinking establishments more than triples in the 3 summer months, and summer employment in lodging increases 60 to 70% over winter employment (ESCNM, 1975-1978). Other secondary and tertiary services affected by tourism (e.g., curio sales, barber shops, cleaners) also show substantial increases.

Tourism is highly seasonal, with visits to Carlsbad Caverns fluctuating from a high of 187,970 in July 1977 to a low of 25,350 in January (USDI, 1970-1978). To support the tourist industry, the City of Carlsbad, which receives most of the impact from the national park, has a total of 20 motels and hotels with more than 1000 rooms.

Financial resources

In Lea and Eddy Counties combined, there are eight chartered banks, four holding state charters and four holding national charters. Five of these (three state and two national) are in Eddy County. There are also 4 savings-and-loan institutions, 3 credit unions, and 19 small-loan licensees.

Mortgage financing in the Carlsbad area is primarily provided through the local savings-and-loan associations. Savings-and-loan officers, in interviews with Larry Adcock and Associates, have characterized the current (August 1978) mortgage money market as being moderately tight. Interest rates as of August 1978 were 9.75%, and most institutions are limiting loans to purchasers of owner-occupied units. Second-mortgage money is scarce, as is money to finance the purchase of used rental units.

Although the mortgage market is fairly tight, officials at all local savings-and-loan associations indicated that they are not currently turning down any qualified requests for financing of owner-occupied homes. For some families, a program of the New Mexico Mortgage Finance Authority provides money at 8%.

The mortgage market in Hobbs is currently similar to that in Carlsbad. Owner-occupied home mortgages are available at 9.75%, while second-mortgage and rental-unit money is not generally available.

H.3.2 Labor Force

Labor force is defined by the Department of Labor as persons who are employed and those who are unemployed and actively seeking employment. In 1977 the combined total labor force in Eddy and Lea Counties was approximately 44,400--approximately 24,200 in Lea County and 20,200 in Eddy County. Total employment in the two-county area was 42,500.

Between 1973 and 1977, when the economy of both counties was expanding, the total labor force grew approximately 25.9% (by roughly 9100 individuals), or 5.9% per year. The overall growth of employment for the 4-year period was 27.5%, or about 6.3% annually. Therefore, the number and the percentage of unemployed persons have decreased during the last 4 years. Although the combined unemployment rate for the two counties in 1977 was just more than 4.3%, the rate varies significantly between the counties (ESCNM, 1975-1978).

Employment

Mining is by far the largest employer in the two-county area. Accurate figures on agricultural employment are difficult to obtain and are normally out of date; the latest available credible information shows just over 2000 employees in the two-county area in 1975 (USDC, 1975-1978). In 1977 manufacturing employed approximately 2100 individuals--about 1085 in Lea County and nearly 1025 in Eddy County (ESCNM, 1975-1978).

The 1977 employment distribution is estimated as follows (ESCNM, 1975-1978): agriculture, 5%; mining, 25%; manufacturing, 6%; construction, 7%; transportation, communications, and utilities, 9%; wholesale and retail trade, 21%; finance, insurance, and real estate, 3%; services, 13%; and government, 12% (percentages do not add to 100% because of rounding).

Unemployment

Unemployment in the two-county area is lower than the State average; the 1977 average rates were 5.2% in Eddy County and 3.5% in Lea County. It varies significantly from season to season, with higher rates during June each year and lower rates in late spring and late fall (ESCNM, 1975-1978), partly because of variations in agricultural employment and because students and certain noncontract school personnel seek summer employment.

Applications for work through the New Mexico Employment Security Commission reveal that a large number of technical skills (many directly connected with construction and mining) and a large number of clerical and secretarial workers are available in the area.

Underemployment and disguised unemployment

The unemployment rate computed by the State and Federal governments is based on persons actively seeking employment. An area may sometimes have a low defined unemployment rate and also significant underemployment (i.e., occupations or jobs that do not take full advantage of an employee's potential). Disguised unemployment may exist when many persons are not actively seeking employment but would take a job if one were available in the area. Labor statistics and wages in the two-county area indicate that there may be some underemployment because of seasonal employment patterns, but it does not appear to be significant in the labor market.

Disguised unemployment is measured by labor-force participation rates. In the two-county area the labor-force participation rate for males is higher than the State average, while the rate for females is lower than the State average (USDC, 1970b). These data imply that not all females who are willing to work are actively seeking employment and that the labor-force availability for females may be greater than current statistics indicate.

Major employers

Nine of the 20 major employers in the two-county area are mining or service-to-mining companies (Table H-9). Only two, Levi Strauss and Holly and Navajo Corporation, are listed by the New Mexico Employment Security Commission as manufacturing companies.

Personal income

Total annual personal income in 1976 was listed by the Bureau of Economic Analysis as $246.8 million in Eddy County and $311.3 million in Lea County. The two-county area accounts for about 9% of the total annual personal income of all State residents. Total annual personal income in Lea County has been showing steady increases in recent years. Because of declines in the potash industry during the middle and late 1960s, Eddy County sustained a decrease in total personal income in 1968 and in 1969 barely achieved the level established in 1967; since 1968, however, it has shown increases. While information after 1976 is not available, trends in the area and the State indicate that total personal income has been increasing at more than 10% per year in the two-county area since 1976 (USDC, 1975-1978).

Per capita income in the two counties is higher than that in the State: in 1976 it was $5722 in Lea County, or approximately 7.5% above the $5325 registered statewide level, and $5453 in Eddy County, about 2.5% above the statewide level. In Lea County per capita income increased 84.9% between 1970 and 1976, while in Eddy County the increase was only slightly less at 82.1%. The statewide level increased 73.1% during the same period; thus the per capita income for the two-county area is increasing faster than the statewide average. It is important to note that per capita income in both counties is above the national average for non-SMSA (standard metropolitan statistical area) counties. In Lea County per capita income is 109.8% of the non-SMSA county national average, while the Eddy County level is 104.7% (USDC, 1975-1978).

Table H-9. Major Employers in Lea and Eddy Counties[a]

Employment range	Company	Services
	LEA COUNTY	
100-150	Halliburton Company	Oil field
	Moran Company	Oil-well drilling
	First National Bank	Banking
151-250	B&M (well service)	Oil field
	Levi Strauss	Manufacturing
	General Telephone	Utility
251-750	Humana of New Mexico (Llano Estacado)	Medical
	El Paso Natural Gas	Refining natural gas
	National Potash	Mining
Not known	M.G.F. Drilling Company	Oil-well drilling
	EDDY COUNTY	
151-250	Mississippi Chemical	Mining
	Lakeview Christian Home	Retirement home
	Holly and Navajo Corporation	Refining
251-500	Kerr-McGee Corporation	Mining
	Duval Corporation	Mining
	Amax Chemical	Mining
	Guadalupe Medical Center	Medical
501-750	Potash Company of America (Ideal Basic Industries)	Mining
	International Minerals	Mining
Not known	Evangelical Lutheran Center	Nursing home

[a]Data from the Industrial Development Corporation of Lea County (1978) and the Carlsbad Department of Development (1977-1978).

H.3.3 Housing and Land Use

Carlsbad

In the summer of 1977, Carlsbad annexed 7200 acres, increasing the city limits to about 12,800 acres. With the annexed land, which is mostly vacant, the total vacant land amounts to about 7500 acres, or nearly 60% of the total municipal land area.

Land-use patterns inside the city limits are currently changing. Much of the city is being rezoned, with the outcome of the rezoning in doubt. Until rezoning is settled, it is not possible to accurately predict either the location or the total amount of land to be available for future residential, commercial, and industrial development.

Since 1970 the construction of new housing units in Carlsbad has not kept pace with population growth. Vacancy rates dropped below 3% during much of the period (HUD, 1975; City of Carlsbad, 1978), with a resulting housing shortage. From 1970 through 1976, 786 new units were added to the housing stock, a rate of 154 per year. However, because of 140 demolitions the net result is the addition of 13 units (City of Carlsbad, 1978).

In 1977 housing construction increased, with the addition of 350 new units. Nonetheless, the housing supply in Carlsbad remains marginal. The stock of 9421 total housing units (Table H-10) allows for a vacancy rate of only slightly more than 1%. About 190 additional units would have been required to bring the year-end vacancy rate up to 3%. More than 4% of the existing housing stock is classified as substandard (with minor to severe violations of the Southern Standard Housing Code). Some 418 occupied housing units (274 owner-occupied and 144 renter-occupied) are substandard, 384 of which are suitable for rehabilitation (personal interview with Homer Roos, Federal Housing Administration, Albuquerque, 1978). In 1976, 547 occupied units were classified as substandard.

Temporary housing is available on a seasonal basis in Carlsbad's 20 motels, which have a total of about 1000 rooms. Between Memorial Day and Labor Day occupancy rates are about 100%. Nonsummer occupancy rates on weekends are as low as 50% in some motels but 95 to 100% on weekdays.

The Federal Housing Authority Section 8 program provides rent and utility assistance (75%) to qualified renters. Generally, to qualify, an individual must be more than 62 years old, disabled, or handicapped and have an income of less than $8500 (single-person limit).

Table H-10. Housing Stock in Carlsbad, 1977

Type	Total	Occupied	Unoccupied
All units	9421[a]	9320[b]	101
Single-family	7992[a]	7906[c]	86
Multifamily	919[a]	909[c]	10
Mobile home	510[d]	505[c]	5

[a]Based on U.S. Department of Commerce, 1970 Census of Housing, and subsequent building permit and demolition data.
[b]Based on population and household-size estimates prepared for this report.
[c]Occupancy rates assumed identical for all housing types.
[d]Larry Adcock and Associates, census, 1978.

Hobbs

The total land area inside the Hobbs city limits, including the Hobbs Industrial Air Park (HIAP), is about 14,720 acres. Not including HIAP, about 960 acres are vacant and available for residential, commercial, or industrial development. Virtually the total area of HIAP is vacant at present, providing an additional 3500 acres for industrial development. Since Hobbs has no zoning ordinance, there are no figures on the total amount of land available for specific types of use.

From 1970 to 1975, new housing units were added to the Hobbs housing stock at a rate of about 100 per year. Actual construction averaged about 150 units per year for the period, with about 50 units per year replacing condemned or removed structures (City of Hobbs, 1978). This relatively low rate of addition to the housing stock caused the vacancy rate to decline from nearly 9% in 1970 to just over 1% in 1975. In 1976 and 1977 construction activity increased, with 414 new housing units added in 1976 and 611 units in 1977, and vacancy rates increasing to about 2% because of the recent construction activity. At the end of 1977, the housing stock in Hobbs was estimated at 10,879 units (Table H-11).

Temporary housing in Hobbs is available in 11 motels with 482 rooms. Seasonal occupancy patterns are very similar to those for Carlsbad. On a year-round basis, occupancy averages 84%, with the Memorial Day to Labor Day rate at 95% or greater. Nonsummer occupancy is lower than summer occupancy on the average, but midweek occupancy is very high even in nonsummer months.

Table H-11. Housing Stock in Hobbs, 1977[a]

Type	Total	Occupied	Unoccupied
All units	10,879	10,661	218
Single-family	8,483	8,313	170
Multifamily	1,223	1,198	25
Mobile home	1,173	1,150	23

[a]Data from the City of Hobbs Housing Count, 1978. Occupancy based on vacancy-rate estimate in this housing count, with vacancy rates assumed to be identical for all housing types.

H.3.4 Community Facilities

Education

There are three public school districts in Eddy County and five in Lea County, with a combined 1976-77 enrollment of 22,279 (NMDFA 1978c). Two public school districts appear likely to experience substantial impacts from the WIPP. Special education, adult education, and technical-vocational programs are offered through the municipal school systems in Carlsbad and Hobbs.

Three institutions of higher education are in the vicinity of the WIPP site: a branch of New Mexico State University in Carlsbad and the New Mexico Junior College and the College of the Southwest (a small 4-year institution) in Hobbs. Eastern New Mexico University maintains a branch in Roswell, about 75 miles north of Carlsbad, and has its main campus in Portales, about 110 miles north of Hobbs. New Mexico Military Institute is also located in Roswell. Somewhat farther from the site are New Mexico State University, with a main campus in Las Cruces and a branch in Alamogordo, and the University of Texas at El Paso.

Carlsbad. The Carlsbad school system consists of 10 elementary schools, 2 junior high schools, 1 mid-high school, and 1 senior high school, with a combined enrollment of about 6500 full-time equivalent students (6737 students, with 465 kindergarten students attending half-days) (Carlsbad School District, 1977). This enrollment is well below the capacity of 10,000 students. The excess capacity exists at all grade levels (Table 9-36).

Hobbs. The Hobbs school system currently consists of 10 elementary schools (kindergarten through grade 6), 3 junior high schools (grades 7 through 9), and 1 high school (grades 10 through 12). Total enrollment for the 1978-79 school year is expected to be about 7675 students (R. Wasson, Hobbs School District, personal communication, 1978), somewhat below the estimated capacity of 8350 students (Table 9-40).

Municipal water systems

Carlsbad. Carlsbad currently obtains its water from a well field in the Capitan reef (Figure H-3). There are eight wells presently pumping water, and a ninth is being equipped to pump. In addition, there are three wells in the city limits that are not used because the quality of the water under Carlsbad is lower than that of water outside the city limits.

The 8833 acre-feet per year of water rights in the Capitan reef is insufficient to meet projected needs. For the past couple of years the city has overdrawn its rights in this water source, and current plans call for a payback of 2200 acre-feet over the next 2 years.

The city has recently purchased the Double Eagle system, including rights to 7648 acre-feet per year. Because this system is about 40 miles northeast of Carlsbad, a pipeline to the municipal system must be constructed and is now in the development stage. In addition, Carlsbad has rights to 10,640 acre-feet per year from a well field north of the city in the Ogallala Formation, giving the city total rights to over 27,000 acre-feet per year.

Current (1977) consumption averages about 7.8 million gallons per day (mgd) in Carlsbad; peak consumption is about 16 mgd. This is well within the current 22.5-mgd capacity of the delivery system.

Hobbs. Hobbs currently has rights to 18,088 acre-feet of water per year from groundwater sources (primarily inside city limits) in the Ogallala Formation. In addition, it has an allocation of 15,340 acre-feet per year from the proposed Eastern New Mexico Water Supply System, which would deliver water from the Ute Reservoir to 10 communities in eastern New Mexico. The status of this project is currently very uncertain, and it is not known when, if ever, delivery of water to Hobbs will begin.

1789 168

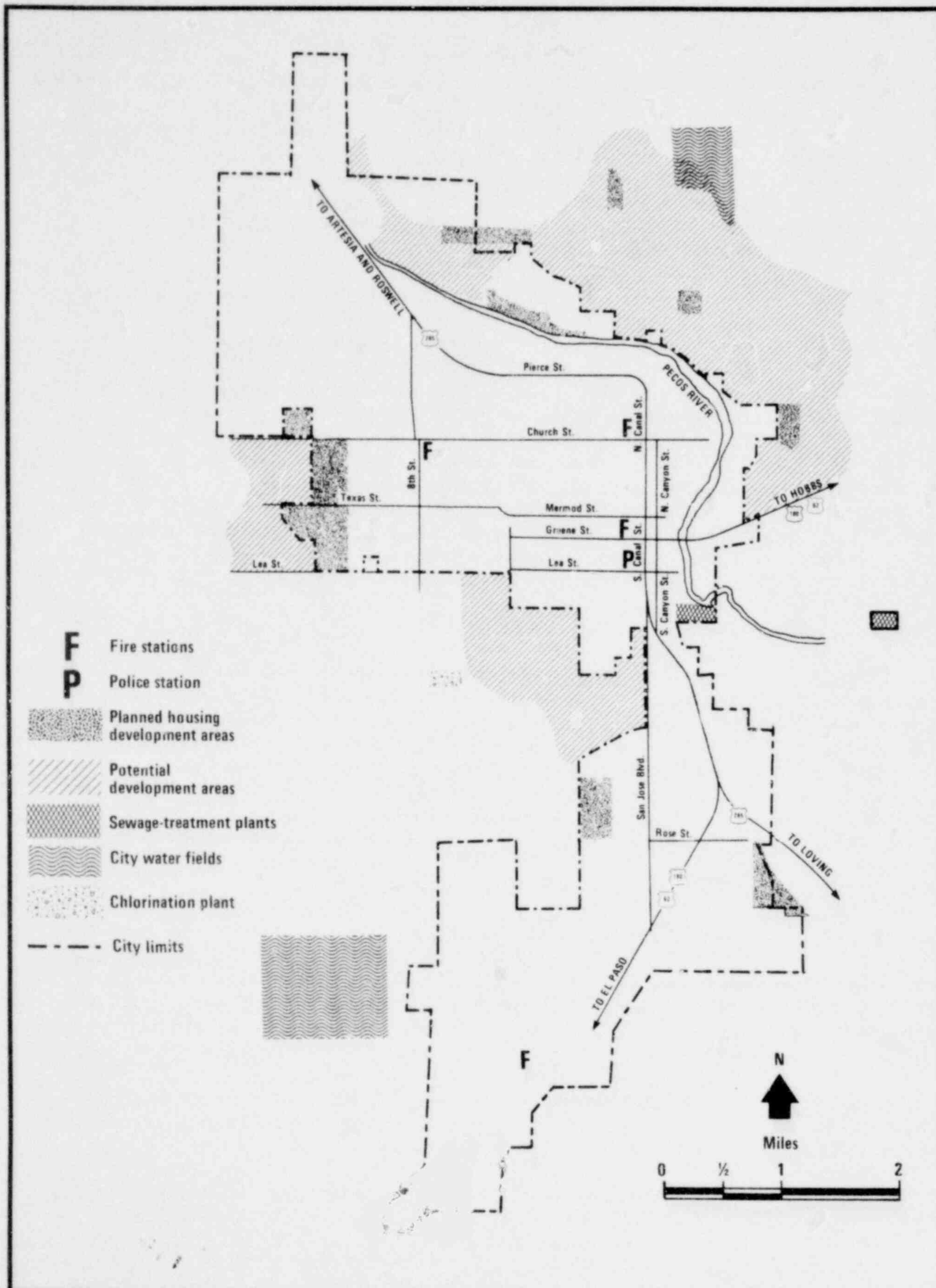


Figure H-3. Municipal facilities, water system, and sewage-treatment plants, Carlsbad.

Municipal water is supplied from 23 wells located in and around the city (Figure H-4). Current potential yield of the wells is about 14 mgd.

Average consumption is currently about 12 mgd. Peak daily consumption, normally about double the average daily rate in this area, is limited by the capacity of the delivery-and-storage system to just over 14 mgd. Thus, although total water rights in the Ogallala Formation are adequate for current demands (about 7050 acre-feet per year), there is a need for additional wells and storage-and-delivery facilities.

Municipal wastewater systems

Carlsbad. The Carlsbad municipal sewage-treatment plant, inadequate for current needs, is being expanded and upgraded, with construction expected to begin about the end of 1978 or early 1979. On completion, the plant will have a design capacity to serve 50,000 people. Effluent will be used to irrigate a 700-acre farm owned by Carlsbad.

Sewage-collection facilities provide service to the entire city (Figure H-3). Residential areas outside city limits use septic systems. About 25 to 30% of the developing areas in the vicinity of the city are currently not suited to the use of conventional percolation septic systems and must use the somewhat more expensive evapotranspiration septic systems (personal interview, Delbert Bell, New Mexico Environmental Improvement Division, Carlsbad, 1978).

Hobbs. Construction of a new municipal sewage-treatment plant is under way, with completion expected in early 1980. The new plant will have an initial capacity of 5 mgd, with expansion capabilities up to 6 mgd.

There are also plans to expand and upgrade the main sewer lines in the city. Two of the three existing main trunk lines will be affected, with one being rebuilt and one being paralleled by a new bypass line.

Since April 1, 1978, developing areas north of Hobbs (Figure H-4) have been restricted by the New Mexico Environmental Improvement Division (NMEID) to the use of evapotranspiration septic systems because of past problems with percolation systems seeping into local water supplies. The use of the evapotranspiration systems is expected to prevent further problems with residential sewage in areas not connected to the Hobbs municipal sewage system (personal interview, Gunther Diehl, NMEID, Hobbs, 1978).

Electric service

Carlsbad. Eddy County and most of Lea County obtain electricity from the Southwestern Public Service Company, the majority of the power being generated by natural gas and 25% by coal. In the Carlsbad area this company currently serves 10,994 residential and 1241 commercial customers as well as a number of large industrial customers and miscellaneous others. Capacity is adequate for present needs and projected demand.

Hobbs. Electric service is provided by the New Mexico Electric Service Company (118 megawatts generated by natural-gas-fired units and 66 megawatts generated by a natural-gas turbine). As of March 1978, this company had 10,803 residential and 2295 commercial, industrial, and other customers in the Hobbs area. Capacity is adequate for present needs and projected demand.

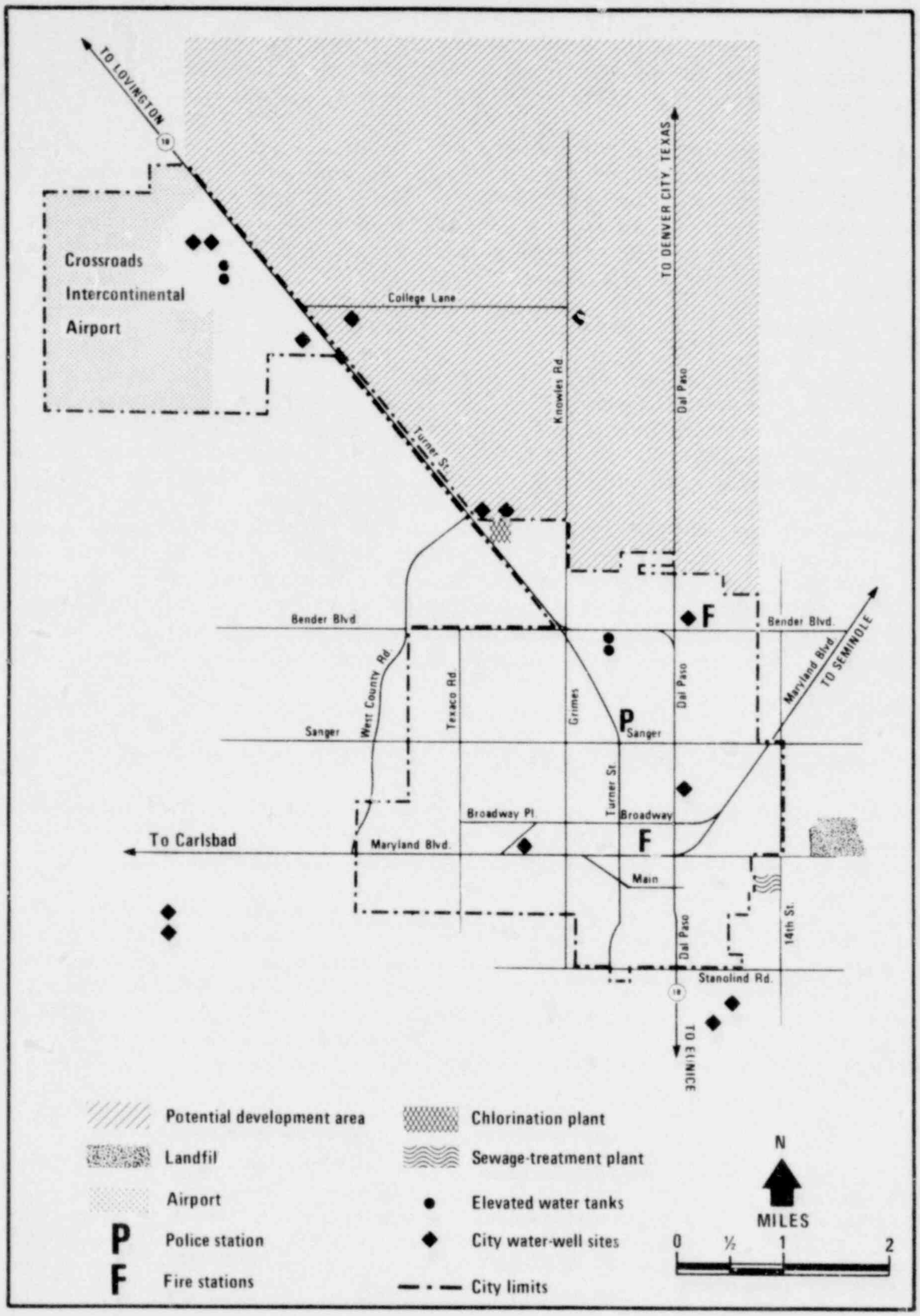


Figure H-4. Municipal facilities, water system, and sewage-treatment plant, Hobbs.

1789 171

Natural-gas service

Carlsbad. The Gas Company of New Mexico serves most of the reference-repository impact area, providing natural gas to 9124 residential customers, 884 commercial customers, and 149 industrial, public, and other special users. In recent years the company has been expanding service at the rate of 300 to 400 customers per year in the Carlsbad area. Capacity is adequate for present needs and projected demand.

Hobbs. The Hobbs Gas Company was serving 10,456 customers in the city at the end of February 1978, an increase of 354 customers over the previous year. Natural gas is provided to 9201 residential, 1208 commercial, and 48 other customers. Capacity is adequate for present needs and projected demand.

Fire protection

Carlsbad and Eddy County. The Carlsbad Fire Department has 22 full-time employees, or about 0.7 per 1000 people, operating out of three substations, including one at the airport (Figure H-3). Major equipment includes one 1500-gpm pumper, one 1000-gpm pumper, three 750-gpm pumpers, and a dry chemical truck at the airport. The primary service area for the department is the city, but occasional trips are made outside the city limits to assist the all-volunteer Eddy County Fire Department. These trips are made on the basis of a verbal mutual aid agreement between the city and the county.

Hobbs and Lea County. The Hobbs Fire Department currently has 44 full-time employees, including two dispatchers, or about 1.35 per 1000 people. There are two fire stations (Figure H-4) and seven fire trucks. Approximately one-third of the department's calls are outside the city limits to assist the all-volunteer Lea County Fire Department.

Police protection

Carlsbad and Eddy County. The Carlsbad Police Department has 40 full-time employees, or about 1.5 per 1000 people. The primary area served by the department is the city, but officers go outside the city limits to assist State police or County Sheriff's officers on request. City police also have Eddy County Sheriff's commissions to facilitate their activities outside city limits.

The Eddy County Sheriff's department has about 23 full-time employees. In addition, as discussed above, the department can call on Carlsbad police officers for assistance if needed.

Eddy County had a total of 81 officers (State police, Sheriff, and Police Department) in 1975, or 1.9 per 1000 people.

Hobbs and Lea County. The Hobbs police department has 81 full-time employees, or about 2.5 per 1000 people. Moreover, Hobbs had developed a program in which off-duty police officers use marked patrol cars. The effect of the program is to increase the apparent size of the department by making police officers visible, whether on or off duty. The police department serves the city primarily, with only occasional calls outside city limits.

Lea County had 99 officers (State police, Sheriff, and Police Department) in 1975, or 1.9 per 1000 people. On the basis of both Part 1 crimes per 1000 population and the Adjusted Crime Index, Lea County was the fifth highest in the state in 1975 (BBER, 1977b).

Health care

Carlsbad and Eddy County. The Guadalupe Medical Center in Carlsbad is the principal short-term hospital in Eddy County. It opened in late 1977 and has 134 beds. There is also the 26-bed Artesia General Hospital. On the basis of mid-1978 Eddy County population estimates, the 160-bed county total amounts to 3.4 per 1000 population. This is below both the national average of 4.0 beds per 1000 and the New Mexico average of 3.5 per 1000. Nonetheless, the mid-1978 Guadalupe Medical Center occupancy rate of 73% is below the Federal standard of 80% proposed for all nonfederal general short-term hospitals (Bennett, 1977). Additional medical facilities available in the area are indicated in Table H-12.

There are 35 physicians in Eddy County, 30 of whom use the facilities of the Guadalupe Medical Center. Some 20 of the county's physicians provide primary care, or about 0.5 per 1200 population. Although there are no generally accepted standards for primary care physician-to-population ratios, the Eddy County ratio of 0.5 is only half the suggested level of 1.0 per 1200 (Bennett, 1977). Eddy County was classified as a medically underserved area in 1976 by the Secretary of Health, Education, and Welfare for purposes of determining eligibility for Health Maintenance Organization funding (Bennett, 1977). In addition, there are 13 dentists in Eddy County.

Emergency medical services are provided by the Guadalupe Medical Center, which operates a 24-hour emergency room staffed by three physicians specializing in emergency treatment.

Ambulance service is provided by the Carlsbad Fire Department. There are currently four vehicles in use, and a fifth has been requested. Ambulance service normally covers an area within a radius of about 30 miles of the city. Each ambulance is staffed by two emergency medical technicians (EMTs). The Fire Department has 3 full-time EMTs on the staff, and 25 additional paid volunteer (part-time) EMTs are available.

Table H-12. Area Medical Facilities

Facility	Carlsbad	Eddy[a]	Hobbs	Lea[b]
Short-term hospitals	1	2	1	1
Hospital beds (plus basinettes)	134 (18)	160 (NA)	180 (20)	180 (20)
Nursing homes	2	2	2	3
Intermediate-care facilities and home health agencies	NA	3	NA	3
Clinics (including mental health)	NA	6	NA	4
Primary-care clinics	0	1	1	1

[a]Includes Carlsbad.
[b]Includes Hobbs.

1789 173

Hobbs and Lea County. The only short-term hospital in Lea County is the new Llano Estacado Medical Center in Hobbs, which has 180 beds. On the basis of mid-1978 population estimates, there are about 3.2 short-term beds per 1000 population, less than the national average of 4.0 beds per 1000 and the New Mexico average of 3.5 per 1000. The 50% occupancy rate for the hospital is well below the Federal standard of 80% proposed as the appropriate rate for all nonfederal general short-term hospitals (Bennett, 1977).

Additional medical facilities in Lea County (Table H-12) include five clinics, one of which, located in Hobbs, provides primary care. In addition, there are three nursing homes and three intermediate-care and home health agencies.

There are 40 physicians in Lea County, 25 of whom are located in Hobbs. Thirty-four of the physicians provide primary care, or 0.7 per 1200 people. This is below the 1.0 per 1200 level suggested by Bennett (1977). Partly as a result of this low primary-care-physician-to-population ratio, Lea County was classified as a medically underserved area in 1976 by the Secretary of Health, Education, and Welfare for purposes of determining eligibility for Health Maintenance Organization funding (Bennett, 1977). In addition, there are 13 dentists in Lea County.

Emergency medical services are provided by the Llano Estacado Medical Center. The new $500,000 emergency room, open 24 hours a day, is staffed by three full-time and six part-time physicians who specialize in emergency treatment.

Ambulance service is provided by the Hobbs Fire Department, which currently operates four ambulances. The ambulance service area extends to Lovington on the north, the county line on the west, into Texas on the east, and about 15 miles to the south of Hobbs. Each ambulance carries two EMTs on all calls. The Hobbs Fire Department employs 40 EMTs full time, which is to say that most fire department personnel are qualified as EMTs. The department also employs one EMT instructor.

Traffic and transportation: regional

Pipeline transportation. A 12.75-inch El Paso Natural Gas pipeline passes through the site about a mile north of its center, running in an east-west direction. This pipeline was built in the 1940s. Approximately 8 to 9 miles south of the site is a 26-inch El Paso Natural Gas line that also runs east-west.

Air transportation. The commercial airport nearest to the site is the Cavern City Air Terminal, about 30 miles to the west. To the east-northeast lies the Hobbs Municipal Airport, about 35 miles from the site. There are no landing strips within 10 miles radius of the site. The site, however, is traversed by commercial air traffic between Carlsbad and Hobbs.

Highway transportation. Figure H-5 shows the average daily traffic flow in the environs of the site (the annual average daily traffic flow at selected control locations is shown in Figures H-6, H-7, and H-8). Data for

1789 174

the overall flow of vehicles indicate sufficient capacity for the highway: capacity ratings vary from 20 to 29 on a scale of 30 on the section of road between Carlsbad and Hobbs.

Portions of N.M. 31 and N.M. 128 lie within 10 miles of the site, and U.S. Highway 62-180 runs east to west a little over 10 miles north of the site. U.S. Highway 62-180, part of the Federal Aid Primary System, is a four-lane divided highway from Carlsbad to the Lea County line. From the Lea County line east until it intersects with N.M. 8, the highway has two lanes. From the intersection with N.M. 8 east into Hobbs, U.S. 62-180 is again a divided four-lane highway.

New Mexico 31, a two-lane road with a bituminous surface, runs north to south about 10 miles west of the site. There is little or no shoulder on certain portions of the highway. One section within 10 miles of the site has an overall pavement width of 18 feet and a total roadway width of 20 feet.

New Mexico 128, running east to west, traverses the southern portion of the 10-mile radius. This State-maintained two-lane bituminous-surface highway is part of the Rural Federal Aid Secondary System, as is N.M. 31. Pavement widths vary between 20 and 22 feet for sections within the 10-mile radius of the site, and the roadbed is at least 22 feet wide. From the intersection of N.M. 31 and N.M. 128 to the present access road to the site, the highway traverses several small salt lakes or ponds; here there is

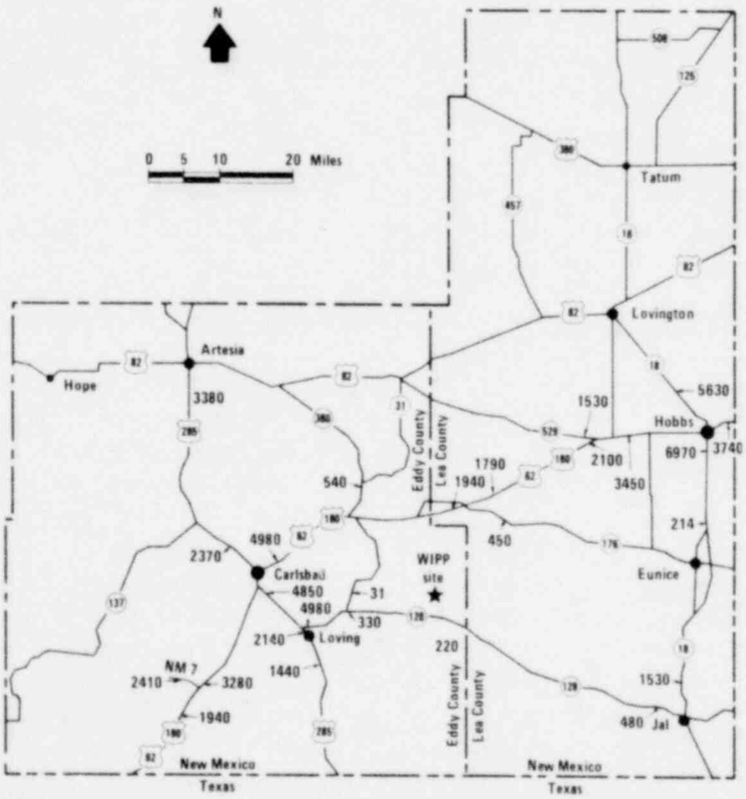


Figure H-5. Road conditions and traffic flow on US 62-180, selected sections.

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	DR[10]	SAF[11]	CAP[12]	OVAL[13] RATG
1	N	7.7	Bit	20	22	663	10	11	09	02	27	56
2	N	8.7	Bit	20	20	250	10	11	07	01	29	63
3	N	3.4	Bit	18	20	272	10	10	05	02	29	60
4	N	2.9	Bit	24	28	487	10	09	10	02	29	60

Source: Ratings for Highway Improvements, Rural Federal-Aid Secondary System, 1976, New Mexico State Highway Department, Planning and Programming Division, in cooperation with U.S. Department of Transportation, Federal Highway Administration.

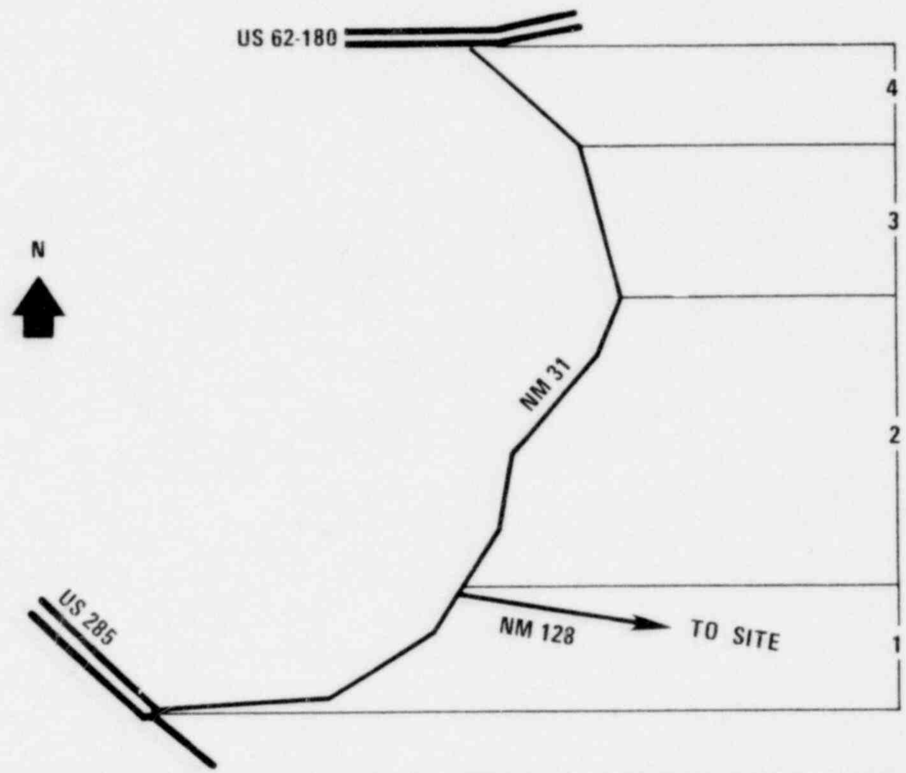


Figure H-6. Average daily traffic flow on NM 31, 1977.

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	WIDTH IN FEET RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	CONDITION RATING DR[10]	CONDITION RATING SAF[11]	CAP[12]	OVAL[13] RATG
1	E	9.1	Bit	20	22	237	10	10	06	01	29	62
2	E	9.8	Bit	22	22	168	10	12	07	02	29	68
3	E	9.5	Bit	22	22	271	10	11	06	02	29	62

Source: Ratings for Highway Improvements, Rural Federal-Aid Secondary System, 1976, New Mexico State Highway Department, Planning and Programming Division, in cooperation with U.S. Department of Transportation, Federal Highway Administration.

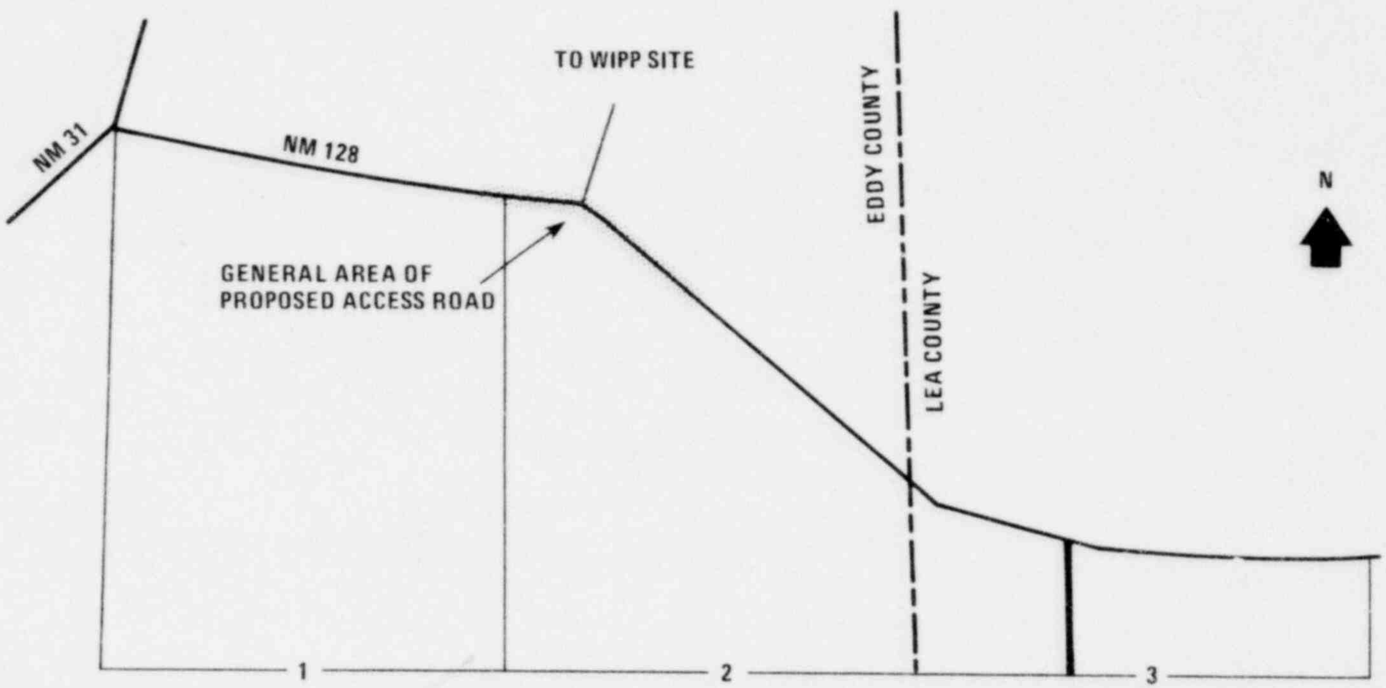


Figure H-7. Road conditions and traffic flow on NM 128, selected sections.

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	DR[10]	SAF[11]	CAP[12]	OVAL[13] RATG
9	E	2.3	Bit	24	36	2,409	10	15	10	03	28	63
9	W	2.3	Bit	22	28	2,409	10	12	10	03	28	59
10	E	4.1	Bit	24	40	2,123	10	24	10	04	28	75
10	W	4.1	Bit	20	26	2,123	10	16	10	02	28	64
11	E	5.3	Bit	24	40	2,031	10	27	10	20	28	95
11	W	5.3	Bit	20	30	2,031	10	16	10	04	28	67
12	E	1.4	Bit	24	40	1,854	10	27	10	20	28	95
12	W	1.4	Bit	20	26	1,854	10	16	09	03	29	66
13	0	8.4	Bit	22	30	1,881	10	12	09	03	20	53

Source: Ratings for Highway Improvements, Rural Federal-Aid Primary System, Interstate System Included, 1977, New Mexico State Highway Department in cooperation with U.S. Department of Transportation, Federal Highway Administration.

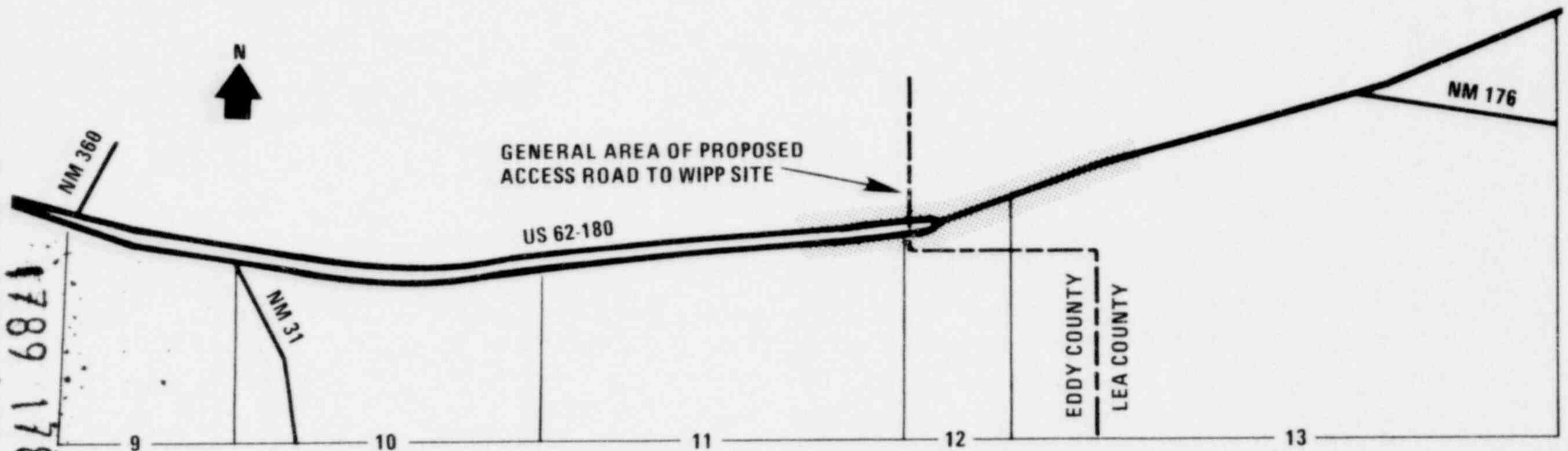


Figure H-8. Road conditions and traffic flow on US 62-180, selected sections.

EXPLANATION OF TERMS FOR

FIGURES H-6, H-7, AND H-8

1. RD SECT, LOC #: Number on route map identifying the subject location.
2. FLOW DIR: Traffic flow or direction. 0 - Undivided highways; N - Northbound; S - Southbound; E - Eastbound; W - Westbound; 5 - Other; and 6 - Other where Average Highway Speed is less than design speed.
3. SECT LENG: Length of the rating section in miles and tenths.
4. SURF TYPE: Existing surface types are indicated as follows: UN - Unimproved; BL - Bladed; G&D - Graded and drained; GR - Gravel; BIT - Bituminous; CON - Portland Cement Concrete.
5. WIDTH IN FEET/PAVT: Width of concrete or bituminous surface recorded in an even number of feet.
6. WIDTH IN FEET/RDWY: The distance between outside shoulder lines.
7. ADT: Average daily traffic, the average number of vehicles passing a given point on the highway in a typical 24-hour period of up to 72 hours; count in both directions on the divided highways.
8. FDNT: Foundation rating - 10 points. Foundation can be rated only 10 for adequacy or 0 for inadequacy. A rating of "0" is given to sections if any of the following conditions exist: 1 - Travelled way less than 18' wide; 2 - Lack of adequate and uniform cross section, including side ditches; 3 - Paved surface indicating failure which could not be corrected by the addition of a few inches of surface material.
9. SURF: Surface. The surface receives a rating on the scale of 0 - 30. If surface is in relatively good condition but showing first signs of deterioration, it receives a rating of 15. More advanced decay, while still in fair, usable condition, is rated between 10 and 15. Pavement in a condition justifying replacement is assigned a rating of 10. Increasingly poor conditions to the point of complete deterioration are rated 10-0.
10. DR: Drainage - 10 points. Lack or inadequacy of drainage facilities reduces the total of 10 points allotted for completely adequate drainage. The amount of reduction is proportional to the relative lengths of the deficient segment to the total rating section and the degree of the deficiency.
11. SAF: Safety - 20 points. The other conditions which are rated also involve features of safety, however, this rating item is concerned with certain conditions as follows: 1 - Stopping sight distance less than permitted by the design speed; 2 - Horizontal curves sharper than permitted by the design speed; 3 - Bridges narrower than the travelled way width; and 4 - Dips.
12. CAP: Capacity. A rating between 0 and 30 is assigned to represent the capacity characteristic of the rating section. From a rating of 30, indicating full capability to carry the actual existing traffic load (ADT), to a rating of 0 to 10 indicating a deficient section, the decreasing numerical value indicates the increasing presence of significant factors contributing to the decline of the traffic-carrying capability of the roadway.
13. OVAL RATG: Overall rating. This overall condition rating is an adjusted indicator representing a weighted average of the previous five categories. The formula used to arrive at this adjusted rating from the total rating takes into account the average traffic volume for the system of which it is a part.

virtually no shoulder, and in some areas there is an abrupt drop of 2 to 3 feet from the paved surface level to the pond or lakebed level. Several inspection trips revealed a significant amount of maintenance along these areas on N.M. 128 and along similar areas on N.M. 31. Surface and safety ratings and Figures H-6 and H-7 show significant deficiencies along certain portions of N.M. 128 and 31. It is suspected that these low ratings are caused partially by the presence of certain low areas that collect salt water and turn into salt lakes or ponds.

Railroad transportation. In the two-county area, two companies operate rail systems: the Atchison, Topeka and Santa Fe, and the Texas-New Mexico Railroad. Atchison, Topeka and Santa Fe enters New Mexico from the south, running parallel to U.S. 285. It connects the communities of Loving, Carlsbad, and Artesia in Eddy County and proceeds north to connect with the Atchison, Topeka and Santa Fe main line at Clovis. Spur lines to the potash-mining area have been constructed.

The spur line to the Duval Nash Draw mine offers the closest access to the WIPP reference site. The proposed extension of this spur will connect the site with the Atchison, Topeka and Santa Fe line. The Texas-New Mexico line enters at the southeast corner of Lea County and parallels N.M. 18, connecting the communities of Jal, Eunice, Hobbs, and Lovington. The line ends just north of Lovington.

Carlsbad transportation system

Current traffic-flow levels are well within the existing capacity of the street system. Inspection of the street system shows few unpaved streets within the city limits. The condition of the street system appears to be good and shows adequate maintenance.

Air Midwest provides commercial air service for Carlsbad, with two departures a day, one to Lubbock, Texas, and the other to Albuquerque, New Mexico.

The Santa Fe Railway provides the area with freight service. Piggyback service is available, and daily switching service is sustained.

Three interstate motor-freight carriers serve the city. Terminal facilities are available for each.

Intrastate and interstate bus transportation is available through Texas, New Mexico, Oklahoma Coaches, Inc., an affiliate of the Greyhound system. A private carrier provides mass transportation to the commercial mining operations. Currently there are 28 round trips per day to the mining sites in the Carlsbad area. There are no public transit facilities in Carlsbad other than a taxicab company that operates four vehicles.

Hobbs transportation system

One U.S. highway, 62-180, and two New Mexico highways, 18 and 132, intersect at Hobbs. Traffic-flow statistics for these highways are included in Figure H-6; Section 9.4 contains traffic-flow information for municipal streets and roadways.

The Hobbs area is served by the Hobbs-Lea County Airport, 3.2 miles west of Hobbs on a paved four-lane highway. The Federal Aviation Administration maintains a control tower and provides air and ground communications. The longest runway at this municipal county airport is 7400 feet.

Air Midwest provides commercial air service for Hobbs, with four departures a day, two each to Lubbock, Texas, and to Albuquerque, New Mexico. This service is to expand to three flights a day to each city in the near future.

Hobbs is served by the Texas-New Mexico Railroad, a subsidiary of the Texas and Pacific Railway. This railroad provides daily freight service to the Hobbs area and operates piggyback service from Lubbock, Texas.

Six motor-freight carriers serving the Hobbs area move freight on both an interstate and an intrastate basis: APEX Freight Lines, C-B Motor Freight, Illinois-California Express, OEA Express, Texas and Pacific Motor Freight, and Yellow Freight Systems, Inc. In addition, several trucking firms provide specialized or custom hauling of heavy equipment. United Parcel Service serves the Hobbs area for the shipment of small packages and envelopes. Bus service is provided by Texas-New Mexico and Oklahoma Coaches, Inc., with nine arrivals and departures daily. There are no public transit facilities in Hobbs other than two taxicab companies operating a total of five vehicles.

Communications services and facilities

Telephone service in the Carlsbad and Hobbs area is provided by General Telephone of the Southwest.

Recreation

The State Comprehensive Outdoor Recreation Plan produced in 1976 lists a variety of popular activities in the two-county area. The 10 most popular activities, in decreasing order of popularity, are park visits, picnicking, attending sports events, bicycling, walking for pleasure, sightseeing, swimming in pools, fishing, tennis, and camping.

The many facilities shown in Figure H-9 meet the demand for these activities. Primary among these facilities are the Lincoln National Forest in the Guadalupe Mountains, the Presidents' Park along the Pecos River in the City of Carlsbad, the Carlsbad Caverns National Park, and several small fishing lakes. New Mexico highway 137, which enters the Lincoln National Forest, has been proposed as a scenic route.

Both Lea and Eddy Counties offer a variety of opportunities for hunting birds and game.

Recreation within 10 miles of the site consists mainly of scattered bird hunting on Bureau of Land Management property, four-wheel-drive vehicle driving, or trail-biking. The 10-mile radius offers very few unique sightseeing attractions. Interviews with ranchers indicate that birdhunters frequent the area mainly for quail. Some target practice and rabbit hunting have been noted. However, none of these activities occurs on a large scale or appears to be coordinated among the local inhabitants.

1789 181

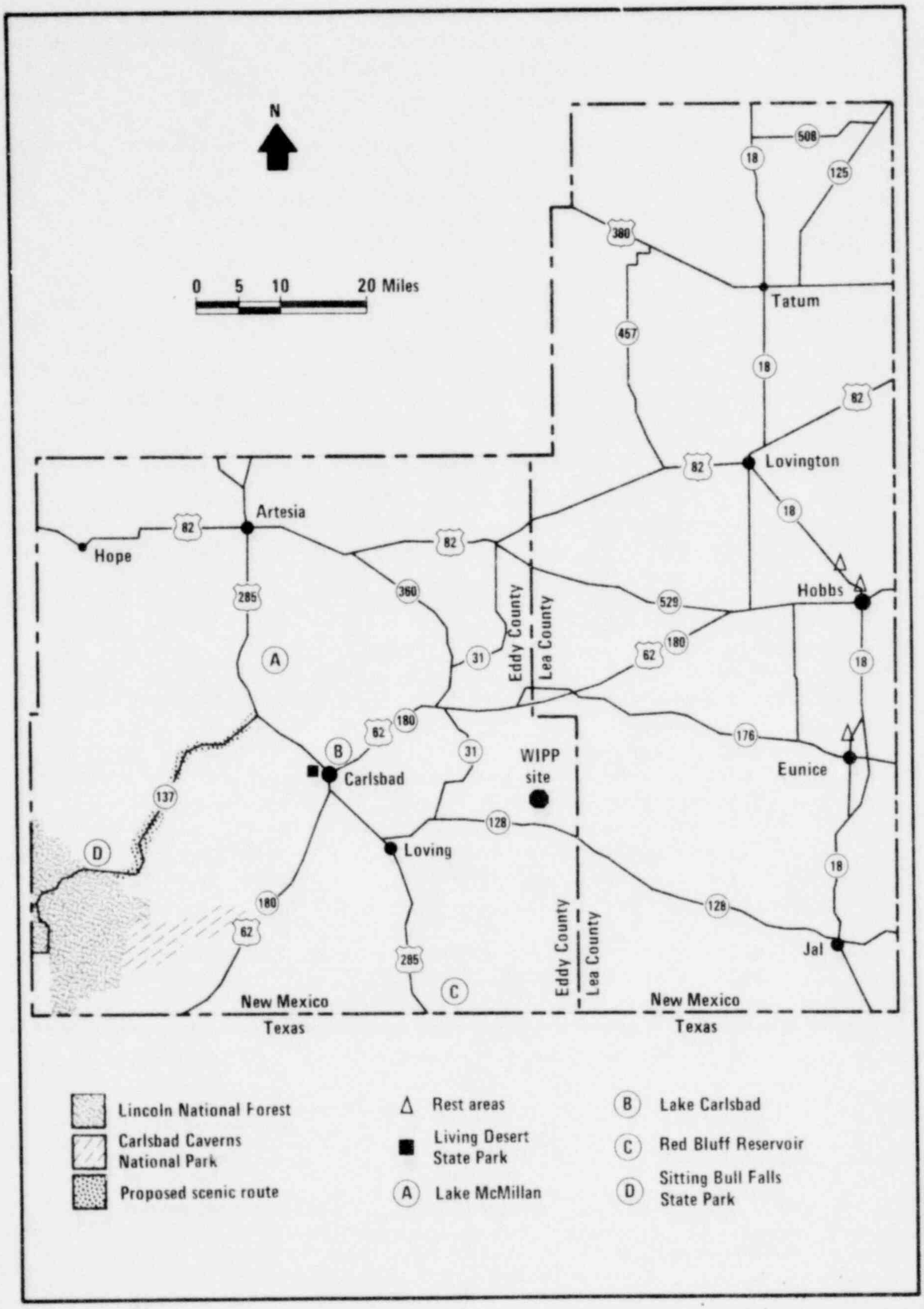


Figure H-9. Major recreational facilities in Lea and Eddy Counties.

1789 182

Carlsbad. The city of Carlsbad has numerous recreational facilities: more than 100 playing fields; 12 tennis courts; 2 golf courses; 1 dirt auto-race track; 1 bowling alley; 1 indoor and 1 outdoor movie theater; and 1 roller skating rink. There are 17 municipal parks and 3 others just outside the city. Other main attractions within the city limits include the Carlsbad Municipal Museum and the complex of Lake Carlsbad and Presidents' Park. At Lake Carlsbad there is an overnight campground as well as many picnic tables. In addition, there is a senior citizens' recreation center. One KOA campground is within the city limits and one is 20 miles south at the entrance to the Carlsbad Caverns National Park at White City.

Hobbs. The recreational facilities include 28 tennis courts, 2 golf courses, 4 swimming pools, and 2 bowling alleys. There are nine municipal parks, 16.5 acres of public picnic grounds, and a variety of playground equipment at the city parks. There are various ball parks throughout the city and an active Little League. In addition, the State of New Mexico is constructing a 120-acre State Park at the Industrial Air Park just north of the city's center. Completion is expected in late 1983 or early 1984.

Just north of Hobbs, at Humble City, there is a dirt track for auto racing. To the south there is a motor cross track on the Kornegay Ranch. Each year in the Hobbs area there is a national soaring meet for sailplanes.

Other local recreational amenities include three fully enclosed handball courts and many outdoor courts. There is a gun club and target range with trap shooting nearby and several rodeo arenas.

Solid-waste management

Carlsbad. Solid-waste collection and disposal service for Carlsbad is provided by the city. The landfill site, northeast of the city (Figure H-3), is operated in conjunction with Eddy County, which excavates the disposal trenches. The landfill site is new and has an estimated life of 10 years. The city uses 13 garbage trucks, 10 of which are over 10 years old, to cover one commercial and nine residential routes. The service area is defined by the city limits.

Hobbs. Solid-waste collection and disposal in Hobbs is provided by a private firm using nine vehicles to cover the four residential and two commercial routes in the city. The landfill site for Hobbs, located east of the city (Figure H-4) is operated in conjunction with Lea County. The 480-acre site has an estimated life of 30 years.

H.3.5 Local Government

Carlsbad. A mayor-council form of city government serves the City of Carlsbad. The mayor is elected for a 2-year term; the council members are elected for 4-year terms.

Revenues for Carlsbad were about $7.3 million in fiscal year 1976-77, an increase of 54% (in constant dollars) over 1969-70. On a per capita basis revenues grew 23% over the same 7-year period, reaching $276. Revenues for fiscal year 1977-78 were just more than $9.4 million (NMDFA, 1978d) and estimated to be $9.2 million in 1977 dollars (Table H-13).

About 41% of Carlsbad revenues came from intergovernmental transfers in 1977-78, with State gross receipts tax distributions accounting for most of the State transfers. More than 73% of Carlsbad's own-source revenues came from utilities in 1977-78. In fact, utility revenues constitute the largest single source of revenues for the city, accounting for more than 25% of the 1977-78 total. On the other hand, as in most New Mexico communities, property taxes contributed very little to total revenues, about 1% of general-fund revenues in 1977-78 and an additional 1% to general-obligation-bond (debt service) revenues for the year.

Table H-13. Carlsbad Municipal Revenues (Thousands of Dollars)[a]

Source of revenue	Actual 1976-1977[c]	Actual 1977-1978[d]	Constant dollars[b] 1976-1977	Constant dollars[b] 1977-1978
Own-source revenues				
Taxes	340	375	349	365
Property	88	96	90	94
Franchise	153	177	157	172
Occupation	99	102	102	99
Charges and miscellaneous	2866	2939	2948	2861
Licenses and permits	79	99	81	96
Charges for services	143	166	147	161
Fines and forfeits	143	133	147	129
Utilities	2385	2425	2453	2360
Debt service	177	117	120	114
Intergovernmental transfers				
State	1887	2438	1941	2372
Gasoline taxes	192	200	198	195
Auto license distribution	2	2	2	2
Cigarette taxes	110	115	113	112
Gross receipts taxes	1556	2018	1600	1964
Fire allotment	24	37	25	36
Grants	2	66	2	64
Federal				
Revenue sharing and grants	155	1399	160	1361
Other[e]	2086	2292	2146	2230
TOTAL	7335	9443	7544	9189

[a] Detail may not sum to total because of rounding.

[b] Constant 1977 dollars, actual revenues deflated by the Gross National Product Price Index.

[c] New Mexico Department of Finance and Administration, New Mexico Municipal Governments, Annual Report, 1977.

[d] New Mexico Department of Finance and Administration, Municipal Quarterly Cash Report (Carlsbad), 1978.

[e] Delinquent street tax, waste-disposal revenue, golf-fund revenue, etc.

Carlsbad municipal expenditures increased about 60% (in constant 1977 dollars) between fiscal years 1969-70 and 1976-77, reaching $6.4 million (NMDFA, 1978a). On a per capita basis, the increase was 27.5%.

In 1977-78, expenditures rose to $9.9 million (Table H-14). One-third of all spending in the most recent fiscal year was for personal services, 18% went to operating expenses, and 41% of the total spending was for capital improvements. Debt service accounted for 7% of the total spending.

The Constitution of the State of New Mexico limits the amount of general-obligation bonded debt that a municipality may incur without voter approval to 20 mills, or $20 per $1000 of assessed property value. On the basis of an assessed valuation at the start of the 1977-78 fiscal year of $40.5 million, the general-obligation bonded debt limit without voter approval for Carlsbad is $810,000. As of June 30, 1978, Carlsbad had an outstanding general-obligation bonded debt in the amount of $860,000 (NMDFA, 1978d).

There are no limits on the amount of bonded debt for bonds other than general-obligation bonds, although many debt issues require voter approval. The total debt outstanding for Carlsbad as of June 30, 1978, was $6.8 million (NMDFA, 1978d).

Hobbs. Hobbs has a commission-manager form of government, with a five-member commission. Commission members are elected at large to 4-year overlapping terms. A mayor is elected from the commission for a term of 2 years. A professional city manager is hired by the commission.

Hobbs municipal revenues rose from about $5.1 million (in constant 1977 dollars) in 1969-70 (NMDFA, 1970a) to $6.4 million in 1976-77 (NMDFA, 1978a). On a per capita basis, this represents a 5% increase, from $195 to $204. Revenues for 1977-78 rose to $9.9 million (1977 dollars) or $304.29 per capita (Table H-15). Intergovernmental transfers accounted for about 38% of 1977-78 revenues, mostly in the form of gross receipts tax distributions from the State. Utility operations provided a second major source of revenues--63% of own-source revenues and 15% of total revenues. Property taxes, including those allocated to debt service, accounted for less than 1% of revenues in 1977-78.

Expenditures for Hobbs were $5.8 million (1977 dollars) in 1976-77 (NMDFA, 1978a), up from $4.4 million in 1969-70 (NMDFA, 1970a). Expenditures for the 1977-78 fiscal year reached $6.6 million. On a per capita basis, expenditures rose from $170.94 in 1969-70 to $187 in 1976-77, an increase of 9%. In the most recent fiscal year, spending rose to nearly $6.6 million (1977 dollars), or $204 per capita (Table H-16).

Spending for personal services amounted to approximately 51% of the total spending for 1977-78. During the same period operating expenses were about 28% of the total, and capital outlays were about 12%. Debt service required an additional 5%.

Table H-14. Carlsbad Municipal Expenditures (Thousands of Dollars)[a]

Fund	Actual		Constant dollars[b]	
	1976-77[c]	1977-78[d]	1976-77	1977-78
General	2461	2768	2531	2694
Personal services	1676	2087	1724	2031
Operating expenses	724	668	744	650
Capital outlay	61	12	63	12
Fire protection	17	13	17	12
Personal services	0	0	0	0
Operating expenses	5	2	5	2
Capital outlay	12	10	12	10
Recreation	0	0	0	0
Personal services	0	0	0	0
Operating expenses	0	0	0	0
Capital outlay	0	0	0	0
Revenue sharing	140	229	144	223
Personal services	0	0	0	0
Operating expenses	0	0	0	0
Capital outlay	31	168	32	164
Lease purchase payment	109	61	113	59
Utility	1133	1156	1165	1612
Personal services	356	431	366	420
Operating expenses	611	701	628	682
Capital outlay	166	524	170	510
Other[e]	1999	4542	2056	4420
Personal services	723	766	743	745
Operating expenses	238	428	244	417
Capital outlay	1038	3348[f]	1068	3258
Debt service	654	692	672	674
General obligation bonds	88	92	91	89
Revenue bonds	565	601	581	585
TOTAL	6403	9900	6586	9635

[a]Detail may not sum to total because of rounding.

[b]Constant 1977 dollars; actual expenditures deflated by the Gross National Product Price Index.

[c]New Mexico Department of Finance and Administration, New Mexico Municipal Governments, Annual Report, 1977.

[d]New Mexico Department of Finance and Administration, Municipal Quarterly Cash Report (Carlsbad), 1978.

[e]Park improvement, golf course, air-park expenditures etc.

[f]Includes $20,887 construction expense from Additions, Extensions, and Improvements Fund (water and sewer); $555,524 construction expense from 1975 Water and Sewer Bond Fund; and $281,221 construction expense from 1975 General Obligation Bond Construction Fund.

Table H-15. Hobbs Municipal Revenues (Thousands of Dollars)[a]

Source of revenue	Actual 1976-1977[c]	Actual 1977-1978[d]	Constant dollars[b] 1976-1977	Constant dollars[b] 1977-1978
Own-source revenues				
Taxes	301	328	309	319
Property	113	101	116	99
Franchise	174	209	179	204
Occupation	14	17	14	17
Charges and miscellaneous	1537	2095	1581	2039
Licenses and permits	39	42	40	41
Charges for services	165	194	170	189
Fines and forfeits	154	159	159	154
Utilities	1087	1529	1118	1488
Debt service	92	170	94	166
Intergovernmental transfers				
State	3244	3920	3337	3816
Gasoline taxes	211	211	217	206
Auto license distribution	72	76	74	74
Cigarette taxes	162	173	166	169
Gross receipts taxes	2705	3332	2782	3243
Fire allotment	19	26	20	25
Grants	76	102	78	99
Federal				
Revenue sharing and grants	209	498	215	485
Other[e]	932	3323	959	3234
TOTAL	6224	10,165	6401	9893

[a]Detail may not sum to total because of rounding.

[b]Constant 1977 dollars; actual revenues deflated by the Gross National Product Price Index.

[c]New Mexico Department of Finance and Administration, New Mexico Municipal Governments, Annual Report, 1977.

[d]City of Hobbs, Municipal Report: Revenues, June 30, 1978; and New Mexico Department of Finance and Administration, Municipal Quarterly Cash Report (Hobbs), 1978.

[e]Delinquent street tax, waste-disposal revenue, golf-fund revenue, etc.

With an assessed valuation of $53 million, Hobbs has a debt limit of $1.06 million on general-obligation bonds* that may be issued without voter approval.

Current (June 30, 1978) general-obligation bonded debt** for the city is $2.5 million (NMDFA, 1978d). Total outstanding bonded debt as of June 30, 1978, was $4.65 million (NMDFA, 1978d).

Eddy County. Eddy County revenues for fiscal 1976-77 were $3.7 million (1977 dollars), up from $2.1 million (1977 dollars) in 1969-70 (NMDFA, 1970b)

---

*Bonding limits based on voter approval.

**General-obligation bonded debt does not need voter approval.

Table H-16. Hobbs Municipal Expenditures (Thousands of Dollars)[a]

Fund	Actual 1976-77[c]	Actual 1977-78[d]	Constant dollars[b] 1976-77	Constant dollars[b] 1977-78
General	3532[e]	3750	3633	3649
Personal services	2480	2814	2551	2738
Operating expenses	925	857	951	834
Capital outlay	127	39	131	38
Fire protection	4	88	4	86
Personal services	0	0	0	0
Operating expenses	(f)	1	(f)	1
Capital outlay	4	87	4	85
Recreation	34	30	35	30
Personal services	34	30	35	29
Operating expenses	0	1	0	1
Capital outlay	0	0	0	0
Revenue sharing	225	172	231	168
Personal services	0	NA	0	NA
Operating expenses	10	NA	11	NA
Capital outlay	214	NA	220	NA
Utility	832	1255	856	1221
Personal services	432	502	444	489
Operating expenses	360	375	370	365
Capital outlay	41	377	42	367
Other[g]	782	1109	804	1080
Personal services	123	126	127	122
Operating expenses	644	648	662	630
Capital outlay	15	321	15	312
Debt service	278	340	286	331
General obligation bonds	136	226	139	220
Revenue bonds	142	114	147	111
TOTAL	5688	6745	5850	6564

[a]Detail may not sum to total because of rounding.

[b]Constant 1977 dollars; actual expenditures deflated by the Gross National Product Price Index.

[c]New Mexico Department of Finance and Administration, New Mexico Municipal Governments, Annual Report, 1977.

[d]City of Hobbs, Municipal Report-Disbursements, June 30, 1978; New Mexico Department of Finance and Administration, Quarterly Cash Report (Hobbs), 1978.

[e]General fund total includes $39,051 not allocated to specific category because of incomplete information.

[f]Less than $500.

[g]Park improvement, golf course, air-park expenditures, etc.

Table H-17. Eddy County Revenues (Thousands of Dollars)[a]

Source of revenue	1976-77 Actual[b]	1976-77 1977 = 100[c]
Own-source revenues		
Taxes	1967	2020
Property	824	846
Oil and gas	1143	1174
Charges and miscellaneous	228	234
Licenses and permits	8	8
Fees	56	57
Interest on investment	92	94
Miscellaneous	73	75
Intergovernmental transfers		
State	550	565
Gasoline	29	30
Cigarette taxes	5	5
Motor vehicle	377	387
Grants	9	9
Miscellaneous	130	134
Federal	866	889
Revenue sharing	758	778
Miscellaneous	107	110
Other	24	25
TOTAL	3635	3733

[a]Data from Adcock and Associates (1978). Detail may not add to total because of rounding.

[b]New Mexico Department of Finance and Administration, New Mexico County Governments, Annual Report, 1977.

[c]Actual revenues deflated by the Gross National Product Price Index.

(Table H-17). Sixty percent of the 1976-77 revenues were from county sources, with taxes on oil-and-gas production and equipment contributing 31% of total revenues. Property taxes accounted for about 23% of the total for the year.

Eddy County expenditures for 1976-77 totaled $2.9 million (1977 dollars), up from $1.7 million (1977 dollars) (NMDFA, 1970b) in 1969-70 (Table H-18). General government functions and public works accounted for most of the spending in 1976-77, with the former requiring more than 46% and the latter 35% of total county expenditures.

The assessed valuation of property in the county as of June 30, 1977, was $406 million (NMDFA, 1978b). With the New Mexico limit on county general-obligation bonded debt of 4% of assessed valuation, Eddy County had a bonding limit of $16.2 million. As of mid-1977, the county had no general-obligation bonds outstanding (NMDFA, 1978b).

Table H-18. Eddy County Expenditures (Thousands of Dollars)[a]

Service function	1976-77 Actual[b]	1976-77 1977 = 100[c]
General government	1330	1366
Public safety	439	451
Public works	1010	1037
Health and welfare	56	57
Recreation and culture	29	30
TOTAL	2865	2942

[a]Data from Adcock and Associates (1978). Detail may not add to total because of rounding.

[b]New Mexico Department of Finance and Administration, New Mexico County Governments, Annual Report 1977.

[c]Actual expenditures deflated by the Gross National Product Price Index.

The effective county property tax rate for 1976-77 was $2.03 per $1000 of assessed valuation, well below the $7.38 per $1000 rate average for all New Mexico counties (NMDFA, 1978b).

Lea County. Lea County revenues in fiscal year 1976-77 were $4.2 million (1977 dollars), virtually unchanged from 1969-70, when they were just under $4 million (1977 dollars) (NMDFA, 1970b). At $1.3 million, oil-and-gas production and equipment taxes provided 32% of county revenues in 1976-77 (Table H-19). Property taxes contributed an additional 15%. Overall, county sources accounted for 55% of total revenues.

Expenditures for 1976-77 were $3.2 million (1977 dollars), up from $1.7 million (1977 dollars) in 1969-70 (NMDFA, 1970b) (Table H-20). Spending on public works accounted for 47% of county expenditures in 1976-77, and general government functions required 39%.

The total assessed valuation of property in Lea County as of June 30, 1977, was $567 million, up from $322 million in mid-1970 (NMDFA, 1978b). The general-obligation-bonded debt limit (4% of assessed valuation) was $22.7 million in mid-1977, at which time Lea County had no outstanding general-obligation bonds (NMDFA, 1978b). The effective property-tax rate for 1976-77 was $1.08 per $1000 of assessed valuation, considerably below the average rate for New Mexico counties of $7.38 per $1000.

School-district finances

Carlsbad. Carlsbad School District C, which encompasses most of southern Eddy County, had total revenues of $8.8 million in 1976-77 (Table H-21). Some 84% of total resources were allocated to the operational fund. State sources provided 70% of operational fund income, and local sources provided 24%.

1789 190

Table H-19. Lea County Revenues (Thousands of Dollars)[a]

Revenue item	1976-77 Actual[b]	1977 = 100[c]
Own-source reveneus		
Taxes	1922	1974
Property	616	633
Oil and gas	1305	1340
Charges and miscellaneous	303	311
Licenses and permits	19	20
Fees	64	66
Interest on investment	161	165
Miscellaneous	58	60
Intergovernmental transfers		
State	460	472
Gasoline taxes	11	11
Cigarette taxes	4	4
Motor vehicle	414	425
Grants	2	2
Miscellaneous	28	29
Federal	1290	1325
Revenue sharing	859	882
Miscellaneous	431	443
Other	76	78
TOTAL	4051	4160

[a]Data from Adcock and Associates (1978). Detail may not add to total because of rounding.

[b]New Mexico Department of Finance and Administration, New Mexico County Governments, Annual Report, 1977.

[c]Actual revenues deflated by the Gross National Product Price Index.

District expenditures totaled $8.8 million in 1976-77, about $17,000 less than income (Table H-22). Operational expenditures accounted for 87% of total spending, with direct-instruction costs contributing the largest single share (46%). On the basis of 6537 students (NMDFA, 1978c) operational costs per pupil were $1170, or $50 more than the statewide average of $1120 for 1976-77 (NMDFA, 1978c).

Total assessed valuation of property in the district in 1976 was $184 million, up 22% from the previous year (NMDFA, 1978c). The total school-district tax rate of $10.925 per $1000 of assessed valuation was in effect during both 1976-77 and 1977-78 (NMDFA, 1978c). As of June 30, 1977, the district had no outstanding or unsold authorized bonds (NMDFA, 1978c).

Hobbs. Hobbs School District 16, which includes much of central Lea County, had a 1976-77 income of $9.5 million (Table H-21). About 85% of the total district income went to the operational fund. State sources provided more than 81% of operational-fund revenues, while local sources provided 18%.

Table H-20. Lea County Expenditures (Thousands of Dollars)[a]

Service function	1976-77 Actual[b]	1976-77 1977 = 100[c]
General government	1235	1268
Public safety	378	388
Public works	1466	1506
Health and welfare	35	36
Recreation and culture	23	24
TOTAL	3140	3224

[a]Data from Adcock and Associates (1978). Detail may not add to total because of rounding.

[b]New Mexico Department of Finance and Administration, New Mexico County Governments, Annual Report, 1977.

[c]Actual expenditures deflated by the Gross National Product Price Index.

Table H-21. School District Income, 1976-77 (Thousands of Dollars)[a]

Source of income	Carlsbad	Hobbs
Operational fund	7414	8105
Local sources	1764	1467
District school tax levy	1653	1348
Other	111	118
State sources	5209	6581
State equalization guarantee	4745	6152
Transportation	302	259
Other	161	170
Federal sources	441	42
Public Law 874	374	4
Regular vocational programs	29	18
Other	38	20
Income transfers	0	14
Debt service fund	46	647
Interest	(b)	128
Principal	46	519
Building funds	415	389
General	0	86
State/local capital improvements, S.B.9	412	0
Federal/local	3	303
Federal projects fund	723	352
O.E.O. funds	208	19
Miscellaneous	0	2
TOTAL	8806	9514

[a]Data from New Mexico Department of Finance and Administration, Statistics, Public School Finance, 1977. Detail may not add to total because of rounding.

[b]Less than $500.

Table H-22. School District Expenditures, 1976-77 (Thousands of Dollars)[a]

Expenditure	Carlsbad	Hobbs
Administration	232	249
Direct instruction	4080	4,816
Instructional support	977	935
Health services	48	27
Pupil transportation services	325	220
Operation of plant	643	671
Maintenance of plant	285	232
Fixed charges	879	923
Food services	0	0
Noninstructional student support	38	52
Community services	37	14
Capital outlay	78	192
Special projects (operational fund)	23	12
Total operational expenditures	7647	8,344
Building fund	0	1,440
Debt service	0	605
Special projects (other funds)	1142	473
Grand total	8789	10,862

[a]Data from New Mexico Department of Finance and Administration, Statistics, Public School Finance, 1977. Detail may not add to total because of rounding.

A total of $10.9 million was spent by the district in 1976-77 (Table H-22). Of this total, $8.3 million, or 77%, were operational expenditures, chiefly for direct instruction. With 7164 students, per-pupil operational expenditures were $1165, somewhat more than the statewide average of $1120 for 1976-77 (NMDFA, 1978c).

Property in the district had a total assessed value of $149 million in 1976, an increase of 7.4% over the previous year (NMDFA, 1978c). The district tax rate for 1977-78 was $11.780 per $1000 of assessed valuation, down from $12.564 for the previous year (NMDFA, 1978c). As of June 30, 1977, the district had $1.7 million in outstanding bonded debt, down from nearly $2.2 million a year earlier (NMDFA, 1978c).

H.4 METEOROLOGY

H.4.1 Regional Climate

The information used to evaluate the climate of the region surrounding the WIPP site consisted of Climatological Data summaries for recording stations in New Mexico and Local Climatological Data summaries for Roswell, New Mexico, and wind summaries for Lubbock, Midland-Odessa, and El Paso, Texas. The climatological data were obtained from the National Climatic Center of the National Oceanic and Atmospheric Administration. Precipitation and temperature summaries from stations at Carlsbad, the Duval potash mine, Jal, Pearl, and Ochoa were also included because of their proximity to the WIPP reference site. The Local Climatological Data summaries provided extreme and normal values of the meteorological parameters (for the period of record at Roswell) that were used to characterize the regional climate.

General climate

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are most commonly from the southeast and moderate. During the winter, the weather is dominated by a high-pressure system often situated in the central portion of the Western United States and a low-pressure system commonly located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona. The regional climate is significantly affected by these large-scale pressure systems and their seasonal variations (EDS, 1968; Baldwin, 1973; NOAA, 1974).

The region, meteorologically referred to in New Mexico as the Southeastern Plains, is an area of over 30,000 square miles that marks the western extremity of the Great Plains, which end at the Sacramento and Guadalupe Mountains 40 to 60 miles west of the site. It is bounded on the east and south by an erosional escarpment in central Texas. Elevations range from less than 3000 feet in the south and east to more than 4000 feet in the north, with the downslope to the east and south averaging 600 feet per 100 miles. The terrain is characterized by gently rolling hills of moderate relief, dissected by many small stream valleys.

Moderate temperatures are typical throughout the year, although seasonal changes are distinct. Mean annual temperatures in southeastern New Mexico are near 60°F (Eagleman, 1976). Temperatures in December through February show a large diurnal variation, averaging 36°F at Roswell (the nearest National Weather Service station with appropriate data and an adequate period of record). Although on approximately 75% of winter days morning temperatures are below freezing, afternoon maximum temperatures average well up in the fifties, and afternoon winter temperatures of 70°F or more are not uncommon. Nighttime lows average near 23°F, occasionally dipping as low as 14°F. There are perhaps only 2 or 3 winter days when the temperature fails to rise above freezing. The lowest recorded temperature at Roswell was -29°F, in February 1905. During June through August, the temperature is above 90°F approximately 75% of the time, with readings of 100°F or higher occurring on a number of afternoons. However, even the hottest month, July, with average daily temperatures in the upper seventies, will have morning lows below 68°F. The highest recorded temperature at Roswell was 110°F, in July 1958 (NOAA, 1974).

Precipitation in the region is light and unevenly distributed through the year, averaging 11 to 13 inches (Table H-23) (NOAA, 1972-1976). Winter is the season of least precipitation, averaging less than 0.6 inch of rainfall per month. Snow averages about 5 inches per year (Baldwin, 1973) and seldom remains on the ground for more than 1 day at a time because of the typically above-freezing temperatures in the afternoon. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region. The minimum annual precipitation measured during the last 40 years at Roswell was 4.35 inches, in 1956; the maximum recorded was 32.92 inches, in 1941. The maximum monthly precipitation was 9.56 inches, in August 1916; the maximum 24-hour rainfall was 5.65 inches, in November 1901 (NOAA, 1974).

Prevailing winds are from the south. The normal mean wind speed at Roswell is 9.6 mph (see Table H-24) (NOAA, 1974).

Heavy precipitation

The maximum point rainfall (Jennings, 1963) at Roswell is shown in Table H-25. The maximum 24-hour snowfall in Roswell was 15.3 inches, in December 1960. The greatest snow accumulation over a 1 month period was 23.3 inches, in February 1905 (NOAA, 1974).

Thunderstorms and hail

The region experiences about 33 thunderstorm days annually, with about 80% occurring from May to September (NOAA, 1978). A thunderstorm day is recorded if thunder is heard; the record is not related to observations of rain or lightning and does not indicate the severity of the storms experienced in the region.

Hail is most likely in April through June and is not likely to develop more than three times a year. During a 39-year period at Roswell, hail was observed 97 times (about 2.5 times per year), occurring nearly two-thirds of the time between April and June (U.S. Army, 1958). For the 1-degree square surrounding the WIPP site (32^{o} to 33^{o} N by 103^{o} to 104^{o} W) hailstones 0.75 inch or larger were reported eight times from 1955 to 1967 (slightly less than once per year) and windstorms with speeds of 50 knots or higher occurred 10 times--approximately one per year (Pautz, 1969).

Tornadoes

For the period 1916-1958, 75 tornadoes were reported in New Mexico on 58 tornado days (Wolford, 1960). Data for 1956 through 1974 indicate a statewide total of 191 tornadoes on 141 tornado days (NOAA, 1975), or an average of 10 tornadoes per year on 7 tornado days. The greatest number of tornadoes in 1 year was 18; the least was 2. Most tornadoes occur in May and June (Pautz, 1969). From 1955 through 1967, 15 tornadoes were reported in the 1-degree square containing the site (Markee, et al., 1974).

Thom (1963) has developed a procedure for estimating the probability of a tornado's striking a given point. The method uses a mean tornado path length and width and a site-specific frequency. Applying Thom's method to the WIPP site yields a point probability of 0.00081 on an annual basis, or a recurrence

Table H-23. Precipitation Rates for Southeastern New Mexico[a]

Station and distance from WIPP (mi)	Elevation above MSL (ft)	Precipitation (inches)																	
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.	1972	1973	1974	1975	1976
Carlsbad, 25	3,120	0.37	0.78	0.24	0.07	1.07	1.31	2.46	1.54	4.51	1.94	0.38	0.28	14.96	18.74	11.47	23.11	10.22	11.26
		(0.45)	(0.30)	(0.5[illegible])	(0.48)	(1.51)	(1.44)	(1.62)	(1.76)	(1.61)	(1.47)	(0.35)	(0.41)	(11.91)					
Duval potash mine[b], 12	3,520	0.53	0.67	0.37	0.33	1.24	0.50	3.11	1.79	4.29	1.92	0.46	0.24	15.46	17.31	11.91	19.49	13.92	14.69
Jal, 31	3,149	0.43	0.53	0.36	0.51	1.23	1.15	2.40	1.72	2.88	1.33	0.28	0.14	12.96	8.16	9.83	20.57	13.68	12.56
		(0.51)	(0.30)	(0.48)	(0.65)	(1.52)	(1.31)	(1.63)	(1.60)	(1.48)	(1.39)	(0.74)	(0.42)	(11.67)					
Pearl, 25	3,79[illegible]	0.35	0.69	0.32	0.32	2.01	2.19	3.74	2.08	3.81	1.50	0.39	0.20	17.54	17.92	11.62	22.10	24.68	11.87
		(0.40)	(0.34)	(0.52)	(0.64)	(1.79)	(1.68)	(2.11)	(1.95)	(1.80)	(1.31)	(0.33)	(0.43)	(13.32)					
Ochoa, 22	3,458	0.53	0.55	0.31	0.24	1.15	0.89	2.25	2.18	3.16	0.96	0.25	0.15	12.74	8.86	9.43	19.14	11.65	14.64
		(0.49)	(0.30)	(0.51)	(0.63)	(1.38)	(1.35)	(1.48)	(1.19)	(1.53)	(1.24)	(0.40)	(0.32)	(11.17)					

[a]Monthly and annual average precipitation for the years 1971-1976, and normal precipitation (shown in parentheses; based on period 1941-1970) for stations in southeastern New Mexico.

[b]Normal values not available.

Table H-24. Normal Mean Wind Speeds for Roswell, New Mexico 1941-1970

Month	Mean wind speed (mph)	Month	Mean wind speed (mph)
January	8.4	July	9.4
February	9.8	August	8.4
March	11.5	September	8.3
April	11.8	October	8.2
May	11.4	November	8.5
June	10.8	December	8.4

Table H-25. Maximum Cumulative Rainfall at Roswell, New Mexico, for Various Time Periods[a]

	Maximum cumulative rainfall (inches)				
	5 min	10 min	15 min	30 min	60 min
Roswell	0.55	1.01	1.34	1.71	2.22
Date	6/6/30	6/6/30	5/12/50	5/12/50	9/14/23
	2 hr	3 hr	6 hr	12 hr	24 hr
Roswell	2.88	3.38	4.82	5.19	5.65
Date	9/16/23	8/8/16	8/7/16	8/7/16	10/31/01

[a]Period of record 1905-1961, except for the 24-hour rainfall, for which the period of record is 1895-1961.

interval of 1235 years. An analysis by Fujita (1978) yields a point tornado-recurrence interval of 2832 years in the Pecos River Valley.

According to Fujita (1978), the design-basis tornado with a million-year return period has a maximum wind speed of 183 mph, a rotational speed of 146 mph, a maximum translational speed of 37 mph, a minimum translational speed of 5 mph, a maximum-rotational-speed radius of 150 feet, a pressure drop of 0.69 psi, and a pressure-drop rate of 0.08 psi/sec.

Freezing precipitation

The region of the site can expect about 1 day of freezing rain or drizzle per year (U.S. Army, 1958). An ice accumulation of more than 0.25 inch has not been observed. Any ice accumulation that does occur is thin because of the scarcity of precipitation during the winter months and because daytime temperatures rise well above freezing.

Strong winds

The maximum 1-minute wind speeds recorded at Roswell in calendar year 1976 are shown in Table H-26 (NOAA, 1974). The fastest 1-minute wind ever recorded at Roswell was 75 mph from the west in April 1953 (NOAA, 1974). The 100-year-recurrence 30-foot-level wind speed in southeastern New Mexico is 82 mph. The mean recurrence interval for high wind speeds at 30 feet above the ground in southeastern New Mexico is shown in Table H-27 (ANSI, 1972; Thom, 1968).

Table H-26. Maximum Wind Speeds at Roswell, New Mexico

Month	Mean wind speed (mph)	Month	Mean wind speed (mph)
January	67	July	66
February	70	August	72
March	66	September	54
April	75	October	66
May	72	November	65
June	65	December	72

Table H-27. Recurrence Intervals for High Winds in Southeastern New Mexico[a]

Recurrence (years)	Speed (mph)[b]
2	58
10	68
25	72
50	80
100	82

[a]Data from Thom (1968).
[b]At 30 feet above the ground.

Inversions and high air-pollution potential

Hosler (1961) and Holzworth (1972) have analyzed records from several National Weather Service stations with the objective of characterizing the atmospheric dispersion potential. Seasonal frequencies of inversions based below 500 feet for the region of the site are shown in Table H-28. A large number of these inversions are diurnal (radiation-induced) as a consequence of the elevation and the continental climate.

Table H-28. Seasonal Frequencies of Inversions[a]

Season	Inversion frequency (% of total hours)	Maximum % - frequency of 24-hr periods with at least 1 hr of inversion based below 500 ft
Spring	32	65
Summer	25	68
Fall	36	72
Winter	47	80

[a]Data from Hosler (1961).

Holzworth (1972) gives estimates of the average depth of vertical mixing, which indicates the thickness of the atmospheric layer available for the mixing and dispersion of effluents. The seasonal afternoon mixing depths for the region (Table H-29) range from 1320 meters in the winter to 3050 meters in the summer.

Table H-29. Seasonal Values of Daily Mixing Depths

Season	Daily afternoon mixing depth (meters)
Spring	2800
Summer	3050
Fall	2000
Winter	1320
Annual	2400

H.4.2 Site Climate

On-site meteorological data were used to characterize the local meteorology of the site. The meteorology station was located in Section 11, R 31 E, T 22 S, from January to June 1976 and in Section 15 from June 1976 to May 1977; it has been in Section 21 since May 1977. These locations are representative of local terrain conditions. Until May 1977, a 10-meter tower was used primarily to collect wind, temperature, and precipitation (surface) data. Subsequently, the station was upgraded to a 30-meter tower designed to comply with most of the criteria of NRC Regulatory Guide 1.23. The primary measurements obtained include wind, temperature, and the temperature difference (ΔT) at the 3-, 10-, and 30-meter levels. Additional climatological data (e.g., dew point, precipitation, solar and terrestrial radiation, etc.) are also collected. In September 1978 the 30-meter-level instruments were raised to 40 meters to improve the accuracy of ΔT measurements in compliance with Regulatory Guide 1.23. All data are recorded by a data logger and backup strip-chart recorders. A detailed description of the data-collection program is given in Appendix J.

Available summary on-site meteorological data presented in this document include temperature and precipitation data for the period May 1976 through April 1977 as well as wind and stability data for June 1977 through May 1978. The representativeness of the on-site data-collection period has been established by comparison of concurrent data from Roswell with long-term data.

Normal and extreme values of meteorological parameters

Wind summaries. Wind-direction and wind-speed measurements were obtained from the 1-year site data collected at the 30-foot level. Annual wind roses for the site and for Roswell, New Mexico, for the period June 1, 1977, to May 31, 1978, are shown in Figure H-10. Long-term (1973-1976) annual wind roses for Roswell and Midland-Odessa, Texas (the next nearest National Weather Station with suitable data) are shown in this figure. Differences between station summaries are attributed to regional terrain effects and variations in the periods of record used.

The 1-year site wind record (Table H-30) shows the southeast, south-southeast, and east-southeast winds occurring most frequently (18.2, 12.7, and 9.0% of the time, respectively). All other directions are about equally represented at 2.7 to 8.1% of the time. Monthly wind-rose data are presented in Tables 1 through 12 in Annex 1.

Temperatures. Monthly average, average daily maximum, and average daily minimum temperatures for May 1, 1976, through April 20, 1977, are presented in Table H-31, which also shows corresponding data and normal values for Roswell (NOAA, 1977). Average temperatures show large seasonal differences, ranging from 38.7° F in the winter to 78.4° F in the summer.

The highest and lowest temperatures recorded at Roswell between January 1, 1973, and December 31, 1976, were 104 and 5° F (NOAA, 1972-1976), respectively; the highest and lowest temperatures recorded at the site between May 1, 1976, and April 30, 1977, were 102.6 and 9.0°F, respectively. At the site, the average winter minimum temperatures are consistently higher than those in Roswell, and the summer maximum temperatures are lower. These differences can be mainly attributed to the locations of the temperature sensors (30 feet above the surface at the site and 5 feet at Roswell).

Precipitation and atmospheric moisture. Precipitation data for the site are available for May 1, 1976, through April 30, 1977. Table H-32 shows the monthly totals for the site, the corresponding totals for Roswell, and the average monthly normals for Roswell (NOAA, 1977). Precipitation at the site ranged from 0.03 inch in February 1977 to 4.40 inches in September 1976; at Roswell it ranged from 0.00 inch in December 1976 to 2.44 inches in July (normal ranges for Roswell are 0.29 and 1.48 inches). The differences between Roswell and data and between Roswell 1-year data and normals are typical of precipitation spatial variations.

Dew-point temperature data for Roswell are available for January 1, 1973, to December 31, 1976. The dew-point temperature is the temperature to which the air must be cooled to become saturated with water vapor (pressure and water-vapor content remaining constant). It is lower than the free-air temperature except when the free air is saturated; then the two temperatures are the same. Thus the difference between the free-air and the dew-point temperatures (the dew-point spread) is a measure of the atmospheric moisture content.

1789 200

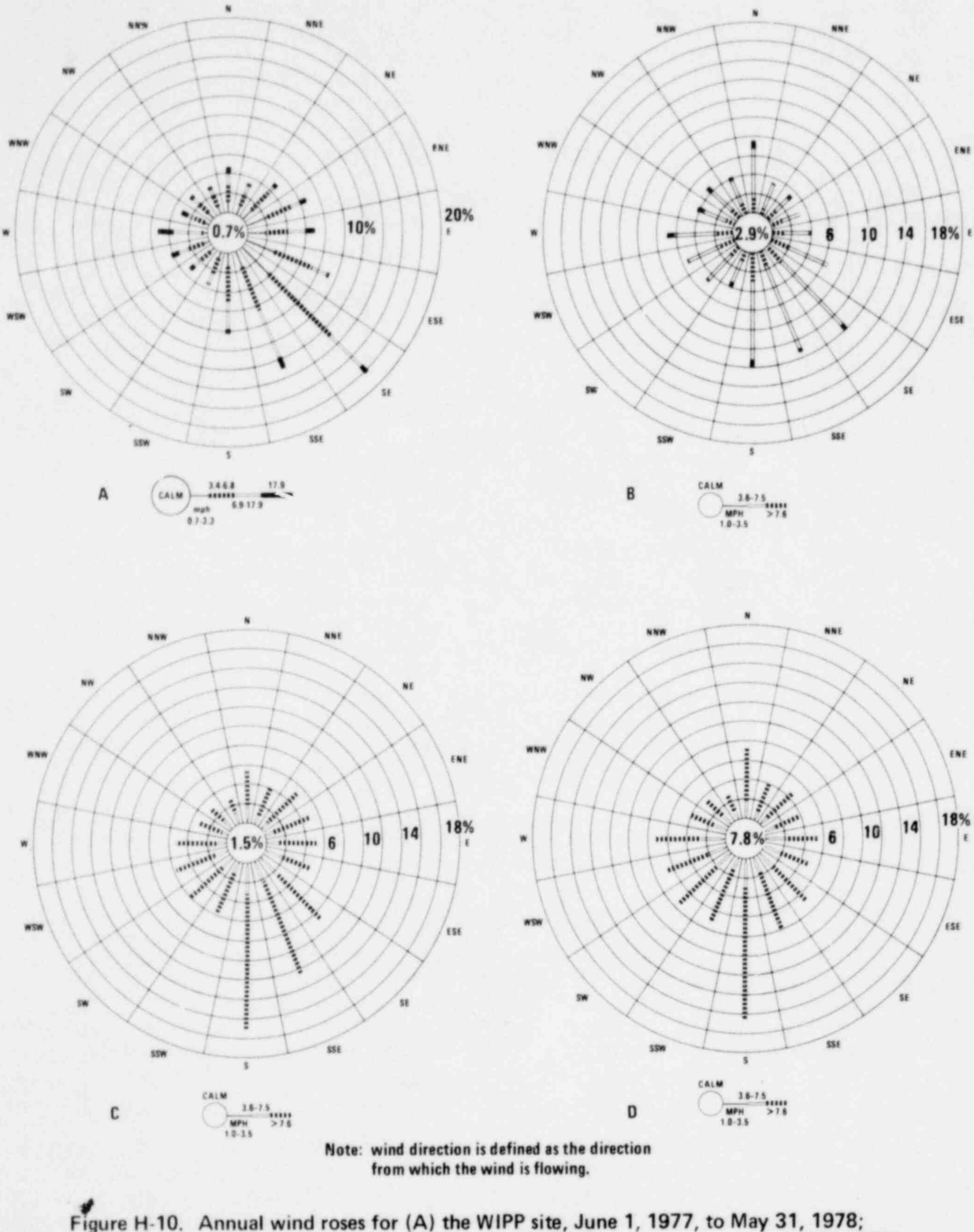


Figure H-10. Annual wind roses for (A) the WIPP site, June 1, 1977, to May 31, 1978; (B) Roswell, June 1, 1977, to May 31, 1978; (C) annual average (1973-1976) for Midland-Odessa, Texas; and (D) annual average for Roswell (1973-1976).

Table H-30. Distributions of Wind Directions at the Site, June 1977-May 1978

Month	Distribution (%)																
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	Calm
January	4.7	5.8	7.3	10.9	12.4	14.8	14.6	7.2	4.0	1.2	2.6	1.7	1.9	2.2	2.8	4.7	1.2
February	3.7	5.9	7.5	9.5	11.5	13.0	8.0	6.4	2.4	3.8	4.2	6.6	4.4	4.4	2.7	4.9	1.1
March	3.4	4.0	6.6	9.4	7.9	17.2	7.9	6.8	3.6	4.1	5.2	7.4	4.8	3.8	3.7	3.6	0.5
April	3.2	5.4	4.7	4.3	6.3	13.8	6.3	7.2	6.9	5.0	8.7	8.9	2.8	4.0	2.9	9.3	0.5
May	2.4	3.1	6.4	3.7	8.2	17.3	10.4	7.6	4.4	5.7	6.4	7.2	2.9	3.6	4.4	4.7	1.5
June	1.9	4.7	6.0	8.5	8.2	32.3	14.6	6.6	3.8	1.3	1.3	2.8	0.6	3.2	2.8	1.3	0.0
July	1.1	1.6	3.5	4.0	13.1	40.7	21.2	6.8	0.9	0.5	1.4	0.6	0.2	1.3	1.7	1.4	0.0
August	1.4	3.6	4.0	6.9	9.2	26.8	24.5	10.0	1.9	2.3	1.7	1.9	0.6	1.3	1.3	2.6	0.0
September	5.0	7.0	9.3	5.8	4.8	12.4	15.3	12.0	1.4	1.5	2.7	7.6	2.6	2.6	1.9	8.1	0.0
October	2.6	5.3	6.6	10.5	7.6	16.2	15.3	12.1	3.5	2.1	3.5	4.8	2.9	1.1	2.6	3.4	0.0
November	5.1	7.5	10.1	7.9	11.2	10.3	7.2	8.7	4.2	4.9	3.1	4.0	3.3	2.7	1.8	6.9	1.2
December	3.5	5.3	8.4	4.3	7.7	10.4	8.7	5.9	4.5	5.3	6.9	9.4	4.5	5.0	4.6	3.9	1.5

Table H-31. Temperatures at Roswell and the WIPP Reference Site, 1976-1977

Month	Temperature (°F)								
	Monthly average			Average daily maximum			Average daily minimum		
	Roswell		Site	Roswell		Site	Roswell		Site
	Normal	5/76-4/77	5/76-4/77	Normal	5/76-4/77	5/76-4/77	Normal	5/76-4/77	5/76-4/77
January	38.1	38.6	38.7	55.4	52.5	51.6	20.8	24.7	27.1
February	42.9	48.2	48.6	60.9	63.0	61.9	24.8	33.4	36.9
March	49.3	52.1	54.3	67.7	68.2	67.6	30.9	35.9	40.6
April	59.7	62.3	63.3	78.2	76.7	77.2	41.2	47.9	48.6
May	68.5	68.7	67.5	86.4	82.4	79.9	50.5	54.9	53.8
June	77.0	79.3	78.4	94.2	93.4	91.2	59.8	65.2	65.1
July	79.2	78.6	75.4	94.7	90.1	87.8	63.7	67.1	65.1
August	77.9	80.3	78.6	93.4	93.1	91.2	62.3	67.4	66.7
September	70.4	71.2	70.3	86.5	82.9	82.0	54.3	59.4	60.8
October	59.6	56.2	56.1	77.0	70.3	69.6	42.2	42.1	44.2
November	46.9	42.7	46.4	64.8	56.5	58.1	29.0	28.9	34.5
December	39.3	39.3	42.1	56.8	56.1	57.0	21.8	22.5	28.9
Year	59.1	59.8	60.0	76.3	73.8	72.9	41.8	45.8	47.7

The annual average and dew-point temperatures at Roswell are shown in Table H-33. At Roswell, 80% of the time the dew-point spread is greater than 7.9°F.

Table H-32. Roswell and WIPP Precipitation

Month	Precipitation (inches)		
	Roswell		WIPP
	Normal	1977	1977
January	0.40	0.07	0.15
February	0.37	0.36	0.03
March	0.47	0.27	0.19
April	0.49	0.76	0.23
		1976	1976
May	1.00	0.82	1.38
June	1.24	1.55	0.07
July	1.71	2.44	1.16
August	1.48	1.98	0.81
September	1.47	2.29	4.40
October	1.22	0.69	0.91
November	0.29	0.41	0.08
December	0.47	0.00	0.09
Annual	10.61	11.64	9.50

Table H-33. Dew-Point Spread at Roswell (1973-1976)

	Temperature (°F)	Dew-point temperature (°F)
Average	59.4	36.1
Average maximum	73.0	42.4
Average minimum	46.9	30.0

Atmospheric stability

Estimates of the average dispersion of effluents by atmospheric fluctuations over extended periods are generally based on the joint probability of wind-speed, wind-direction, and atmospheric-stability frequencies. These frequencies have been estimated (Table H-34) from data collected at the site by the temperature-difference method outlined in NRC Regulatory Guide 1.23.

The joint frequencies of these stability categories with winds (Annex 1) show two dominant trends. The first is the very unstable category (category A), where southeast to south winds in the 6.9- to 11.2-mph range are most frequent. The second is in the slightly stable (E) and extremely stable (G) categories (and, to a lesser degree, categories D and F), where the southeast wind in the 3.4- to 11.2-mph range predominates.

A comparison of available stability data for Roswell is presented in Table H-35. The Roswell data show that the on-site data-collection period is representative of long-term conditions. However, there are major differences in the stability distributions between Roswell and the site.

Table H-34. Frequency of Stability Categories at the WIPP Site, June 1977-May 1978

Stability category	Frequency (%)											
	J	F	M	A	M	J	J	A	S	O	N	D
A, extremely unstable	14.2	15.7	25.2	31.0	31.8	28.2	42.2	37.4	27.7	17.0	19.6	15.7
B, unstable	3.0	4.2	1.6	3.1	4.9	3.8	2.7	3.2	3.6	3.2	3.4	3.2
C, slightly unstable	3.0	3.8	3.8	2.6	2.9	4.1	1.7	2.0	2.9	5.1	1.6	3.9
D, neutral	26.1	19.2	14.2	7.6	10.5	17.4	7.8	13.5	10.5	16.7	9.6	10.5
E, slightly stable	15.7	34.2	19.3	15.7	25.1	26.9	24.1	31.4	17.9	18.8	10.6	14.4
F, stable	14.5	8.6	13.0	12.2	9.8	11.1	11.6	6.7	13.2	14.5	13.9	13.6
G, extremely stable	22.4	13.2	22.3	27.2	13.5	8.5	10.0	5.7	24.2	24.6	40.1	37.0

Different methods were used in categorizing the Roswell and the WIPP-site data since the hourly data for Roswell obtained from the National Climatic Center did not contain the data needed for the temperature-difference method (temperature difference ΔT) and standard deviation of the horizontal wind

Table H-35. Comparison of Frequency of Stability Categories at Roswell with Those at the Site

Stability category	Frequency (%)		
	Roswell,[a] 1973-1976	Roswell,[a] June 1977-May 1978	Reference site,[b] June 1977-May 1978
A, extremely unstable	1.8	1.0	25.5
B, unstable	8.1	7.1	3.3
C, slightly unstable	14.1	14.8	3.1
D, neutral	39.5	43.0	13.6
E, slightly stable	16.0	17.6	21.2
F, stable	15.8	14.4	11.9
G, extremely stable	4.7	2.1	21.6

[a]Based on the Turner method.
[b]Based on the temperature-difference method.

direction). The method used for the Roswell data (Turner, 1964) is based primarily on surface wind speed and net solar radiation. It tends to be biased toward the neutral category D (Table H-35).

Like the site data, Roswell stability-wind-rose data (Tables 13 through 20 in Annex 1) show unstable conditions during light easterly winds of 3.6 to 7.5 mph. Although stability categories B, C, and D are much more frequent at Roswell, high occurrences of slightly stable conditions (E) are seen with relatively high winds of 7.6 to 12.5 mph.

H.4.3 Short-Term (Accident) Diffusion Estimates

Conservative (5% probability level), realistic (50%) as well as worst case estimates of the local atmospheric-diffusion factors (χ/Q) for the site have been prepared for the site boundary (control zone IV radius of 3 miles) and distances of 0.5, 1.5, 2.5, 3.5, 4.5, 7.5, 15, 25, 35, and 45 miles. Calculations were made for a 1-hour effluent-release period from hourly data collected at the site for the period June 1977 through May 1978.

The ground-level atmospheric-diffusion factors for the site were calculated from Gaussian plume-diffusion models for a continuously emitting ground-level source (a conservative assumption). Hourly centerline χ/Q values were computed from the concurrent hourly mean wind speed, wind direction, and stability category. The wind speed at the 30-foot level sensor was used since a ground-level release was assumed for conservatism. The stability class was determined by the temperature-difference method. Calms were assigned a wind-speed value equal to the starting speed of the wind vane (0.6 mph) and the wind direction in the last noncalm hour. Cumulative frequency distributions were prepared to determine the χ/Q values that were exceeded only 5 and 50% of the time as well as worst case values.

Gaussian plume-diffusion models for a ground-level concentration were used to describe the downwind spread of effluents from the repository. A continuous ground-level release of effluents at a constant emission rate was assumed in the diffusion estimates. Total reflection of the plume at ground level was assumed in the diffusion estimates. Since it allows for no depletion by deposition or reaction at the surface, this assumption is conservative. For each hour in the year of record χ/Q values were calculated as follows:

$$\frac{\chi}{Q} = \frac{1}{\Sigma_y \sigma_z u_{10} \pi} \quad (1)$$

$$\frac{\chi}{Q} = \frac{1}{\sigma_y \sigma_z u_{10} \pi} \quad (2)$$

where

χ/Q = the relative centerline concentration (sec/m^3) at ground level

u_{10} = wind speed (m/sec) at 10 meters above the ground

1789 206

Σ_y = lateral plume spread (meters), a function of atmospheric stability, wind speed, and downwind distance from the point of release. For distances of up to 800 meters, $\Sigma_y = M\sigma_y$, M being a function of atmospheric stability and wind speed. For more than 800 meters, $\Sigma_y = (M - 1)\ \sigma_y(800\ m) + \sigma_y(x)$

σ_y, σ_z = lateral and vertical plume spread (meters), respectively, as a function of atmospheric stability and distance

For neutral to stable conditions (D to G) with wind speeds of less than 6 m/sec, equation 1 was used to calculate χ/Q values in accordance with NRC Draft Regulatory Guide 1.XXX (Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants). For all other stability and/or wind-speed conditions, χ/Q was selected on the basis of equation 2.

From this year's worth of 1-hour χ/Q values, cumulative frequency distributions were prepared for each of 16 wind sectors and for several distances from the release point. The values of χ/Q exceeded only 5 and 50% of the time are presented in Table 21 in Annex 1.

H.4.4 Long-Term (Routine) Diffusion Estimates

Annual average diffusion factors were computed for routine releases from WIPP operations. The MESODIF model was run (Start and Wendell, 1974) with meteorological data recorded at the site from June 1977 through May 1978.

MESODIF uses an integrated puff model that differs from other Gaussian puff models in that it allows released materials to be transported back over the source should the wind shift. The effluent is treated as a string of puffs released every hour through the year of record into the wind field recorded by the on-site meteorological station. Individual puffs are tracked until they are too dilute to be of significance or until they leave the area being considered. Concentrations are integrated for the year and then averaged to yield the mean expectation for single puffs. A ground-level release was assumed for conservatism. The results are listed in Table H-36 for the year of record. The strong lobe of concentration in the northwest sector in Table H-36 is consistent with the prevailing winds, which are from the southeast.

H.4.5 Air Quality

The United States has been divided by the EPA into Air Quality Control Regions (AQCRs; 40 CFR 81). The EPA has divided its programs in the country into administrative regions. The reference site is located in AQCR 155 and is administered by EPA Region VI. The New Mexico Environmental Improvement Division (NMEID) has designated a seven-county area, including Eddy and Lea

Table H-36. Calculated Long-Term Average χ/Q Values for the Site (Period of Record June 1977 through May 1978)

Downwind sector	χ/Q (sec/m³) Downwind distance (miles) 0.5	1.5	2.5	3.5.	4.5	5.0	7.5	10.0	15.0	25.0	35.0	45.0
N	4.2-5[a]	3.5-6	1.1-6	5.0-7	2.9-7	2.2-7	9.0-8	4.6-8	1.7-8	5.2-9	2.5-9	1.4-9
NNE	1.4-5	1.4-6	4.2-7	2.2-7	1.3-7	1.0-7	4.0-8	2.2-8	9.0-9	3.0-9	1.5-9	9.0-10
NE	1.3-5	1.9-6	7.4-7	4.0-7	2.5-7	2.2-7	1.0-7	6.0-8	3.0-8	1.2-8	7.0-9	4.2-9
ENE	1.6-5	1.4-6	4.8-7	2.2-7	1.2-7	1.0-7	4.0-8	2.0-8	8.4-9	2.8-9	1.3-9	8.0-10
E	1.0-5	1.3-6	4.2-7	1.9-7	1.2-7	8.0-8	3.2-8	1.7-8	7.0-9	2.1-9	1.0-9	5.8-10
ESE	1.8-5	1.5-6	4.6-7	2.1-7	1.2-7	9.4-8	3.7-8	1.9-8	7.6-9	2.4-9	1.1-9	6.2-10
SE	1.5-5	1.3-6	4.2-7	2.0-7	1.2-7	9.0-8	3.7-8	2.0-8	8.0-9	2.7-9	1.3-9	7.2-10
SSE	1.5-5	1.7-6	6.4-7	3.3-7	2.0-7	1.6-7	7.2-8	4.2-8	1.9-8	7.0-9	3.6-9	2.3-9
S	1.3-5	1.8-6	7.0-7	4.0-7	2.4-7	2.0-7	1.0-7	6.0-8	2.8-8	1.1-8	6.0-9	4.0-9
SSW	1.5-5	2.0-6	9.0-7	4.6-7	3.0-7	2.5-7	1.2-7	7.0-8	3.6-8	1.5-8	8.2-9	5.4-9
SW	2.1-5	3.0-6	1.1-6	6.0-7	4.0-7	3.2-7	1.5-7	9.0-8	4.0-8	1.7-8	9.0-9	6.0-9
WSW	1.8-5	2.3-6	9.0-7	5.0-7	3.3-7	2.5-7	1.2-7	7.0-8	3.3-8	1.3-8	7.0-9	4.4-9
W	3.0-5	4.0-6	1.5-6	8.0-7	5.0-7	4.2-7	1.9-7	1.2-7	5.6-8	2.2-8	1.2-8	7.0-9
WNW	9.0-5	1.0-5	3.5-6	1.7-6	1.1-6	9.0-7	3.7-7	2.1-7	9.4-8	3.3-8	1.7-8	1.1-8
NW	6.2-5	1.0-5	4.2-6	2.4-6	1.6-6	1.3-6	6.8-7	4.2-7	2.1-7	9.0-8	5.0-8	3.3-8
NNW	3.7-5	6.8-6	3.0-6	1.8-6	1.2-6	1.1-6	5.6-7	3.5-7	1.9-7	8.6-8	5.0-8	3.4-8

[a]4.2-5 = 4.2×10^{-5}.

Counties, as State Air Quality Control Region 5 (Chapter 277, Laws of 1967 as amended).

Existing air pollution in the vicinity of the site consists mostly of high concentrations of total suspended particulates. The entire state experiences occasional high concentrations of total suspended particulates from natural wind-blown dust; near the site, the concentrations are even higher because of potash operations. According to the most recent EPA State Attainment Status Report (Federal Register, September 11, 1978), air quality in the region meets primary and secondary national ambient air-quality standards, except locally near industries.

To better define the ambient air quality at the site, the levels of selected air pollutants have been monitored since January 1976 and will be used to analyze the effects of repository construction and operation on air quality locally and regionally. The parameters being measured are total suspended particulates, chemical species in particulates, nitrogen dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide, and ozone (Metcalf and Brewer, 1977).

Table H-37 presents State and Federal air-quality standards. State standards are not to be exceeded at any time, while Federal standards are not to be exceeded more than once a year. The Federal standards are divided into primary and secondary standards, which are defined in 40 CFR 50.2: "National primary ambient air-quality standards define levels of air quality which the Administrator (Administrator of EPA) judges are necessary, with an adequate margin of safety to protect the public health. National secondary ambient air-quality standards define levels of air quality which the Administrator judges necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant."

Table H-37. Ambient Air-Quality Standards[a]

Pollutant	New Mexico standard	Federal standards	
		Primary	Secondary
Sulfur dioxide (SO_2)			
24-hour average	0.10 ppm (260 $\mu g/m^3$)	0.14 ppm (365 $\mu g/m^3$)	
Annual arithmetic mean	0.02 ppm (52 $\mu g/m^3$)	0.03 ppm (80 $\mu g/m^3$)	
3-hour average			0.50 ppm (1300 $\mu g/m^3$)
Total suspended particulates			
24-hour average	150 $\mu g/m^3$	260 $\mu g/m^3$	150 $\mu g/m^3$
7-day average	110 $\mu g/m^3$		
30-day average	90 $\mu g/m^3$		
Annual geometric mean	60 $\mu g/m^3$	75 $\mu g/m^3$	60 $\mu g/m^3$
Carbon monoxide (CO)			
8-hour average	8.7 ppm	9 ppm	9 ppm
1-hour average	13.1 ppm	35 ppm	35 ppm
Photochemical oxidants (ozone)			
1-hour average	0.06 ppm	0.12 ppm	0.12 ppm
Hydrocarbons (nonmethane)			
3-hour average	0.19 ppm	0.24 ppm	0.24 ppm
Nitrogen dioxide (NO_2)			
24-hour average	0.1 ppm (200 $\mu g/m^3$)		
Annual arithmetic average	0.05 ppm (100 $\mu g/m^3$)	0.05 ppm (100 $\mu g/m^3$)	0.05 ppm (100 $\mu g/m^3$)

[a]State standards--State of New Mexico ambient air quality data summaries (1973-1976). Federal standards--40 CFR 50.

1789 209

The concentrations of pollutants measured at the WIPP site are presented in Table H-38. The only concentrations that exceeded New Mexico standards during 1976 are the 1-hour carbon monoxide concentration and the 1-hour ozone concentration. The carbon monoxide value does not exceed Federal standards, however. The high ozone concentrations may be at least partially explained by the fact that the concentrations were measured by ultraviolet techniques instead of chemiluminescence; the ultraviolet techniques generally produce higher values. Chemiluminescence is now used for measurements, but no new values are available.

Table H-38. Pollutants Measured at the Site During 1976

Pollutant	Measured concentration	New Mexico standard
Nitrogen dioxide		
Annual arithmetic mean	32.19 $\mu g/m^3$	100 $\mu g/m^3$
Sulfur dioxide[a]		
Annual arithmetic mean	4.29 $\mu g/m^3$	52 $\mu g/m^3$
24-hour average	38 $\mu g/m^3$	260 $\mu g/m^3$
Total suspended particulates		
Annual arithmetic mean	18.47 $\mu g/m^3$	[b]60 $\mu g/m^3$
24-hour average	77.7 $\mu g/m^3$	150 $\mu g/m^3$
Carbon monoxide		
1-hour average	17 ppm	13.1 ppm
Daily mean	3.17 ppm	
Ozone		
1-hour average	0.167 ppm	0.06 ppm
Daily mean	0.02 ppm	
Hydrogen sulfide		
Daily mean	0.11 $\mu g/m^3$	

[a]Below the detection capability of the method used.
[b]Geometric mean.

H.4.6 Paleoclimatology

The range of climates that have occurred in the past indicates the long-term variabilities of the climate in a region and provides a basis for postulating the bounds of future climatic changes that may affect the long-term impact of the repository. Considering the expected storage-time commitments for nuclear wastes at a repository, the most significant historical period is

1789 210

the last 10,000 to 100,000 years. Detailed climatological information is not available for this historical period. However, qualitative estimates of temperature and precipitation regimes have been made, and the extent of glaciation and flooding can be fairly accurately estimated from geologic evidence. Much of the available paleoclimatological information refers to large geographical areas (continents, hemispheres, etc.), and specific climatic conditions for the site region frequently must be inferred from these generic descriptions. However, limited geologic investigations have provided some specific information directly applicable to the site region.

Periodically, at intervals of about 250 million years, there have been major glacier advances from the polar regions lasting on the order of millions of years (Sellers, 1965). The Pleistocene Epoch, which began about 1 to 2 million years ago, is the latest glacial period (Sellers, 1965; NAS/NRC, 1975, 1977; John, 1977). Within the Pleistocene there have been several glacier advances (glacials) and retreats (interglacials), as illustrated by worldwide temperature variations in Figure H-11 (Norwine, 1977). This epoch ended some 10,000 years ago with the beginning of the Holocene Epoch, although continuous ice sheets are still present in the polar regions.

Continental ice sheets of the Pleistocene Epoch did not advance south of Colorado (latitude 37° N); however, during these glaciations, individual mountain glaciers were widespread throughout the Rocky Mountains from Canada to central New Mexico, and local ice caps were present in a number of ranges (Richmond, 1965). Glaciers developed as far south as latitude 33°22' N (Sierra Blanca, peak elevation 13,000 feet, west of Roswell) during the glaciations of late-Pleistocene time. The average end moraines of late Pleistocene glaciers are at elevations of between 10,200 and 11,400 feet at this latitude (Richmond, 1965). Summer temperatures were about 7 to 16°F colder than at present, but winter temperatures were much the same as at present (Richmond, 1965; Gates, 1976).

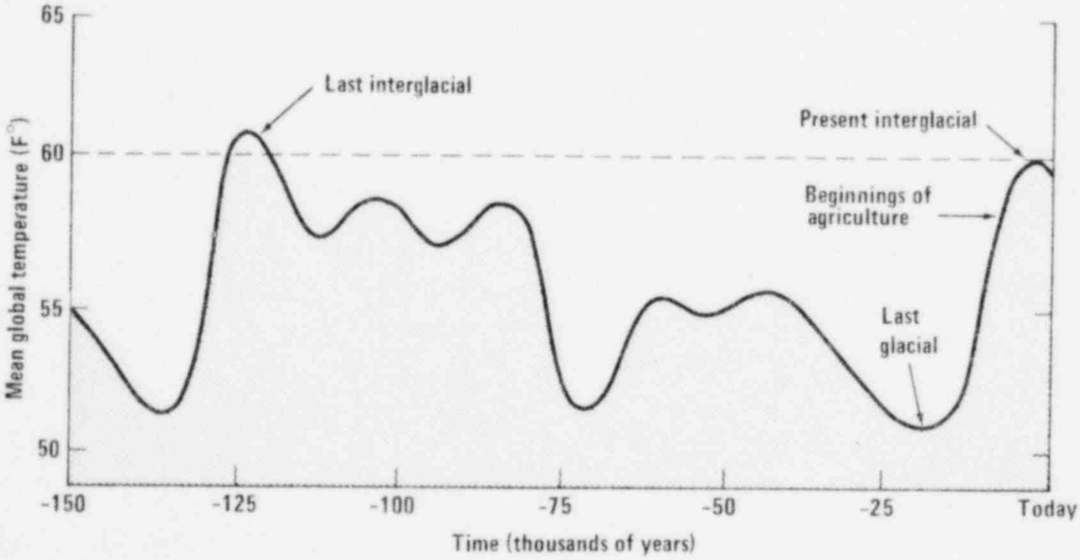


Figure H-11. Worldwide temperature variations.

1789 211

The advance of glaciers was initially associated with a cold, damp climate, followed by a cold, dry climate that developed over the contiguous ice sheet itself (Schwarzbach, 1963). Precipitation over this area was probably less than that over the same region at present. During these periods, the weather was much more variable than at present. Winters were longer; spring, fall, and summer were shorter; and diurnal and day-to-day variations were greater (Kukla, 1976).

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 continental glacier received increased (pluvial) precipitation (Schwarzbach, 1963). In the United States, pluvial effects occurred in the central and western regions. Several lakes were formed or expanded during the pluvial, especially in the Western United States, in areas that are now deserts (Flint, 1967; Schwarzbach, 1963). The climate of New Mexico during this period was characterized by more precipitation (about 64% more than at present), less evaporation (only about 73% of present), and a mean June-September temperature about 18°F lower than at present (Antevs, 1954).

In summary, it can be inferred that the climate of the region 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 geologic history of the region that indicates such effects has been addressed in Section 7.2.

Major glacial epochs have been alternating with interglacials on a 100,000-year cycle (Norwine, 1977). These interglacials have previously lasted 11,000 to 15,000 years. The present global climate is considered interglacial and has lasted approximately 10,000 to 12,000 years (Richmond, 1972; Sellers, 1965), although this has varied by region, and glacial advances have at times occurred. The interglacials of the Pleistocene were typically free of ice and were drier than the present (Sellers, 1965). Moreover, temperatures were similar or at times slightly warmer than those at present: average world temperatures were approximately 3°F above those at present (Sellers, 1965). In the Rocky Mountains, the present interglacial has been less arid and colder than previous interglacials (Richmond, 1972).

A brief summary of the climate of the current epoch is presented in Table H-39. The most significant events are the Cochrane Glacial Readvance (6800 to 5600 B.C.), the Climate Optimum (5600 to 2500 B.C.), and the Little Ice Age (1500 to 1900 A.D.). However, the 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 in about 1950) of global warming (Kukla and Matthews, 1972; Lamb, 1966; Alexander, 1974).

Table H-39. A Brief Chronology of the Climate of the Southwestern United States in the Last 10,000 Years[a]

Dates	Climate
9000-6000 B.C.	Warm and arid in southern Arizona.
6800-5600 B.C.	Cool and dry, with possible extinction of mammals, particularly in Arizona and New Mexico.
5600-2500 B.C.	Warm and moist, becoming warm and dry by 3000 B.C. (Climate Optimum). Intermittent drought in the Western United States after 5500 B.C.
2500-500 B.C.	Generally warm and dry with periods of heavy rain (after 660 B.C.) and intense droughts (near 510 B.C.) in the Western United States.
330 A.D.	Drought.
800	Start of moist period in Mexico.
1180-1215	Wet in the West.
1220-1290	Drought in the West.
1276-1299	"Great Drought" in the Southwest.
1300-1330	Wet in the West.
1500-1900	Generally cool and dry (Little Ice Age). Periodic glacial advances in North America (1700-1750). Drought in the southwestern United States from 1573 to 1593.
1880-1940	Increase of winter temperatures by 1.5°C. Drop of 5.2m in the level of the Great Salt Lake. Alpine glaciation reduced by 25% and arctic ice by 40%.
1920-1958	25% decrease in mean annual precipitation in the Southwest.
1942-Present	Worldwide temperature decrease and halt of glacial recession.

[a]Data from Sellers (1965).

1789 213

H.5 ECOLOGY

H.5.1 Introduction

This section characterizes the terrestrial and aquatic ecology of the site region, describes the ecological resources at the site and in its vicinity, and characterizes preexisting environmental stresses. "Site region" is defined as Eddy and Lea Counties, New Mexico, except for the Guadalupe Mountains; "site vicinity" is a 5-mile-radius circle centered on the site (Figure H-12). Emphasis is placed on characterizing terrestrial and aquatic habitats and the important plant and animal species that might be affected by the repository. Important species are defined (NRC, 1976) as follows:

a. The species is commercially or recreationally valuable.

b. The species is threatened or endangered.

c. The species is critical to the well-being of some important species within criterion a or b.

d. The species is critical to the structure and function of the ecological system or is a biological indicator of radionuclides in the environment.

This section is based on data collected since 1975 by the New Mexico Environmental Institute (NMEI) in the area of the site. The study was to provide baseline environmental data for an assessment of environmental impacts. These investigations were conducted in a 72-square-mile study area, with intensive studies in a 3-mile intensive-study area over a 2-year period. The results were published in two progress reports (Wolfe et al., 1977a, b).

In 1977, the biological team was reorganized, and ecological studies were continued at the site and in its vicinity. Several quarterly reports have already been issued. Field and laboratory methods are detailed in these reports and in Draft Biological Program (Best, 1978). Ecosystem modeling plans are also being developed.

All of the major habitats at and near the site have been and are being sampled on a seasonal basis for plants, mammals, birds, reptiles, amphibians, terrestrial invertebrates, and aquatic species. Microbial flora, soils, and nutrient cycling have also been and are being studied at the site and its vicinity.

H.5.2 Terrestrial Ecology

H.5.2.1 Soil and Agricultural Resources

Site region

The site region lies in the Southern Desert Basins, Plains, and Mountains Land Resource Area of the Western Range and Irrigated Land Resource Region (Austin, 1972). Climate and soil limit agriculture to ranching and some irrigated and dry-land farming, with the major cultivated areas being along

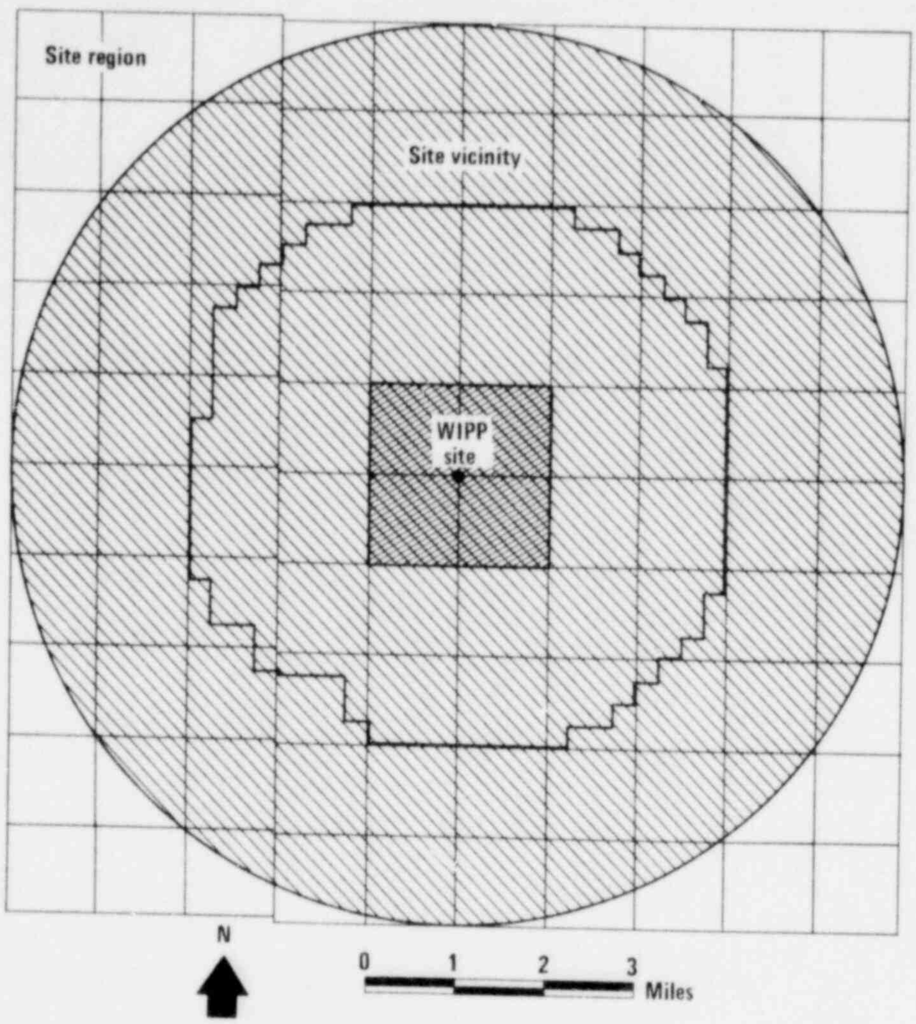


Figure H-12. Location of WIPP site, site vicinity, and site region.

the Pecos and Black Rivers in Eddy County and in northeastern Lea County. Irrigated lands produce sorghum, cotton, alfalfa, and small-grain crops. Over 90% of the site region is grassland, and beef-cattle ranching is the major agricultural enterprise. Grazing areas are used the year round.

The major soils in the site region are Aridisols, which occur in arid regions and contain small amounts of organic matter, and Mollisols, found in more moist regions with dark, organic-matter-rich surface horizons. The major suborders of the Aridisols, which are used primarily for rangeland and some irrigated crops, are the Orthids, which have accumulations of calcium carbonate, gypsum, or other salts more soluble than gypsum but no horizontal clay accumulation; and the Argids, which have clay accumulations with or without alkali (sodium). Ustols, the major suborder of Mollisols in the site region, are intermittently dry during the warm season and have subsurface horizons in which salts or carbonates have accumulated. They are used for wheat or small grains and some irrigated crops.

Also present are lesser amounts of other soil orders, including Entisols, recent soils with no horizon development, and Alfisols, which have a gray to brown surface horizon and a subsurface horizon of clay accumulations. Entisols are used primarily as rangeland. The Alfisols are being used as rangeland, for dry-land farming of small grain, and for irrigated crops.

Site and site vicinity

The physical and chemical properties of the three soil associations that occur in the site vicinity and the two soil series that occur at the site are described in Section 7.2.8. All of the soil associations in the vicinity of the site are Aridisols (Argids and Orthids) or Entisols. The two soil mapping units that occur on the site are in the Kermit-Berino Soil Association (Table H-40). Approximately half the site is mapped as Berino complex and the other half as Kermit-Berino fine sands. Both mapping units are Class VII soils--unsuitable for cultivation and suitable only for pasture and wildlife habitat. All the soils in the site are subject to severe wind erosion. They are generally stabilized by shinnery oak, mesquite, and other vegetation.

The soils at the site include sandy surface soils with wind-blown particles, a thin (1-mm-thick) soil crust, and a layer of moist subsoil. The wind-blown soil and subsoil contain sparsely distributed bacteria attached to the surfaces of the sand grains but no fungi or algae. The surface material, however, contains partially degraded plant detritus and relatively dense fungal hyphae. This thin crust seems to resist wind erosion and covers most of the site (Caldwell, 1978).

H.5.2.2 Native vegetation

Site region

The site region is an area of transition between the Great Plains Short-Grass Prairie and the Chihuahuan Desert. Since early in the twentieth century, however, salt cedar trees, naturalized from Eurasia, have invaded major drainageways. The native vegetation consists of mixed grasses and mixed shrubs. Vegetative cover is largely controlled by water availability and livestock grazing. Specific plant communities are dependent on such factors as the infiltration rate of the surface soil, depth to a restrictive layer, and the extent to which the surface soil has been reworked by wind or water erosion.

According to Bailey's (1976) ecoregion classification, the site region is in the Grama-Tobosa Section and the Tarbush-Creosote Bush Section of the Chihuahuan Desert and the Grama-Buffalo Grass Section of the Great Plains Shortgrass Prairie. Grama-Tobosa Section is a climax desert grassland community. At lower elevations in this section, dense stands of shrubs are common. The Tarbush-Creosote Bush Section has been described as a disclimax shrub type that was originally desert grassland (Castetter, 1956). Overgrazing has caused an increase in shrub species that once only occupied isolated areas (Gardner, 1951). The Grama-Buffalo Grass Section is a short-grass prairie found in arid areas where the growing season is short and precipitation is not retained in the soil (Weaver and Albertson, 1956).

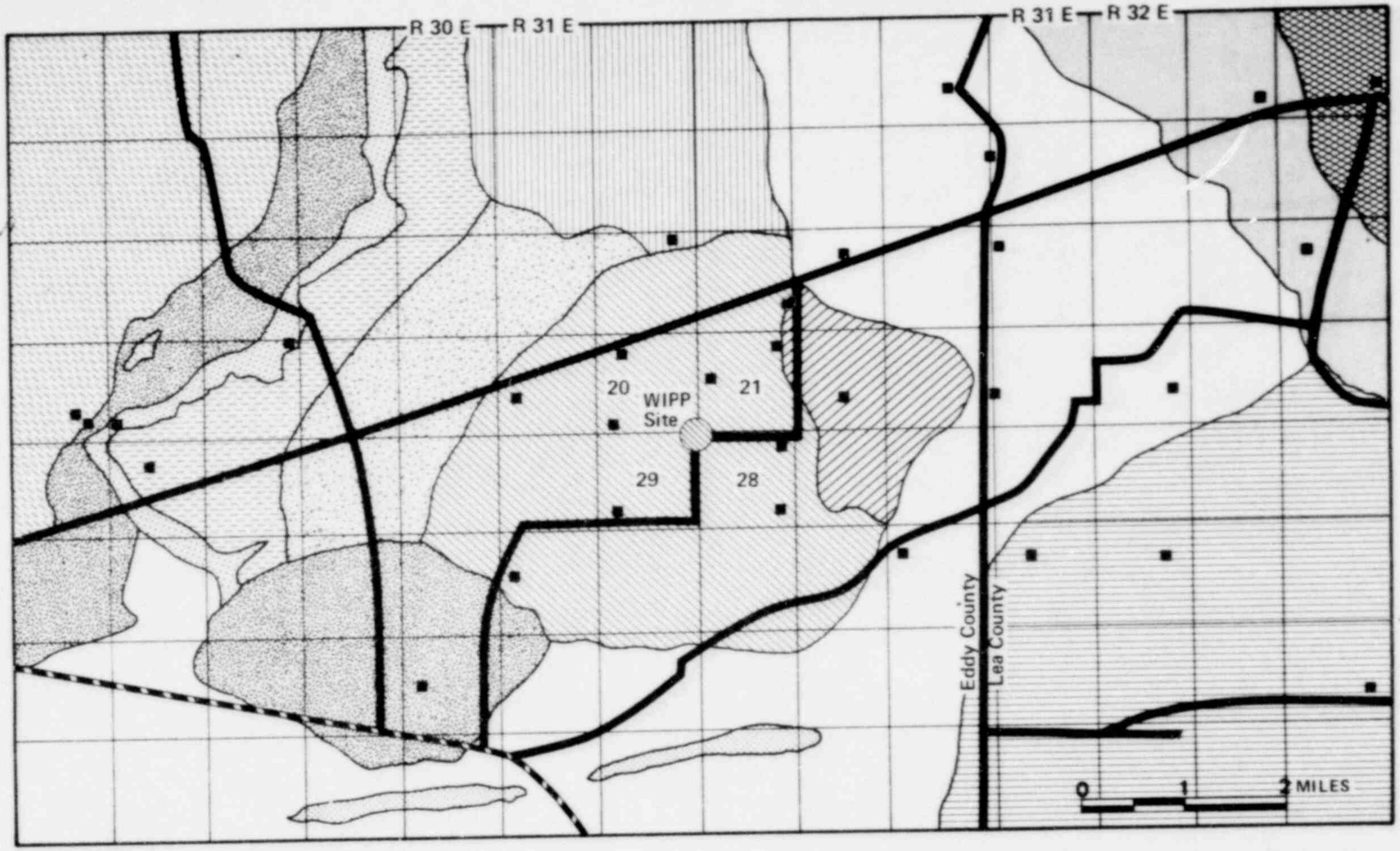
1789 216

Table H-40. Ecological Characteristics of Soils at the WIPP Reference Site[a]

Soil mapping unit	Soil series	Soil order/ suborder	Soil capability unit	Soil-management considerations: Agricultural potential[b]	Soil-management considerations: Management considerations
Berino complex, 0-3% slopes, eroded	Berino	Aridisol Argid	VIIe-1	Unsuitable for dryland farming. Soils are too sandy and rainfall too low and undependable. Suitable only for native pasture and wildlife habitat.	Soils subject to severe wind erosion if vegetative cover not maintained. Natural revegetation of eroded areas is difficult and slow. Soils must be constantly protected from overgrazing.
Kermit-Berino fine sands, 0-3% slopes:	Kermit	Entisol Psamment			
Kermit fine sand			VIIe-3	Unsuitable for dryland farming. Rainfall is low and undependable and soil texture is too coarse. Suitable for wildlife habitat and native pasture.	Soils subject to severe wind erosion if vegetative cover not maintained. Natural fertility and organic-matter content are low. Grasses should not be overgrazed.
Berino fine sand			VIIe-3	Unsuitable for dryland farming. Rainfall is low and undependable and soil texture is too coarse. Suitable for wildlife habitat and native pasture.	Soils subject to severe wind erosion if vegetative cover not maintained. Natural fertility and organic-matter content are low. Grasses should not be overgrazed.

[a]Based on data from the Soil Conservation Service (1971).

[b]None of the soils at the site or in the vicinity are suitable for irrigated farmland. Due to the physical and chemical characteristics of the soils, there is a lack of an adequate supply of good-quality water in the site region.



A Dominants: Prosopis, Muhlenbergia, and Gutierrezia. High frequency of Tridens, Tragia, and Sphaeralcea. Occasional Yucca torreyi.

B Dominants: Quercus, Aristida, and Prosopis. High frequency of Muhlenbergia and Panicum.

C Dominants: Quercus, Artemesia, and Aristida. High frequency of Yucca, Sporobulus, and Gutierrezia.

D Dominants: Aristida, Gutierrezia, Prosopis, and Yucca. High frequency of Artemesia and Croton.

E Dominants: Prosopis, Gutierrezia, Bouteloua, and Opuntia. High frequency of Artemesia and Aristida.

F Dominants: Quercus, Sporobolus, Artemesia, and Muhlenbergia. High frequency of Pectis and Houstonia.

G Dominants: Artemesia, Prosopis, Muhlenbergia, Sporobulus, Yucca, and Aristida. High frequency of Cenchurus, Houstonia, and Panicum.

H Dominants: Larrea, Gutierrezia, and Muhlenbergia. High frequency of Bouteloua and Aristida.

I Dominants: Prosopis, Aristida, and Quercus. Occasional Koeberlinia.

J Dominants: Acacia, Quercus, Prosopis, and Krameria. High frequency of Koeberlinia, Rhus, Houstonia, and Pectis.

K Dominants: Larrea, Acacia, Prospis, and Gutierrezia. High frequency of Tridens and Muhlenbergia.

L Alkali soils, Tobosa flats: Dominated by Hilaria, Lepidum, and Greggia.

M Dominants: Prosopis, Sapindus, Artemesia, and Cenchurus.

Paved highway

Improved dirt road

■ Completed study plots

Figure H-13. Preliminary vegetation-type map of the WIPP reference site.

Kuechler (1975) has described the potential natural vegetation of the region largely as Trans-Pecos Scrub Savanna in the southern and central portions, Grama-Buffalo Grass in the north and east, and Grama-Tobosa Shrubsteppe and Creosote Bush-Tarbush in the north and west.

More recently, Donart et al. (1978) have described Eddy County as belonging largely to the Chihuahuan Region of the Grassland Formation and the Chihuahuan Region of the Desert Shrub Formation; the potential natural vegetation of Lea County is classified as the Chihuahuan Region, the Plains Region, and the Prairie Region of the Grassland Formation. In the site region, the following Chihuahuan Region associations are defined:

- Creosote/Bush Muhly--at one time predominantly grasslands with scattered creosote bush; principal grasses were black grama, bush muhly, and scattered tobosa.

- Catclaw--primarily an Arizona shrub-dominated association in small amounts around Carlsbad and in southwestern New Mexico.

The Chihuahuan Region of the Grassland Formation contains four associations in the site region (Donart et al., 1978):

- Burrograss--dominated by burrograss in association with tobosa and inclusions of gyp grama, gyp dropseed, coldenia, and fluffgrass.

- Mixed Grama/Three-Awn--dominated by black grama and three-awns in association with moderate amounts of blue, hairy, and sideoats gramas and occasional plants of mesa and sand dropseed.

- Black Grama/Mixed Dropseed--dominated by black grama in association with mesa dropseed, sand dropseed, spike dropseed, giant dropseed, and scattered yucca.

- Mixed Dropseed/Black Grama--dominated by dropseed species in association with black grama, yucca, and, in some areas, sand sagebrush.

Several authors have characterized the successional patterns in the region. Shantz (1917) described the area as a grazing disclimax. Explanations for the shift of vegetation from tall and mid-grasses to shrubs (notably sagebrush, shinnery oak, mesquite, and creosote bush) include the exclusion of fire (Sauer, 1950; Humphrey, 1953; Wingfield, 1955), overgrazing by cattle (Campbell, 1929; Whitfield and Anderson, 1938; Whitfield and Beuther, 1938), and changing climate. York and Dick-Peddie (1969) have attributed the recent occupation by mesquite in southern New Mexico to the effects of cattle and note that the appearance of grazing is the only event that coincides with the time of this spectacular change in vegetation.

Several plant species in the region are important to wildlife. For example, mesquite and snakeweed provide abundant forage for herbivorous and granivorous species, such as scaled quail (BLM, 1977). Shinnery oak and other shrub species provide forage and cover for a variety of game and nongame species, such as mule deer and mourning dove.

Site and site vicinity

The vegetation at the site and in the vicinity consists of native shrub scrubland, which is apparently a grazing disclimax. No crops are cultivated on the site or in the site vicinity.

Thirteen plant associations have been identified in the site vicinity, with mesquite, snakeweed, three-awn, and shinnery oak being the major dominants (Table H-41 and Figure H-13). Creosote bush is dominant on the poorer sites, including hills and breaks. The dominant plants on the site are sagebrush, mesquite, muhly grass, dropseed, yucca, and three-awn. Sandbur, bluets, and panicum are also common. Plants reported at the site are listed in Table H-42. Species potentially present are listed in Table 1 of Annex 2.

H.5.2.3 Wildlife

Typical grassland and shrubland species dominate the regional fauna, whose distribution and abundance are strongly affected by water availability. The limited areas of cropland are of special importance to many species of wildlife because they provide both food and water. Stock watering ponds on rangelands also are water sources for wildlife.

Mammals

Site region. About 70 species representing seven mammalian orders may occur in the site region. Few are restricted to a specific habitat. The one marsupial, the Virginia opossum, is an omnivore present in nearly all habitats. The one insectivore, the desert shrew, is widely distributed but scarce throughout its range.

The 15 species of bats that can be expected in the site region may be common in areas with suitable roosts and water within a few miles. A few species form very large colonies (e.g., the Brazilian free-tailed bat in the Carlsbad Caverns area). The preferred habitats of the nine-banded armadillo, an edentate found in southeastern Lea County, include brushy areas and rock outcrops. The lagomorphs (rabbits and hares) of the region include the Eastern cottontail, generally associated with agricultural land, and the desert cottontail and black-tailed jack rabbit, typically found in desert-shrub communities but also present in grassland and farmland. Of the 30 rodent species found in the site region, 6 species (pocket mice and kangaroo rats) inhabit grassland and desert-shrub habitats. Two introduced species, the house mouse and the Norway rat, have become pests and are typically found near human habitation. Porcupines are present but not common.

Several carnivore species are widespread and relatively common (e.g., coyote, gray fox, badger, striped skunk, bobcat). Others have ranges that include most of the site region but are generally restricted to uncommon habitats (e.g., ringtails prefer rock outcrops near water). Some are relatively rare because their geographic range includes only a small portion of the site region (e.g., hognose skunk).

1789 220

Table H-41. Plant Associations on or Near the Site

Genus	Common name	Plant association[a]												
		Aa	Bb	Cc	Dd	Ee	F	G	H	I	J	K	L	M
Acacia	Acacia										**	**		
Aristida	Three-awn		**	**	**	*		**	*	**				
Artemesia	Sagebrush			**	*	*	**	**						**
Bouteloua	Grama					**			*					
Cenchurus	Sandbur							*						
Croton	Croton				*									
Greggia	Greggia												**	
Gutierrezia	Snakeweed	**		*	**	**			**			**		
Hilaria	Galleta												**	
Houstonia	Bluets						*	*			*			
Koeberlinia	All-thorn									**	*			
Krameria	Ratany										**			
Larrea	Creosotebush							**					**	
Lepidium	Pepper grass												**	
Muhlenbergia	Muhly	**	*				**	**	**			*		
Opuntia	Prickly pear/cholla					**								
Panicum	Panicum		*					*						
Pectis	Fetid marigold						*				*			
Prosopis	Mesquite	**	**		**	**		**	**		**	**		
Quercus	Oak		**	**				**			**	**		
Rhus	Sumac										*			
Sapindus	Soaptree													**
Sphaeralcea	Globe mallow	*												
Sporubolus	Dropseed			*			**	**						
Traiga	Nose burn	*												
Tridens	Fluffgrass	*										*		
Yucca	Yucca			*	**			**						

[a]See Figure H-13 for location of the plant associations. Key: ** = dominant plants; * = high-frequency plants.

Table H-42. Plants Reported at the Site

Taxon	Common name	Life form
Amaranthaceae		
Froelichia arizonica	Arizona cottonweed	Perennial forb
Kochia scoparia[a]	Summer cypress	Annual forb
Asclepiadaceae		
Sarcosterma cynanchoides	Climbing milkweed	Perennial forb
Asclepias latifolia[a]	Broadleaf milkweed	Perennial forb
Cactaceae		
Opuntia kleiniae[a]	Klein's cholla	Subshrub
Opuntia leptocaulis[a]	Christmas cholla	Subshrub
Opuntia phaeacantha[a]	Prickly pear	Subshrub
Capparidaceae		
Polanisia jamesii[a]	Clammyweed	Annual forb
Chenopodiaceae		
Atriplex canescens[a]	Fourwing saltbush	Shrub
Chenopodium album[a]	Goosefoot	Annual forb[b]
Chenopodium incisum	Cutleaf goosefoot	Annual forb
Convolvulaceae		
Evolvulus pilosus		Perennial forb
Convolvulus arvensis	Field bindweed	Perennial forb[b]
Compositae		
Ambrosia spp.	Ragweed	Annual forb
Artemisia filifolia[a]	Threadleaf (sand) sagebrush	Suffrutescent
Chrysothamnus pulchellus	Rabbitbrush	Shrub
Dyssodia spp.	Dogweed	Perennial forb
Flourensia cernua[a]	Tarbush	Shrub
Gutierrezia sarothrae[a]	Snakeweed	Suffrutescent
Helianthus annuus[a]	Common sunflower	Annual forb
Hymenopappus flavescens	White ragweed	Biennial forb
Leucelene ericoides[a]	White aster	Perennial forb
Machaeranthera spp.	Aster	Perennial forb
Melampodium leucanthum	Blackfoot	Perennial forb
Palafoxia sphacelata	Palafoxia	Annual forb
Parthenium incanum[a]	Mariola	Shrub
Pectis angustifolia	Fetid marigold	Annual forb
Perezia nana[a]	Desert holly	Perennial forb
Psilostrophe tagetina[a]	Paper daisy	Perennial forb
Senecio longilobus[a]	Threadleaf groundsel	Suffrutescent
Senecio multicapitatus[a]	Groundsel	Suffrutescent
Senecio spartioides	Senecio	Suffrutescent
Xanthium spinosum[a]	Cocklebur	Annual forb
Cruciferae		
Dithyrea wislizenii[a]	Spectacle pod	Biennial forb
Sisymbrium spp.[a]	Tumble mustard	Annual forb

1789 222

Table H-42. Plants Reported at the Site (continued)

Taxon	Common name	Life form
Cyperaceae		
Cyperus schweinitzii	Flatsedge	Perennial forb
Euphorbiaceae		
Croton dioicus[a]	Rosval	Perennial forb
Croton texensis[a]	Texas croton	Annual forb
Euphorbia hexagona	Spurge	Annual forb
Phyllanthus polygonoides	Leafflower	Perennial forb
Fagaceae		
Quercus havardii[a]	Shinnery oak	Shrub
Gramineae		
Andropogon barbinodis[a]	Beardgrass	Perennial grass
Andropogon hallii	Sand bluestem	Perennial grass
Andropogon saccharoides	Silver beardgrass	Perennial grass
Andropogon springfieldii		Perennial grass
Andropogon scoparium	Little bluestem	Perennial grass
Aristida longiseta[a]	Red three-awn	Perennial grass
Aristida wrightii	Wright three-awn	Perennial grass
Bouteloua barbata[a]	Six-weeks grama	Annual grass
Bouteloua eriopoda[a]	Black grama	Perennial grass
Bouteloua hirsuta[a]	Hairy grama	Perennial grass
Brachiaria ciliatissima?	Brachiaria	Perennial grass
Calamovilfa gigantea	Sandreed	Perennial grass
Cenchurus incertus[a] (*C. pauciflorus*)	Sandbur	Annual grass
Chloris cucullata[a]	Fingergrass	Perennial grass
Eragrostis intermedia[a]	Lovegrass	Perennial grass
Eragrostis secundiflora	Lovegrass	Perennial grass
Leptoloma cognatum	Fall witchgrass	Perennial grass
Muhlenbergia porteri[a]	Bush muhly	Perennial grass
Munroa squarrosa	False buffalograss	Annual grass
Panicum obtusum	Panicum	Perennial grass
Paspalum setaceum[a]	Millet	Perennial grass
Setaria leucophila[a]	Bristlegrass	Perennial grass
Sporobolus contractus[a]	Sand dropseed	Perennial grass
Sporobolus cryptandrus[a]	Sand dropseed	Perennial grass
Sporobolus flexuosus	Mesa dropseed	Perennial grass
Trichachne californica	Cottontop	Perennial grass
Tridens pulchellus[a]	Fluffgrass	Perennial grass
Triplasis purpurea		Annual grass
Leguminosae		
Dalea formosa[a]	Featherplume	Shrub
Dalea lanata	Wolly dalea	Perennial forb
Hoffmanseggia jamesii[a]	Rush pea	Suffrutescent
Prosopis glandulosa[a]	Mesquite	Shrub
Schrankia spp.	Sensitive briar	Perennial forb

Table H-42. Plants Reported at the Site (continued)

Taxon	Common name	Life form
Liliaceae		
Yucca X Campestris[a]	Soapweed yucca	Subshrub
Yucca torreyi[a]	Torrey yucca	Subshrub
Loasaceae		
Mentzelia reverchonii	Blazing star	Perennial forb
Martyniaceae		
Proboscidea spp.[a]	Unicorn plant	Annual forb
Nyctaginaceae		
Abronia fragrans	Sand verbena	Perennial forb
Boerhaavia spicata	Spiderling	Annual forb
Mirabilis exaltata??	Four-o'clock	Perennial forb
Onagraceae		
Calylophus drummondianus		Perennial forb
Gaura villosa		Perennial forb
Polemoniaceae		
Ipomopsis longiflora	Long-flowered gilia	Biennial forb
Polygonaceae		
Eriogonum annuum	Annual buckwheat	Annual forb
Portulacaceae		
Portulaca parvula	Purslane	Annual forb
Rhamnaceae		
Condalia ericoides[a]	Javelinabrush	Shrub
Condalia obtusaefolia	Lotebush	Shrub
Rubiaceae		
Houstonia humifusa	Bluets	Annual forb
Sapindaceae		
Sapindus saponaria	Soaptree	Tree-shrub
Scrophulariaceae		
Penstemon fendleri	Fendler beardtongue	Perennial forb
Solanaceae		
Solanum elaeagnifolium	Horse nettle	Perennial forb
Solanum rostratum[a]	Spiny nightshade	Annual forb
Lycium pallidum[a]	Wolfberry	Shrub

[a]Identifications confirmed from winter studies.
[b]Naturalized.

1789 224

Four game and ten furbearer species are found in the site region (Table H-43). Furbearers that are closely associated with water (e.g., beaver and muskrat) are not common and occur only along the Pecos River, more than 10 miles from the site. Coyote are intensively trapped throughout the region. Mule deer, an important game species in the region, are more abundant than white-tailed deer and occur in all natural habitats. The pronghorn is basically a plains animal, but it is also found in desert-shrub and desert grassland habitats in the arid southwest (Wallmo, 1975).

Site and site vicinity. The desert cottontail, black-tailed jack rabbit, northern grasshopper mouse, southern plains woodrat, porcupine, and coyote are observed in all habitats on, and in the vicinity of, the site. Other species demonstrate affinities for particular habitats. Merriam's kangaroo rat, desert pocket mouse, and Mexican ground squirrel are found in transitional desert vegetation in the southwestern portion of the site vicinity.

Some of the mammals demonstrate a preference for a particular soil structure. The spotted ground squirrel, plains pocket mouse, and Ord's kangaroo rat prefer habitats with sandy soils such as shinnery oak-mesquite and active dune land. The bannertail kangaroo rat prefers the compact soils commonly found in creosote-grassland and mesquite-grassland. The silky pocket mouse prefers compact soils wherever they occur. The white-footed mouse does not show a habitat preference.

The mule deer is the only big-game species on, and in the vicinity of, the site. Some hunting is conducted by local people who know its preferred habi-

Table H-43. Game Mammals and Furbearers in the Site Region

Common name[a]	Scientific name[a]	Status[b]
Beaver	*Castor canadensis*	F
Muskrat	*Ondatra zibethicus*	F
Swift fox	*Vulpes velox*	F
Gray fox	*Urocyon cinereoargenteus*	F
Ringtail	*Bassariscus astutus*	F
Raccoon	*Procyon lotor*	F
Long-tailed weasel	*Mustela frenata*	F
Badger	*Taxidea taxus*	F
Western spotted skunk	*Spilogale gracilis*	F
Striped skunk	*Mephitis mephitis*	F
Mountain lion	*Felis concolor*	G
Mule deer	*Odocoileus hemionus*	G
White-tailed deer	*Odocoileus virginianus*	G
Pronghorn	*Antilocapra americana*	G

[a]Common and scientific names follow Jones et al. (1975).

[b]Game status from 1977 hunting and trapping regulations: F = furbearer, G = game species.

tats and movements. The Mescalero Sands white-tailed deer is confined to the sandhills east of Roswell and many miles north of the site. Pronghorn are scattered throughout the area but have not been found on the site itself.

The mammals observed at the site are listed in Table 4-44. Those potentially inhabiting the site and its vicinity are listed in Table 2 of Annex 2.

Birds

Site region. A large variety of bird species inhabit the site region. A contributing factor is that many genera have both eastern and western representatives. Before they were disturbed, the plains of the Midwest formed effective geographic barriers separating the eastern and western counterparts of many sibling species. Recent disturbances, particularly the construction of towns and the planting of trees (Anderson, 1971), have brought many of these closely related species together. As a result, the site region has several closely related species that interbreed.

Among the typical birds of grassy portions of the region are the mountain plover, a regular breeder in the region, and the burrowing owl, a year-round resident in much of the site region. Other fairly common breeding species are the dickcissel, long-billed curlew, horned lark, and western meadowlark. The upland plover is a common migrant throughout the area, as are the lark bunting, Sprague's pipit, and several species of longspurs. American avocets breed along marshes. Common raptors in the site region include the marsh hawk, American kestrel, and Swainson's hawk.

Scaled quail are widespread and heavily hunted. The lesser prairie chicken, bobwhite, and ring-necked pheasant are also hunted. Bobwhite are generally restricted to wooded or brushy river valleys. The mourning dove is common in agricultural land and is outnumbered only by scaled quail in total numbers harvested. The game birds of the region are listed in Table H-45.

Migratory birds that might be hunted in the region include several species of waterfowl. The region is not an important breeding area for waterfowl.

The region is in the Central Flyway (Federal administrative management unit for waterfowl). Mallards, pintails, blue-winged teal, and green-winged teal are the most common dabbling ducks in the region; the first two species constitute one-half to two-thirds of the annual harvest of waterfowl in the Central Flyway (Buller, 1964). The redhead, canvasback, and lesser scaup are common diving ducks in the Flyway.

Site and site vicinity. Eighty species have been observed on, and in the vicinity of, the site (Table H-46). Six of these (mallard, blue-winged teal, green-winged teal, bobwhite, scaled quail, and mourning dove) are classified as game species. Only the scaled quail and the mourning dove, however, are present in huntable numbers (J. Herring, New Mexico Game and Fish Department, personal communication, August 2, 1978). The three duck species were rare visitors observed on stock ponds near the site (Wolfe et al., 1977a).

In addition to scaled quail and mourning dove, mockingbird, loggerhead shrike, pyrrhuloxia, black-throated sparrow, mourning dove, western meadow-

Table H-44. Mammals Observed at, and in the Vicinity of, the Site

Common name[a]	Scientific name[a]	Trophic level[b]	Food type[c]	Abundance
Bats				
Hoary bat	Lasiurus cinereus	C_2C_3	IV	Uncommon
Lagomorphs				
Desert cottontail	Sylvilagus audubonii	C_1	P	Very common
Black-tailed jack rabbit	Lepus californicus	C_1	P	Very common
Rodents				
Mexican ground squirrel	Spermophilus mexicanus	$C_1C_2C_3$	P, S, IV, SV	Uncommon
Spotted ground squirrel	Spermophilus spilosoma	$C_1C_2C_3$	P, S, IV, SV	Very common
Plains pocket gopher	Geomys bursarius	C_1	R	Common
Silky pocket mouse	Perognathus flavus	$C_1(C_2C_3)$	S, P, IV	Common
Plains pocket mouse	Perognathus flavescens	$C_1(C_2C_3)$	S, P, IV	Uncommon
Hispid pocket mouse	Perognathus hispidus	$C_1(C_2)$	S, P, IV	Uncommon
Desert pocket mouse	Perognathus penicillatus	$C_1(C_2C_3)$	S, P, IV	Common
Ord's kangaroo rat	Dipodomys ordii	C_1	P, S	Very common
Banner-tailed kangaroo rat	Dipodomys spectabilis	C_1	P, S	Very common
Merriam's kangaroo rat	Dipodomys merriami	C_1	P, S	Very common
Western harvest mouse	Reithrodontomys megalotis	C_1C_2	P, IV	Uncommon
Deer mouse	Peromyscus maniculatus	$C_1(C_2C_3)$	S, P, IV	Uncommon
White-footed mouse	Peromyscus leucopus	$C_1(C_2C_3)$	S, P, IV	Common
Northern grasshopper mouse	Onychomys leucogaster	$C_1C_2C_3$	S, IV, SV	Very common
Hispid cotton rat	Sigmodon hispidus	$C_1(C_2)$	P	Common
Southern Plains woodrat	Neotoma micropus	C_1	S, F, P	Common
White-throated woodrat	Neotoma albigula	C_1	S, P	Uncommon
Porcupine	Erethizon dorsatum	C_1	P	Uncommon

Table H-44. Mammals Observed at, and in the Vicinity of, the Site (continued)

Common name[a]	Scientific name[a]	Trophic level[b]	Food type[c]	Abundance
Carnivores				
Coyote	Canis latrans	$C_2C_3(C_1)$	V, IV, P	Very common
Badger	Taxidea taxus	C_2C_3	SM	Uncommon
Striped skunk	Mephitis mephitis	$(C_2C_3)C_1$	C, P	Common
Bobcat	lynx rufus	C_2C_3	V	Uncommon
Ungulates				
Mule deer	Odocoileus hemionus	C_1	P	Common

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

[b]Trophic levels C_1, C_2, or C_3) are listed in the order of their relative importance in the forage habitats of the species. The level listed first is most important. Parentheses indicate that the levels are equally important. Data for the trophic levels were obtained from Burt and Grossenheider (1964) and Findley et al. (1975).

[c]Food Type: P = plant tissue; F = fruit, S = seeds; K = roots and tubers; IV = invertebrates; SV = small vertebrates; V = vertebrates.

Table H-45. Game Birds in the Site Region[a]

Common name	Scientific name[b]	Status[c]
Canada goose	Branta canadensis	1
White-fronted goose	Anser albifrons	1
Snow goose	Chen caerulescens	1
Mallard	Anas platyrhynchos	1
Gadwall	Anas strepera	1
Pintail	Anas acuta	1
Green-winged teal	Anas crecca	1
Blue-winged teal	Anas discors	1
Cinnamon teal	Anas cyanoptera	1
American wigeon	Anas americana	1
Northern shoveler	Anas clypeata	1
Redhead	Aythya americana	1
Ring-necked duck	Aythya collaris	1
Canvasback	Aythya valisineria	1
Lesser scaup	Aythya affinis	1
Common goldeneye	Bucephala clangula	1
Bufflehead	Bucephala albeola	1
Ruddy duck	Oxyura jamaicensis	1
Hooded merganser	Lophodytes cucullatus	1
Common merganser	Mergus merganser	1
Red-breasted merganser	Mergus serrator	1
Bobwhite	Colinus virginianus	2
Scaled quail	Callipepla squamata	2
Ring-necked pheasant	Phasianus colchicus	2
Turkey	Meleagris gallopavo	2
Sandhill crane	Grus canadensis	1
Virginia rail	Rallus limicola	1
Sora	Porzana carolina	1
American coot	Fulica americana	1
Common snipe	Capella gallinago	1
Band-tailed pigeon	Columba fasciata	1
Mourning dove	Zenaida macroura	1

[a]Ranges from Bellrose (1976) and Johnsgard (1973, 1975).

[b]Nomenclature follows the American Ornithologists' Union (1957, 1973, 1976).

[c]Key: 1 = migratory species, hunting regulations controlled by Federal government; 2 = permanent resident.

lark, lark bunting, vesper sparrow, Cassin's sparrow, and white-throated sparrow are the avian species present in greatest densities on, and in the vicinity of, the site (Table 3 of Annex 2). The Harris hawk, white-necked raven, Swainson's hawk, marsh hawk, and American kestrel are never more numerous than one per 100 hectares but were sighted consistently. Many other species are present in low densities and in only one or a few months. Many of these are migrants, such as the blue-winged teal, myrtle warbler, Wilson warbler, and clay-colored sparrow.

Rocky escarpments along Livingston Ridge (4 to 5 miles northwest of the site) provide suitable nesting habitat for several raptor species. The marsh hawk, a ground-nesting species, may nest in undisturbed areas near the site.

Table H-46. Birds Observed on and in the Vicinity of the Site

Common name	Trophic level[a]	Abundance
<u>Aquatic birds</u>		
Green heron	C_3C_2	Uncommon
Cattle egret	C_3C_2	Uncommon
<u>Ducks</u>		
Mallard	$C_1C_2C_3$	Incidental
Green-winged teal	$C_1C_2C_3$	Incidental
Blue-winged teal	$C_1C_2C_3$	Incidental
<u>Hawks and allies</u>		
Turkey vulture	C_3C_2	Common
Red-tailed hawk	(C_2C_3)	Common
Swainson's hawk	(C_2C_3)	Common
Ferruginous hawk	(C_2C_3)	Common
Harris' hawk	(C_2C_3)	Common
Marsh hawk	(C_2C_3)	Common
Prairie falcon	(C_2C_3)	Uncommon
American kestrel	(C_2C_3)	Common
<u>Quails and allies</u>		
Bobwhite	C_1	Uncommon
Scaled quail	C_1	Very common
<u>Cranes</u>		
Sandhill crane	(C_2C_3)	Common
<u>Shorebirds</u>		
Killdeer	(C_2C_3)	Common
Black-necked stilt	(C_2C_3)	Common
<u>Doves</u>		
Mourning dove	C_1	Very common
<u>Cuckoos</u>		
Yellow-billed cuckoo	(C_2C_3)	Incidental
Roadrunner	(C_2C_3)	Common
<u>Owls</u>		
Barn owl	C_2C_3	Uncommon
Great horned owl	(C_2C_3)	Uncommon
Burrowing owl	(C_2C_3)	Common
<u>Night hawks</u>		
Poor-will	(C_2C_3)	Uncommon
Common nighthawk	(C_2C_3)	Very common
Lesser nighthawk	(C_2C_3)	Very common
<u>Kingfishers and woodpeckers</u>		
Belted kingfisher	C_2C_3	Uncommon
Red-shafted flicker	C_2C_3	Common
Ladder-backed woodpecker	(C_2C_3)	Common
<u>Perching birds</u>		
Western kingbird	(C_2C_3)	Common
Scissor-tailed flycatcher	(C_2C_3)	Common
Ash-throated flycatcher	(C_2C_3)	Uncommon

Table H-46. Birds Observed on and in the Vicinity of the Site (continued)

Common name	Trophic level[a]	Abundance
Say's phoebe	(C_2C_3)	Common
Western empidonax flycatcher	(C_2C_3)	Incidental
Western wood pewee	(C_2C_3)	Common
Horned lark	$C_1C_2C_3$	Uncommon
Cliff swallow	C_2C_3	Incidental
Blue jay	$(C_1C_2C_3)$	Incidental
White-necked raven	$(C_1C_2C_3)$	Very common
House wren	C_2C_3	Common
Carolina wren	C_2C_3	Common
Cactus wren	C_2C_3	Common
Rock wren	(C_2C_3)	Uncommon
Mockingbird	(C_2C_3)	Common
Brown thrasher	(C_2C_3)	Incidental
Curve-billed thrasher	(C_2C_3)	Common
Crissal thrasher	(C_2C_3)	Common
Sage thrasher	(C_2C_3)	Common
Loggerhead shrike	(C_2C_3)	Very common
Starling	(C_2C_3)	Common
Myrtle warbler	(C_2C_3)	Incidental
Audubon's warbler	(C_2C_3)	Common
Wilson's warbler	(C_2C_3)	Common
House sparrow	(C_2C_3)	Common
Eastern meadowlark	(C_2C_3)	Common
Western meadowlark	(C_2C_3)	Very common
Red-winged blackbird	(C_2C_3)	Uncommon
Bullock's oriole	(C_2C_3)	Incidental
Brewer's blackbird	(C_2C_3)	Common
Brown-headed cowbird	C_2C_3	Common
Pyrrhuloxia	$C_1(C_2C_3)$	Very common
Black-headed grosbeak	$C_1(C_2C_3)$	Very common
House finch	$C_1(C_2C_3)$	Common
Pine siskin	$C_1(C_2C_3)$	Common
American goldfinch	$C_1(C_2C_3)$	Common
Green-tailed towhee	$C_1(C_2C_3)$	Incidental
Rufous-sided towhee	$C_1(C_2C_3)$	Incidental
Lark bunting	$(C_1C_2C_3)$	Very common
Savannah sparrow	$(C_1C_2C_3)$	Common
Baird's sparrow	$(C_1C_2C_3)$	Incidental
Vesper sparrow	$(C_1C_2C_3)$	Very common
Lark sparrow	$(C_1C_2C_3)$	Incidental
Cassin's sparrow	$(C_1C_2C_3)$	Very common
Black-throated sparrow	$(C_1C_2C_3)$	Common
Sage sparrow	$(C_1C_2C_3)$	Common
Oregon junco	$(C_1C_2C_3)$	Common
Clay-colored sparrow	$(C_1C_2C_3)$	Incidental
Brewer's sparrow	$(C_1C_2C_3)$	Incidental
White-crowned sparrow	$(C_1C_2C_3)$	Very common

[a]Trophic levels (C_1 = primary consumer, C_2 = secondary consumer, or C_3 = tertiary consumer) are listed in the order of their relative importance in the forage habits of the species. The level listed first is most important. Parentheses indicate that the levels are equally important. Data for trophic levels were obtained from Robbins et al. (1966).

Reptiles and amphibians

Site region. Amphibians are not an important part of the regional fauna because suitable habitat is limited. However, several amphibian species (e.g., bullfrog and Great Plains toad) thrive in irrigated cropland. Characteristic reptiles in the region include the western box turtle, side-blotched lizard, western whiptail, bullsnake, and prairie rattlesnake.

Site and site vicinity. Eighteen species (2 amphibians and 16 reptiles) are observed in the site vicinity (Table H-47). Suitable habitat for amphibians and aquatic reptiles is limited to stock tanks. Sand dunes, rocky outcrops, and the various shrub associations provide a variety of habitats for several species of reptiles. Species potentially inhabiting the site and site vicinity are listed in Table 4 of Annex 2.

The two amphibian species (tiger salamander and green toad) are both adapted for survival in relatively arid situations. Both require water for breeding and for the aquatic larval stages, but adults can survive periods of drought.

One aquatic and one terrestrial species of turtle are observed. The yellow mud turtle is commonly found in stock tanks and small ponds throughout the region. The western box turtle is more terrestrial and inhabits most habitats with relatively level terrain and adequate vegetative cover.

Lizards (seven species) are the most abundant and conspicuous reptiles, with the side-blotched lizard and the western whiptail common in most habitats. The Texas horned lizard, six-lined racerunner, and Great Plains skink are present but not common. All species are diurnal and primarily insectivorous.

Several species of snakes are common in the area, including the western hognose snake, coachwhip, and western rattlesnake. Less common are the night snake, western diamondback rattlesnake, and massasauga. All species are carnivorous.

Terrestrial invertebrates

Site region. Important crop pests are the alfalfa caterpillar, cutworms, and aphids, which damage alfalfa; and the cotton boll worm and stinkbugs, which attack cotton. Grasshoppers are the principal range pest, destroying both domestic and wildlife forage. The fleas that transmit plague are the only important disease vectors.

Site and site vicinity. Sand crickets, ground beetles, darkling beetles, and ants are the most abundant ground-dwelling insects found. Most of the arthropods collected are scavengers, plant feeders, and granivores. Predatory forms include scorpions, whiptails, spiders, praying mantids, and ants. Ants and grasshoppers are common in all plant communities.

1789 232

Table H-47. Amphibians and Reptiles Observed on and in the Vicinity of the Site

Common name[a]	Scientific name[a]	Trophic level[b]	Food type[c]	Abundance
Amphibians				
Tiger salamander	Ambystoma tigrinum	C_2C_3	I	Common
Green toad	Bufo debilis	C_2C_3	I	Common
Reptiles				
Yellow mud turtle	Kinosternon flavescens	$C_1C_2C_3$	P, I, SV	Very common
Western box turtle	Terrapene ornata	$C_1C_2C_3$	P, F, I	Common
Longnose leopard lizard	Gambelia wislizenii	C_2C_3	I, SV	Uncommon
Lesser earless lizard	Holbrookia maculata	C_2C_3	I	Uncommon
Side-blotched lizard	Uta stansburiana	C_2C_3	I	Very common
Texas horned lizard	Phrynosoma cornutum	C_2C_3	I	Uncommon
Western whiptail	Cnemidophorus tigris	C_2C_3	I	Common
Six-lined racerunner	Cnemidophorus sexlineatus	C_2C_3	I	Uncommon
Great Plains skink	Eumeces obsoletus	C_2C_3	I	Uncommon
Western hognose snake	Heterodon nasicus	C_2C_3	I, SV	Common
Coachwhip	Masticophis flagellum	C_2C_3	I, SV	Common
Gopher snake	Pituophis melanoleucus	C_2C_3	SV	Common
Night snake	Hypsiglena torquata	C_2C_3	SV	Uncommon
Massasauga	Sistrurus catenatus	C_3C_2	SV	Uncommon
Western diamondback rattlesnake	Crotalus atrox	C_3C_2	SV	Uncommon
Western rattlesnake	Crotalus viridis	C_3C_2	SV	Common

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

[b]Trophic levels (C_1 = primary consumer, C_2 = secondary consumer, or C_3 = tertiary consumer) are listed in the order of their relative importance in the forage habitat of the species. The level listed first is most important. Data for trophic levels were obtained from Stebbins (1954, 1966).

[c]Key: P = plant tissue; F = fruit; I = invertebrates; SV = small vertebrates.

Domestic livestock and range management

Domestic livestock. Ranching is the main agricultural enterprise in the site region, and beef cattle are the principal livestock. Most of the cattle are kept on the range throughout the year and are given supplementary feed in winter. In summer, sudangrass, bermuda grass, and stubble are used for temporary grazing while native grasses rest during part of the growing season and produce seed for regrowth (SCS, 1971, 1974).

In 1969, there were about 123,000 beef cattle in Eddy and Lea Counties (BLM, 1973). Other livestock raised in the region are hogs (approximately 12,400 in 1969), sheep (approximately 42,300 in 1969), and a few thousand dairy cows (BLM, 1973). Horses are less common and are used mainly for ranching and recreation. Domestic-poultry farming is quite limited.

Range management. The reference site lies entirely within Deep Sand and Sand Hills range sites (Table 5 in Annex 2). The site vicinity also includes Sandy, Rocky Land, Loamy, Salty Bottomland, and Bottomland range sites (SCS, 1971).

There are three BLM grazing allotments in the site vicinity: Nos. 7032, 7027, and 7033 (BLM, 1978). The site itself is all on allotment 7032, which BLM classifies as in fair condition for livestock grazing. The recent average licensed use of this allotment (BLM, State, and private land) has been, on the average, a little over six head per section. The carrying capacity of the allotments in the site vicinity (an animal unit is defined as the amount of feed required to sustain one adult for 1 year) vary greatly from one section to the next and from one year to the next, depending on rainfall. In addition, allotment 7032 has an allotment management plan (AMP) that BLM revised in 1973. According to the AMP, the actual qualifications for allotment 7032 are for 13,239 AUMs (a little over nine head per section). The AMP indicates grazing deferments of various pastures for different lengths of time. Preliminary revised BLM data for allotment 7032 indicate a suggested stocking rate varying from 7 to 21 acres/AUM, based on a 40 to 60% range utilization. This stocking rate is roughly equivalent to 7.6 to 2.5 head per section, assuming yearlong grazing.

Mesquite-control programs have been implemented in allotments 7033 and 7027, and, according to BLM (1977), have been fairly successful. After the spraying of mesquite, native grasses have increased, thus supporting the historical record that much of the area was once productive grassland.

Plants potentially poisonous to livestock occur throughout the area but cause very little trouble except in extreme weather conditions (BLM, 1977). Both shinnery oak, which is poisonous to cattle during about 6 weeks in the spring, and broom snakeweed are common. Careless weed (Amaranthus palmeri) and senecio (Senecio longilobus) are also likely to occur.

1789 234

H.5.3 Aquatic Ecology

H.5.3.1 The Site Region

Aquatic habitats

The site region is in the basin of the Pecos River, which originates in the Sangre de Cristo Mountains in northern New Mexico. The Pecos River flows to the south through New Mexico and into the Red Bluff Reservoir, continuing southeasterly across western Texas, and joining the Rio Grande. It has an overall length of about 500 miles and drains about 25,000 square miles in New Mexico and 17,000 square miles in Texas. The hydrologic characteristics of the region are discussed in Section 7.3.

The area is semiarid, and away from the river aquatic habitats are limited to intermittent streams and livestock-watering ponds. Poor water quality is characteristic of much of the Pecos River basin in the lower sections. Both surface water and groundwater are contaminated with salt from natural sources (salt springs, brine seeps, or gypsum overburden) and from human activities (e.g., irrigation return flow, potash mining). An important natural source of salt is the concentrated brine springs at Malaga Bend, which increase the salt content of the Pecos River by an estimated 70 tons per day (FWPCA, 1967). These sources progressively concentrate salts downstream.

Seasonally wet, shallow lakes (playas), are also common, and many of them are salty. Permanent salty lakes also occur in the area; an example is the Laguna Grande de la Sal about 11 miles west-southwest of the WIPP site.

Aquatic biota

Although contaminated by natural brines and irrigation return flows, the Pecos River basin supports a diverse floral and faunal community. According to J. E. Sublette (personal communication, 1978), the aquatic fauna of the Pecos River and Red Bluff Reservoir are probably the least known in New Mexico in both species and population density. Thirteen sampling stations have been selected to study the faunal composition of the site, site vicinity, and site region (Figure H-14). Physicochemical data collected at some of these stations are presented in Table 6 of Annex 2.

Fish

Fish have been studied in more detail than other aquatic organisms in the site region. Table 7 of Annex 2 lists fish species collected before 1972, those observed in 1974-1975, and those observed in 1977-1978 surveys.

At present, there is no active commercial fishery in the site region (R. R. Patterson, New Mexico Game and Fish Department, personal communication, January 20, 1978), although several suitable species (carp, carpsucker, small-mouth bass, and various minnows) occur throughout the Pecos River basin.

A limited recreational fishery--based on such warm-water species as crappie, channel catfish, walleye, white bass, bluegill, bullheads, and large-mouth bass--is located in the Pecos River basin. Because of the generally low water quality of the lower Pecos mainstem, most of the recreational fishing activity is concentrated in impoundments on the upper reaches of the Pecos and its tributaries (R. R. Patterson, personal communication, January 20, 1978).

Both warm- and cold-water sport fish are stocked in Chaves, Eddy, and Lea Counties. In the 1973-1974 fiscal year, a total of 1,242,086 fish (trout, channel catfish, and walleye) were stocked (USDA, 1975).

Macroinvertebrates

Studies of the macroinvertebrate communities in the site region began in the spring of 1978. Results from the first survey are presented in Table 8 of

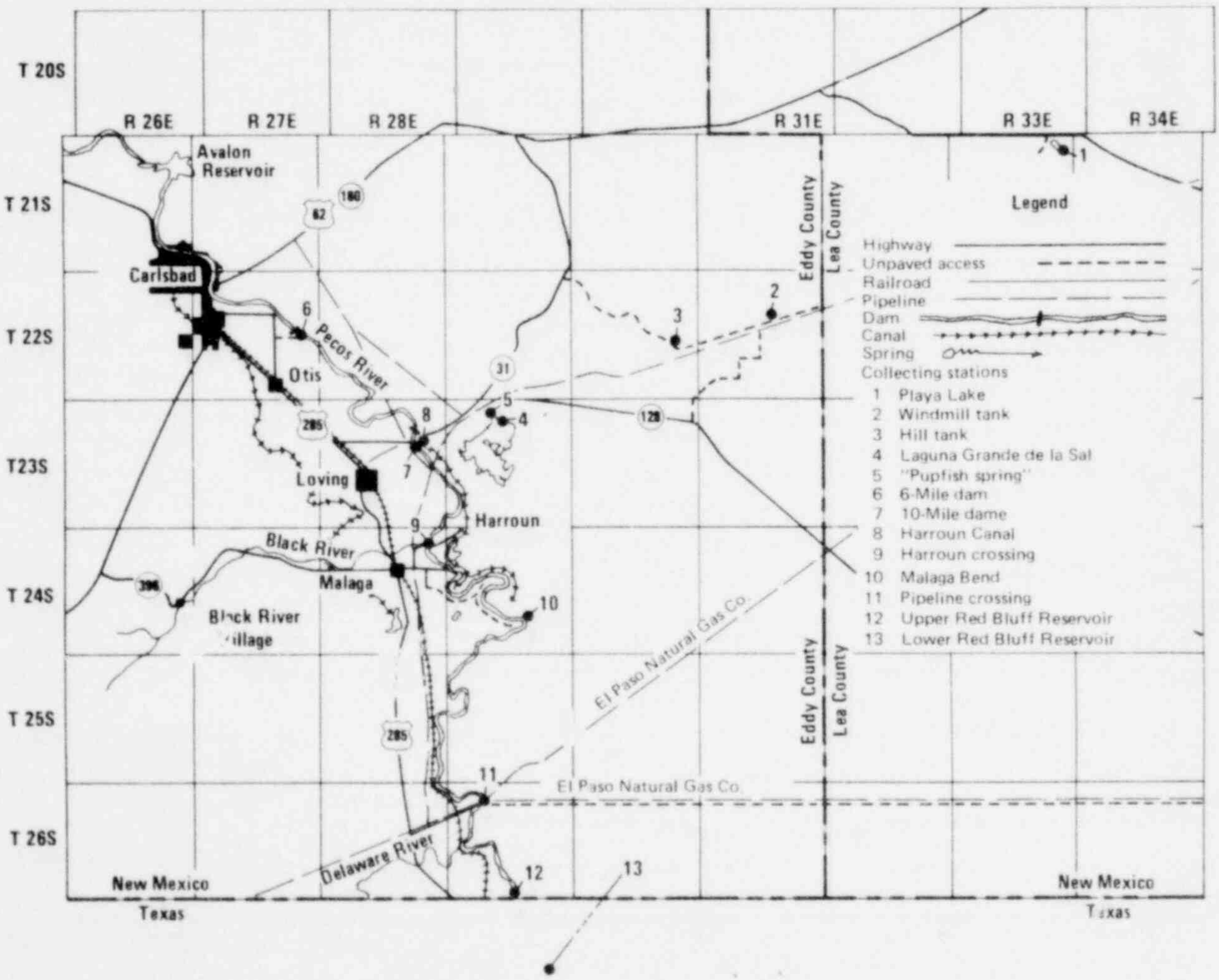


Figure H-14. Map of aquatic collecting stations.

Annex 2. Chironomidae were very abundant in many of the habitats investigated. At Harroun Crossing, the caddisfly family, Hydropsychidae, was also very abundant. Chironomids have been studied in more detail than other aquatic insects throughout New Mexico (Table 9 of Annex 2).

The invertebrate fauna of windmill-pumped water and playa lakes of eastern New Mexico and western Texas has been studied by Sublette (1978). The species found in these habitats are listed in Tables 10 and 11 of Annex 2. Most of the species that successfully invade the windmill-pumped waters are strong fliers and are able to travel considerable distances. The playa lakes contain many temporary pond forms, including the fairy, tadpole, and clam shrimps.

Microorganisms and plankters

The microbial biochemistry investigations of the site region include surface-water studies, subterranean aquifers, and surface soils (Caldwell, 1978). Preliminary microbiological information for surface waters and subterranean aquifers is provided in Table 12 of Annex 2.

Diatoms are the principal planktonic producers in the fresh surface waters of the site region. The flora of Laguna Grande de la Sal consists of Halobacterium spp. and Dunaliella spp. A layer of cyanobacteria and photosynthetic sulfur bacteria was found below the salt crust surrounding the salt lake (Caldwell, 1978). Periphyton (epiphyton, epipelon, and filamentous algae) probably account for most of the production in the Pecos River. No blue-green algae were detected in the Pecos River (Caldwell, 1978).

Vascular plants

Other primary producers in the site region include the vascular aquatic plants. A rather extensive survey of vascular plants has been completed in Chaves, Eddy, and Lea Counties (Martin, cited by Sublette, 1978). The species observed and their distribution are presented in Table 13 of Annex 2.

H.5.3.2 The Site and Site Vicinity

No permanent surface waters exist on the site. There may, however, be ephemeral surface waters in land depressions during thunderstorm periods. This rainfall is generally of brief duration but is occasionally intense. These temporary surface waters on the site provide minimal aquatic habitat.

Surface waters in the site vicinity are limited to livestock-watering ponds, which are either metal or earthen stock tanks. The windmill tank (station 2) and the hill tank (station 3) are being monitored for physical and for biotic characteristics. No macroinvertebrates were found in the February 1978 sampling of the windmill tank, but substantial numbers of seed shrimp (Ostracoda), nonbiting midges (Chironomidae), biting midges (Ceratopogonidae), fingernail clams (Sphaeriidae), aquatic worms (Oligochaeta), and copepods (Copepoda), were collected in the hill tank.

No fish species are known to occur on the site or in the site vicinity.

1789 237

H.5.4 Endangered and Threatened Species

H.5.4.1 Terrestrial Species

Plants

Of the five species proposed for the Federal list of endangered plants (FWS, 1976) in Eddy County, four are located in the Guadalupe Mountains, outside the site region: a cactus species (Coryphantha sneedii var. Leei), milkwort (Polygala rimulicola), wild columbine (Aquilegia chaplinei), and bladderpod (Lesquerella valida). The fifth species is a wild buckwheat (Eriogonum gypsophilum) that occurs on gypsum outcrops about 20 miles north of Carlsbad (Spellenberg, 1977). No species have been proposed for the Federal list of endangered plants for Lea County.

New Mexico does not have an official State list of rare, threatened, or endangered plant species. However, the New Mexico Plant Protection Act of 1953 protects all or some species in 23 plant families and includes some of the species proposed for the Federal list of endangered species in the State.

No plants proposed for the Federal list of endangered or threatened species have been observed on the site or site vicinity, and the lack of suitable habitat makes their occurrence at the site unlikely.

Terrestrial vertebrates

Table H-48 lists the endangered terrestrial vertebrates that have been recently observed in the region of the site. Most of these species are usually associated with habitats that are not on or in the vicinity of the site.

Only two of these species, bald eagle and peregrine falcon, are included on the Federal list. Both species usually forage in the vicinity of larger bodies of water such as the Pecos River and associated reservoirs. Livingston Ridge (4 to 5 miles northwest of the site) provides potential nesting habitat for the peregrine falcon. It is unlikely that either species would be more than an occasional visitor at the site.

One mammal, ten bird, four reptile, and two amphibian species listed as endangered by the State of New Mexico may occur in the site region (Hubbard et al., 1978).

Nelson's pocket mouse is known from a single specimen collected 4 miles west of White City in western Eddy County (Webb, 1954). Although it is highly unlikely than the species inhabits the site or site vicinity, suitable habitat (i.e., desert grassland) is present.

Five of the ten bird species (little blue heron, Mississippi kite, bald eagle, osprey, and peregrine falcon) usually forage and nest near water and would not be expected to inhabit the site or site vicinity. In New Mexico the red-headed woodpecker is strictly associated with planted groves of trees and lower elevation riparian woodland (Hubbard et al., 1978). These habitats do not occur on, or in the vicinity of, the site. The four remaining species

Table H-48. Endangered Terrestrial Vertebrates in the Region of the Site[a]

Common name	Scientific name	Status[b]
Mammals		
Nelson's pocket mouse	Perognathus nelsoni canescens	NM II
Birds		
Little blue heron	Florida caerulea caerulea	NM I
Mississippi kite	Ictinia mississippiensis	NM II
Bald eagle	Haliaeetus leucocephalus	FE, NM I
Osprey	Pandion haliaetus carolinensis	NM II
Peregrine falcon	Falco peregrinus anatum	FE, NM I
Aplomado falcon	Falco femoralis septentrionalis	NM I
Red-headed woodpecker	Melanerpes erythrocephalus caurinus	NM II
Varied bunting	Passerina versicolor	NM II
Baird's sparrow[c]	Ammodramus bairdii	NM II
McCown's longspur	Calcarius mccownii	NM II
Reptiles		
(Texas) slider turtle	Chrysemys concinna texana	NM II
(Sand dune) sagebrush lizard	Sceloporus graciosus arenicolous	NM II
(Blotched) plain-bellied water snake	Natrix erythrogaster transversa	NM II
(Pecos) western ribbon snake	Thamnophis proximus diabolicus	NM II
Amphibians		
(Eastern) barking frog	Hylactophryne augusti latrans	NM II
(Blanchard's) cricket frog	Acris crepitans blanchardi	NM II

[a]Information on status and distribution from Hubbard et al. (1978).

[b]FE = on the Federal list of endangered species; NM I = New Mexico endangered Group I, NM II = New Mexico endangered Group II.

[c]Observed in site vicinity during project field studies.

(Aplomado falcon, varied bunting, Baird's sparrow, and McCown's longspur) occupy habitats similar to those on and near the site and could occur there. In New Mexico the Aplomado falcon is typically found in areas with yucca grasslands and associated shrubby habitats at lower elevations. Baird's sparrow and McCown's longspur are grassland species. A single Baird's sparrow was observed in the vicinity of the site on October 19, 1975; it was evidently a migrant.

Three of the four endangered reptiles inhabiting the site region (Texas slider turtle, blotched plain-bellied water snake, and Pecos western ribbon snake) are associated with aquatic environments and are not likely to inhabit the site or site vicinity. The fourth species, sand dune sagebrush lizard, apparently occurs only on or near active sand dunes. Suitable habitat is available in the vicinity of, but not on, the site.

Both amphibian species listed as endangered in New Mexico are common elsewhere in their ranges. Blanchard's cricket frog inhabits moist terrestrial habitats associated with permanent water, like those along the Pecos River. The Eastern barking frog is usually associated with rocky ledges (usually limestone) and might inhabit the area along Livingston Ridge northwest of the site but is not likely on the site.

H.5.4.2 Aquatic Species

Fish

A number of fish species in the Pecos River basin are considered threatened or endangered (Table H-49) because of their highly restricted distributions and dependence on unique habitats. Two categories of endangered species are recognized by the State of New Mexico: Group I includes those whose prospects or survival or recruitment in the State are in jeopardy; Group II includes species whose prospects of survival or recruitment in the State may be jeopardized in the foreseeable future. Six species within each group are believed to occur in the site region.

The species in Group I include the American eel, blue sucker, gray redhorse, silverband shiner, bluntnose shiner, and Pecos gambusia. The American eel was last taken from New Mexico in 1958 and is possibly extinct; Hubbard

Table H-49. Endangered Fish in the Site Region[a]

Common name	Scientific name	Status[b]
American eel	Anguilla rostrata	NM I
Blue sucker	Cycleptus elongatus	NM I
Gray redhorse	Moxostoma congestum	NM I
Silverband shiner	Notropis shumardi	NM I
Bluntnose shiner	Notropis simus	NM I
Pecos gambusia	Gambusia nobilis	FE[c], NM I
Mexican tetra	Astyanax mexicanus	NM II
Roundnose minnow	Dionda episcopa	NM II
Pecos pupfish	Cyprinodan pecosensis	NM II
Greenthroat darter	Etheostoma lepidum	NM II
Bigscale logperch	Percina macrolepida	NM II
Rainwater killifish	Lucania parva	NM II

[a]Information from Hubbard et al. (1978).

[b]NM I = fish species whose prospects of survival or recruitment in New Mexico are in jeopardy; NM II = species whose prospects of survival or recruitment in New Mexico may become in jeopardy in the foreseeable future.

[c]FE = species on the Federal list of endangered species (Federal Register, Vol. 42, pp. 36420-31, 1977).

1789 240

et al. (1978) suggest that dams on the Pecos River have blocked its migration. The blue sucker is known in New Mexico only from the lower Pecos drainage. Recent records of the blue sucker are from Black River and Pecos River south of Lake McMillan (Hubbard et al., 1978). The gray redhorse is fairly well established only in the Pecos drainage below Lake McMillan. The silverband shiners occur only in the Pecos River of New Mexico. Sublette (1975) collected two specimens of this species from Chaves County, and in 1977 considerable numbers were found below McMillan Dam in Eddy County (Hubbard et al., 1978). Hubbard et al. (1978) stress that reduced flows of the Pecos River have contributed to its extinction. The existence of the bluntnose shiner in New Mexico is questionable. It was not taken in the survey by Sublette (1975). Of the endangered fish species in the New Mexico Group I, the Pecos gambusia is perhaps the most widely publicized because of its Federal status as an endangered species (Federal Register, Vol. 42, p. 135, 1977). It occurs in seven isolated populations in the Bitter Lakes National Wildlife Refuge northeast of Roswell and in a 2-mile portion of Blue Spring (Bednarz, 1975).

Six fish species belong to New Mexico Group II of endangered species (Table H-49). The Pecos pupfish, Cyprinodon pecosensis n.sp. (Eschelle, personal communication, 1978) is of particular interest because of its occurrence in Pupfish Spring (station 5), which issues into Laguna Grande de la Sal and in the Pecos River (station 11). Thus this species occurs in the site region.

Aquatic invertebrates

The only aquatic invertebrate presently listed in either group, the Socorro isopod (Exosphaeroma thermophilum), does not occur in the site region.

H.5.5 Preexisting Environmental Stresses

Several natural and man-induced factors have operated to produce stress on the terrestrial and aquatic ecosystems throughout the site region.

Vegetation often undergoes water stress because of the variable and generally low rainfall in the area. In addition, the sandy soils in the site vicinity and on the site have little water and are susceptible to wind erosion, thus making seedling establishment difficult. High winds in the spring and heavy rains in the summer contribute to soil erosion.

The great quantity of salt naturally occurring in the area is also a major ecological stress in the site region. Much of the water, both surface and ground, is quite salty. A lack of nearby good-quality watering areas is an important limiting factor for many of the wildlife species in the area. Adding to the natural salt loads are the brine effluent and dust (primarily potassium chloride, langbeinite, and potassium sulfate) from potash refineries. The potash industry uses approximately 12,000 acre-feet of fresh water annually and discharges approximately 10,000 acre-feet as brine. This waste commonly goes into tailings ponds from which some brine seeps into the ground. Estimated at about 200 million tons in 1976 and increasing at 14 million tons annually, these tailings consist principally of sodium chloride. Small quantities of these tailings are also airborne; however, the amount airborne is small compared to the 55 tons per day of dust emitted by the potash refineries in the site region.

Vegetation has been severely affected by the potash-mining operations, with a reduction or elimination of vegetation around potash plants, tailings piles, and tailings ponds. The soil area under the tailings piles and brine-disposal area is essentially sterile. The distance from the potash refinery to areas where salt no longer visibly affects vegetation varies, depending on such factors as level of emission, prevailing wind direction, terrain, and soil types. The zone of effect ranges from no effect beyond the refinery site to effects observable nearly a mile away. At some refineries, all native vegetation within 0.25 mile has been killed. Beyond 0.25 mile, the more salt-tolerant species (e.g., greyhorn, allthorn, mesquite, and catclaw) have been defoliated, while salt-tolerant species such as saltbush appear to be growing well. These vegetational modifications in the area have, in turn, modified the wildlife habitat (BLM, 1975).

The most apparent ecological stress at the site itself and in the site vicinity is heavy grazing by livestock. Historically many rangelands in the region have been subject to overgrazing and mismanagement ever since livestock were introduced into the area in the late 1800s (BLM, 1977). It has been estimated that overuse and abuse resulting in the invasion of weedy species and soil erosion, coupled with fire, insect depredations, and drought, have reduced forage production on these lands to about half their potential (SCS, 1975). Persistent heavy grazing by livestock has affected plant species composition and cover and thus has influenced available wildlife forage throughout the area. In addition, to a certain extent, livestock compete with herbivorous wildlife species such as deer, rodents, and granivorous birds for grasses and palatable browse.

The construction of roads or their use by off-road vehicles has also affected the native vegetation and wildlife. Indiscriminate off-road use by vehicles has led to significant animal disturbance, vegetation damage, and soil erosion (BLM, 1977).

H.6 BACKGROUND RADIATION

This section discusses the existing background radiation levels, presents the data currently available, and discusses additional information that will be obtained.

The major components of the external background radiation at any location are (a) cosmic rays, (b) terrestrial radiation sources such as potassium-40 and the decay products of the uranium and thorium series in the earth's crust, and (c) global fallout from nuclear tests in the atmosphere. The background-radiation level can vary between geographical locations by more than twofold. At a specific location, it can also vary, to a lesser extent, with time and with weather conditions. Therefore, the natural variability of background radiation levels at the site must be well documented to determine any facility contribution above this ambient level.

Some preliminary measurements of background radiation were begun at the site early in 1976, in conjunction with the on-site meteorological program. Direct measurements have been made with a Reuter-Stokes pressurized ionization chamber, and a number of thermoluminescent dosimeters (TLDs) have been emplaced in the area (Figure H-15). Sampling to determine the average gross beta-particle concentration in air has also begun. The results of preliminary measurements are summarized in Tables H-50 through H-53; some have been discussed in a recent report (Metcalf and Brewer, 1977). Additional data will be required to permit accurate comparison of preoperational and operational dose contributions at specific locations or by specific pathways.

Table H-50. Background Radiation Measured in 1977 at the WIPP Reference Site with a Reuter-Stokes Pressurized Ion Chamber

Exposure period		Radiation exposure (μR/hr)		
Begin	End	Average	Maximum	Minimum
8/22	8/28	7.83	9.30	6.82
8/29	9/4	7.74	10.27	6.52
9/5	9/11	7.78	9.73	6.30
9/12	9/18	7.83	9.66	6.36
9/19	9/25	7.77	9.57	6.33
9/26	10/2	7.88	9.64	6.69
10/3	10/9	7.99	11.58	6.84
10/10	10/16	7.81	9.02	6.52
10/17	10/23	8.04	11.30	6.54
10/24	10/30	7.93	10.24	6.86
10/31	11/6	7.89	10.71	5.98
11/7	11/13	7.97	11.45	5.94
11/14	11/20	8.01	12.12	5.79
11/21	11/27	8.00	12.29	6.12
11/28	12/4	8.04	12.39	6.28
12/5	12/11	8.14	14.18	6.68
12/12	12/18	8.06	12.95	6.65
12/19	12/25	7.99	14.80	6.47
12/26	12/31	8.11	10.78	6.58
Yearly average		7.94[a]	11.16	6.44

[a]A similar average measurement in Albuquerque showed an exposure rate of about 15 μR/hr, which illustrates the types of spatial variation that can be expected in the Mountain States, where elevations vary greatly.

From data published by the National Council on Radiation Protection and Measurements (NCRP, 1975), the annual external whole-body exposure rates at the site from cosmic rays, terrestrial sources, and global fallout are estimated to be 37, 26, and 1 mrad, respectively, for a total of 64 mrad (or 64 mrem if a quality factor of 1 is assumed). These data were partly based on a flyover of an area that now includes the site. The aerial survey was part of the Aerial Radiological Measurement Surveys (ARMS), conducted for the U.S. Atomic Energy Commission during the period 1958 to 1963. A second aerial survey of the site area was made in September 1977 under the Aerial Measuring Systems (AMS)

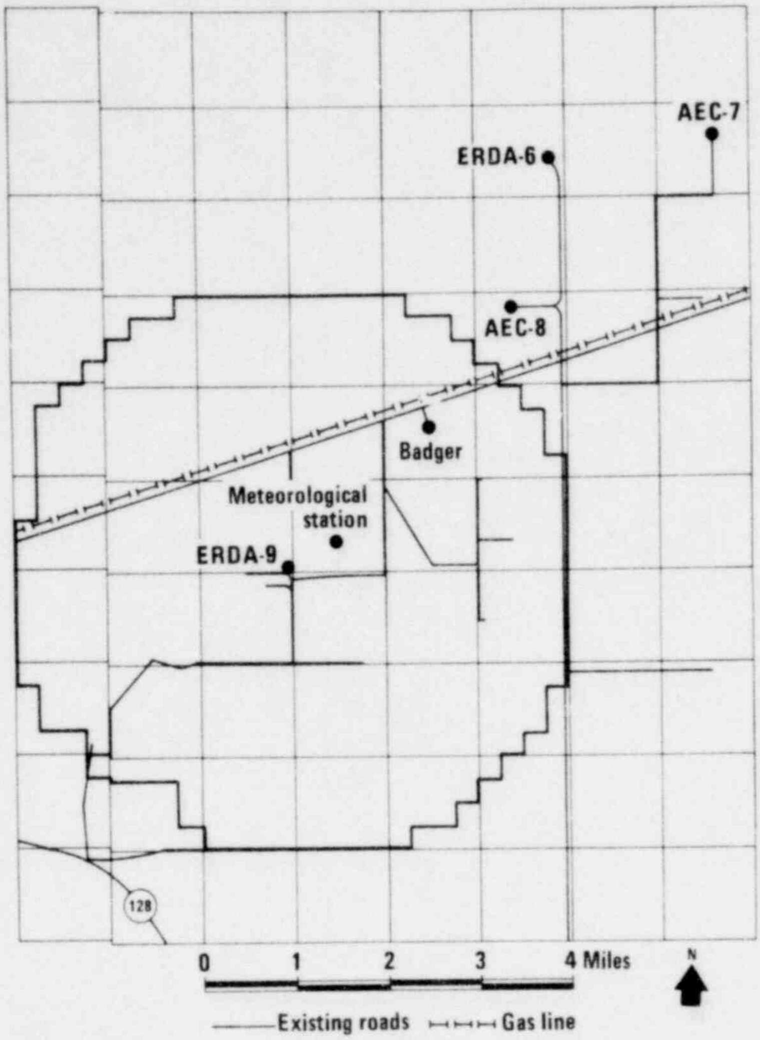


Figure H-15. Locations of thermoluminescent dosimeters in the site area. An additional thermoluminescent dosimeter will be located in Carlsbad.

Program, the successor to the ARMS program (Jobst, 1977). The later flyover was made to both verify the data collected by the first aerial survey and also to locate any areas of abnormally high radiation levels (hot spots). The data are presently being evaluated. If any hot spots are located, air samplers and thermoluminescent dosimeters will be emplaced at such locations to obtain more information.

The data published by the NCRP (1975) and the latest flyover data, when reduced, can be compared with the background-radiation data presented in Tables H-50 and H-51, which were collected with ground-based monitoring equipment. For example, between August 22 and December 31, 1977, the average dose rate measured in the area with the Reuter-Stokes pressurized ionization chamber was 7.9 μR/hr (approximately 69 mR/yr), with a maximum of 14.8 μR/hr and a minimum of 5.8 μR/hr (Table H-50). The average dose rate compares favorably with the NCRP data. The dose rates measured by the thermoluminescent dosimeters (Table H-51) indicate a somewhat higher background-radiation level, but no significant

Table H-51. Thermoluminescent Dosimeter Data from the Site Area--1977

Location	First quarter 1/10/77 to 4/12/77		Second quarter 4/12/77 to 7/18/77		Third quarter 7/18/77 to 10/7/77		Fourth quarter 10/7/77 to 1/9/78	
	mR	μR/hr	mR	μR/hr	mR	μR/hr	mR	μR/hr
Sandia Office (Carlsbad)	28.1±3.7	12.7±1.6	25.1±2.3	10.8±1.0	24.4±4.4	12.6±2.3	22.0±3.1	9.8±1.4
Meteorological station					18.6±3.9	9.6±2.0	19.0±2.7	8.4±1.2
Old Badger drill site	24.4±4.2	11.0±1.9	19.7±2.4	8.5±1.0	22.8±3.7	11.7±1.9	19.0±3.1	8.4±1.4
ERDA-6	25.7±3.6	11.6±1.6	19.9±2.6	8.5±1.1	21.3±3.8	11.0±2.0	21.5±3.3	9.5±1.5
AEC-7	24.9±3.7	11.3±1.7	22.5±2.8	9.7±1.2	21.4±3.6	11.0±1.9	19.7±3.0	8.7±1.3
AEC-8	24.4±4.1	11.0±1.9	20.1±2.4	8.6±1.0	18.0±3.2	9.3±1.6	16.7±3.1	7.4±1.4
ERDA-9	26.8±3.6	12.1±1.6	19.2±2.3	8.2±1.0	17.0±3.8	8.7±2.0	17.7±2.8	7.8±1.2

NOTES

1. The reported precision of each measurement includes a statistical propagation of errors resulting from calibration procedures, the correction for dosimeter response during transit and storage, and variations in the TLD response of the five chips at each measurement location.

2. The differences between the TLD and ion-chamber data are probably due to differences in the wall thicknesses of the two systems (240 mg/cm^2 for TLDs and ~2400 mg/cm^2 for the ion chamber).

3. Variations in TLD data from quarter to quarter are probably due to the method of field installation of the TLD package. The dosimeters are exposed in a hollow pipe capped on the end that is above the ground. This pipe may act as a reservoir for radon and thoron emanations, increasing the local radiation field around the dosimeter package. This effect would be more apparent in the dry climate of the WIPP area, which has periods of precipitation alternating with dry periods.

4. The effects mentioned in notes 2 and 3 will be studied further in the 1979 calendar year.

Table H-52. Monthly Average Gross Beta Concentrations in Air at the Site--1976

Month	Average gross beta concentration (pCi/m^3)	Month	Average gross beta concentration (pCi/m^3)
February	0.016	August	0.019
March	0.024	September	0.017
April	0.019	October	0.427[a]
May	0.020	November	0.226[a]
June	0.017	December	0.075[a]
July	0.012		

[a]Increase because of nuclear explosions in the atmosphere conducted by the People's Republic of China on September 26 and November 17.

Table H-53. Average Gross Beta Concentrations in Air at the Site--1977

Month	Average gross beta concentration (pCi/m^3)	Month	Average gross beta concentration (pCi/m^3)
January	0.041	July	0.101
February	0.048	August	0.045
March	0.082	September	0.753
April	0.127	October	0.111
May	0.175	November	0.075
June	0.173	December	0.072

differences are noted. Background-radiation levels at the WIPP site are expected to be similar to, or lower than, those in other parts of the Mountain States--lower especially than the levels at higher elevations, where cosmic-ray doses are greater.

Naturally occurring sources of radiation (e.g., potassium-40) are present in the human body and contribute an internal component to the total background-radiation dose. Thus, if an internal annual whole-body dose of 25 mrem (EPA, 1977) is added to the 64-mrem external dose, the estimated background-radiation whole-body dose at the site is approximately 90 mrem.

In December 1961 a nuclear device was detonated at the Project Gnome site, 9 miles south-southwest of the site. A venting of radioactive material during the explosion as well as postshot activities contaminated nearby ground surfaces. Sampling programs conducted by the EPA have shown that there would be no significant radiological hazard to man from the ingestion of resident wildlife that were possibly affected by the Gnome event. The impact of the Gnome event on the site background-radiation levels is also negligible.

H.7 NOISE BACKGROUND

The location of the site has been remote from human intrusion and thus from man-induced noise. Measurements indicate background noise levels in the range of 26 to 28 dBA. Noise sources were animals (birds, cattle), wind, occasional traffic, aircraft, intermittent use of heavy equipment, and (in the distance) potash-mine ventilation fans. Movement of drilling machinery to and from the site has led to the construction of a number of unimproved roads. The occasional use of these roads introduces a new, but minor, noise source to the area.

H.8 THE FUTURE OF THE SITE

H.8.1 Climatic Changes

Future climate changes cannot be predicted with great certainty at this time because of the complexity of atmospheric-oceanic-extraterrestrial interactions (Mitchell, 1968), complicated by the impacts of human activities. Although climatic experts have varying opinions, there appears to be a consensus (National Defense University, 1978) that there will not be a catastrophic climatic change during the next couple of decades. The long-term (thousands of years) natural trend is for another ice age (Keeling and Bacastow, 1977; Mitchell, 1978). However, man's impact on the climate could counterbalance this trend or result in a warming trend, possibly a global warming of 4.5 to 13°F or more, with greater aridity in the Western United States starting within the next century (Kukla and Matthews, 1972; Norwine, 1977). The possible variability in the next 10,000 to 20,000 years of the climate in the site region is similar to that experienced during the latter portion of the Pleistocene and the Holocene, as described in Section H-4. The climate of New Mexico may range from that associated with glaciers to the north (rainfall about 60-70% greater than at present and summer temperatures about 20°F less than at present) to that associated with interglacial periods (global temperatures about 3°F warmer and greater aridity in the Southwest than at present).

If continental glaciation returns, there is no possibility that the site itself will be glaciated, judging from the Pleistocene record; the increased rainfall, however, will increase the amount of water in the Pecos River, will increase the amount of vegetation in the regions, and will cause the composition of the vegetation to shift toward prairie grasslands. If, on the other hand, man's influence causes a global warming, flow in the Pecos will decrease, and the region will shift toward the flora of the Chihuahuan desert.

H.8.2 Demographic Changes

The population of the area is expected to change very little in the next few decades. It will grow slowly. The number of workers at nearby mines and at oil and gas wells in the area is not expected to change significantly. A ranch house will probably be built about 8 miles west-southwest of the site. A small trailer park is being built on private land on U.S. Highway 62-180 east of the intersection with N.M. Highway 360.

Population changes beyond the next few decades cannot be predicted in any detail. However, the return of glaciation would probably result in an increase in population and in intensity of land use as the mass of the human population is forced to move south. A global warming would be expected to make little, if any, change in population.

H.8.3 Land-Use Changes

There is very little private land within 30 miles of the site. Most of the land is State or Federal land. The dominant use of the land in and near the site is grazing at levels of 6 to 8 animals per square mile. There are also many active oil and gas wells. The only agricultural land within 30 miles is along the Pecos River near Carlsbad and Loving. With or without the WIPP, this pattern of land use is expected to change little in the near future.

Beyond the next few decades, the return of glaciation and the accompanying increase in rainfall would probably mean an increase in land use, perhaps including a shift from grazing to dry-land farming. A global warming would be expected to make little change in land use.

H.8.4 Geologic Changes

There has been no major tectonic activity at the site since the subsidence of the Delaware basin about 225 million years ago. Other major activity has been uncommon and not close to the site; even the most recent of these events occurred over 1 million years ago. The age of the structural features and the lack of evidence for presently active tectonic processes indicate that stable conditions similar to the recent past can be expected to continue in the near geologic future. This means that the only tectonic activity that may occur in the future is an indeterminately small regional upwarping.

Both erosional-depositional and salt dissolution-collapse processes are responsible for many of the landforms at the site and the region. In the past these processes and resulting features have been significantly affected by changes in climate. Although there have been many small climatic cycles, past worldwide glacial ice advances and interglacial periods have been alternating in 100,000-year cycles (Norwine, 1977). As indicated in Section H.4.6, the stage of the glacial-interglacial period cycle has a great effect on the climate of the Delaware basin. During interglacial times, the site has been warm and dry, while during glacial periods the site climate has been cooler and more humid. If, as Norwine suggests, the worldwide climate continues to move along 100,000-year cycles, two glacial periods and two interglacial periods are possible during the next 250,000 years.

1789 248

Surface and near-surface processes can be used to some degree to estimate future erosion and deposition at the site. Though wind erosion can be expected to produce blowouts and dunes in the near future, eolian features will be minor and local. For the last million years, erosion at the site has exceeded deposition; however, the thickness of the resistant caliche cover at the site indicates that there has been no significant erosion since its formation 500,000 years ago. Erosion of this layer will resume only when climatic conditions at the site become more humid (Powers et al., 1978, p. 3-24). If the site becomes more humid, water runoff will drain toward and along Nash Draw and San Simon Swale, increasing erosion in these areas. Since the site is on a divide between these two features, it will not be significantly affected by fluvial erosion.

The process of salt dissolution and collapse can be expected to continue. The solution front at the Rustler-Salado interface will move over the site. Based on Bachman and Johnson's (1973) estimate of dissolution rates, surface subsidence due to dissolution of the top of the Salado will lower the land surface by about 125 feet over the next 250,000 years. Related collapse features (sink-holes, solution troughs, downwarps, fractured strata, and breccias) can be expected to form in future subsidence areas.

REFERENCES

Adcock, Larry and Associates, 1977-1978. Demographic analysis using personal interviews with county officials: Clerk, Lee County, February 1978; Clerk, Eddy County, New Mexico, February 1978; Clerk, Loving County, New Mexico, February 1978; Clerk, Winkler County, Texas, March 19, 1978; various U.S. Geological Survey maps; Bureau of Land Management, land-use maps; and quadrangles of the State of New Mexico, 1963 and 1965, from the New Mexico Highway Department, Planning Division.

Alexander, T., 1974. "Ominous Changes in the World's Weather," Fortune, 89(2), pp. 90-95ff.

American Ornithologists' Union, 1957. Checklist of North American Birds, 5th ed., Baltimore, Md.

American Ornithologists' Union, 1973. Thirty-second Supplement to the American Ornithologists' Union Check-list of North American Birds, Auk, 90, pp. 411-419.

American Ornithologists' Union, 1976. Thirty-third Supplement to the American Ornithologists' Union Check-list of North American Birds, Auk, 93, pp. 875-879.

Anderson, B. W., 1971. "Man's Influence on Hybridization in Two Avian Species in South Dakota," Condor, 73, pp. 342-347.

ANSI (American National Standards Institute), 1972. "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures," ANSI A58.1-1972, revised A58.1-1955.

Antevs, E., 1954. "Climate of New Mexico During the Last Glacio-Pluvial," Journal of Geology, 62, pp. 182-191.

Austin, M. E., 1972. Land Resource Regions and Major Land Resource Areas of the United States, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

Bachman, G. O., and R. B. Johnson, 1973. Stability of Salt in the Permian Salt Basin of Kansas, Oklahoma, Texas, and New Mexico, with a section on Dissolved Salts in Surface Water by F. A. Swenson, Open-File Report 73-14, U.S. Geological Survey, Denver, Colo.

Bailey, R. D., 1976. Ecoregions of the United States, U.S. Department of Agriculture, Forest Service, Ogden, Utah.

Baldwin, J. L., 1972. Climates of the United States, National Oceanic and Atmospheric Administration, Washington, D.C.

BBER (Bureau of Business and Economic Research), 1962. New Mexico Population Since 1910, Business Information Series No. 40.

BBER (Bureau of Business and Economic Research), 1977a. Community Profile: Carlsbad-Eddy County, University of New Mexico.

BBER (Bureau of Business and Economic Research), 1977b. Community Profile: Hobbs-Lea County, University of New Mexico.

Bednarz, J., 1975. A Study of the Pecos Gambusia, unpublished report to Endangered Species Program, New Mexico Department of Game and Fish, 30 pp.

Bellrose, F. L., 1976. Ducks, Geese and Swan of North America, Stackpole, Harrisburg, Penn.

Bennett, M. D., 1977. "Medically Underserved Areas of New Mexico," working paper, School of Medicine, University of New Mexico.

Best, T., 1978. Draft Biological Program for the Waste Isolation Project, prepared for Sandia Laboratories, Albuquerque, N.M.

BLM (U.S. Bureau of Land Management), 1973. Socio-Economic Data Systems, Roswell, New Mexico, BLM Office, computer printouts by county, unpublished.

BLM (U.S. Bureau of Land Management), 1975. Preliminary Regional Environmental Analysis Record--Potash Leasing in Southeastern New Mexico, Department of the Interior, New Mexico State Office.

BLM (U.S. Bureau of Land Management), 1977. East Eddy Planning Unit; Unit Resource Analysis, Department of the Interior, Roswell, N.M.

BLM (U.S. Bureau of Land Management), 1978. Unpublished files of Grazing Allotments No. 7027, No. 7032, and No. 7033, Department of the Interior, Roswell, N.M.

Brooks, C. E. P., 1970. Climate Through the Ages (2nd rev. ed.), Dover Publications, Inc., New York.

Buller, R. J., 1964. "Central Flyway," Waterfowl Tommorow, pp. 209-232, J. P. Linduska, ed., U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Burt, W. H., and R. P. Grossenheider, 1976. A Field Guide to the Mammals, Houghton Mifflin, Boston, Mass.

Caldwell, D. E., 1978. "Preliminary Report for Los Medanos Biology Program," Microbiol. Biogeochemistry (February 4, 1978-February 16, 1978), unpublished.

Campbell, R. S., 1929. "Vegetative Succession in the Prosopis Sand Dunes of Southern New Mexico," Ecology 10(4), pp. 392-398.

Carlsbad Department of Development, 1977-1978. This is Carlsbad, New Mexico.

Carlsbad School District, 1977. Forty-Day Average Daily Membership.

Castetter, E. F., 1956. "The Vegetation of New Mexico," University of New Mexico, Albuquerque, N.M., Third Annual Research Lecture, pp. 257-288.

City of Carlsbad, 1978. Building permit data.

1789 251

City of Hobbs, 1978. Housing Count.

Donart, G. B., D. D. Sylvester, and W. C. Hickey, 1978. Potential Natural Vegetation of New Mexico, U.S. Department of the Interior, Soil Conservation Service, Portland, Ore.

Eagleman, J. R., 1976. The Visualization of Climate, D.C. Heath and Co., p. 2.

EDS (Environmental Data Service), 1968. Weather Atlas of the United States (originally titled Climatic Atlas of the United States), reprinted in 1975 by the Gale Research Co.

EPA (U.S. Environmental Protection Agency), 1977. A Compilation of Air Pollutant Emission Factors, AP-42, 3rd ed.

ESCNM (Employment Secruity Commission of New Mexico), 1975-1978. Research and Statistics Division, various published and unpublished data.

Findley, J. S., et al., 1975. Mammals of New Mexico, University of New Mexico Press, Albuquerque, N.M.

Flint, R. F., 1967. Glacial and Pleistocene Geology, John Wiley & Sons, Inc., New York.

Fujita, T. T., 1978. A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico, Research Project, Department of Geophysical Sciences, University of Chicago, SMRP Research Paper No. 155.

FWPCA (U.S. Federal Water Pollution Control Administration), 1967. Immediate Water Pollution Control Needs, Pecos River Basin, New Mexico and Texas, PB-266-387, South Central Region, Dallas, Texas.

FWS (U.S. Fish and Wildlife Service), 1976. "Endangered and Threatened Species, "Department of the Interior, Washington, D.C.; Federal Register, 41(117), pp. 24524-24572.

FWS (U.S. Fish and Wildlife Service), 1977. "Endangered and Threatened Wildlife and Plants," Department of the Interior, Washington, D.C.; Federal Register, 42(135), pp. 36420-36431.

Gardner, J. L., 1951. "Vegetation of the Creosote Bush Area of the Rio Grande Valley in New Mexico," Ecological Monographs, 21, pp. 379-403.

Gates, W. L., 1976. "Modeling the Ice-Age Climate," Science, 191(4232), pp. 1138-1144.

Holzworth, G. C., 1972. Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States, U.S. Environmental Protection Agency (EPA), Research Triangle Park, N.C.

Hosler, C. R., 1961. "Low-Level Inversion Frequency in the Contiguous United States," Monthly Weather Review, 89(9), pp. 319-339.

Hubbard, J. P., M. C. Conway, H. Campbell, G. Schmitt, and M. D. Hatch, 1978. Handbook of Species Endangered in New Mexico, New Mexico Department of Game and Fish.

HUD (U.S. Department of Housing and Urban Development), 1975. Postal Vacancy Survey, Federal Housing Administration Director's Release.

Humphrey, R. R., 1953. "The Desert Grassland, Past and Present," J. Range Management, 6, pp. 159-164.

Industrial Development Corporation of Lea County (IDCLC), 1978. Data, Hobbs, New Mexico.

Jennings, A. H., 1963 (rev.). Maximum Recorded U.S. Point Rainfall, Weather Bureau Technical Paper No. 2, U.S. Department of Commerce.

Jobst, J., 1977. "The Aerial Measuring Systems (AMS) Program, Equipment and Instrumentation," presented at the American Nuclear Topical Symposium: Aerial Techniques for Environmental Monitoring, March 8.

John, B. S., 1977. The Ice Age Past and Present, William Collins Sons & Co., Ltd., London, p. 144.

Johnsgard, P. A., 1973. "North American Game Birds of Upland and Shoreline," University of Nebraska, Lincoln, Nebr.

Johnsgard, P. A., 1975. Grouse and Quails of North America, University of Nebraska, Lincoln, Nebr.

Jones, J. K., Jr., D. C. Carter, and H. H. Genoways, 1975. "Revised Checklist of North American Mammals North of Mexico," Occas. Papers Mus., Texas Technical University, 28, pp. 1-14.

Keeling, C. D., and R. B. Bacastow, 1977. Impact of Industrial Gases on Climate, Energy and Climate, National Academy of Sciences, Washington, D.C., pp. 72-82.

Kuechler, A. W., 1975. "Potential Natural Vegetation of the Conterminous United States," Amer. Geographical Society, New York.

Kukla, G. J., 1976. "Around the Ice Age World," Natural History, 85, pp. 56-61.

Kukla, G. J., and R. K. Matthews, 1972. "When Will the Present Interglacial End?" Science, 178(4057), pp. 190-191.

Lamb, H. H., 1966. The Changing Climate, Methuen & Co., Ltd., London, England.

Markee, E. H., Jr., J. G. Beckerly, and K. E. Sanders, 1974. Technical Basis for Interim Regional Tornado Criteria, WASH-1300, U.S. Atomic Energy Commission, Washington, D.C.

Metcalf, J. H., and L. W. Brewer, 1977. Environmental Monitoring at the WIPP Site CY 1976, SAND77-1021, Sandia Laboratories, Albuquerque, N.M.

Mitchell, J. M., Jr., ed., 1968. "Causes of Climate Changes," Meteorological Monograph, American Meteorological Society, 8(30), pp. 155-159.

NAS/NRC (National Academy of Sciences/National Research Council), 1975. Understanding Climate Change, A Program for Action, Washington, D.C., pp. 43-46.

NAS/NRC (National Academy of Sciences/National Research Council), 1977. Climate, Climate Change and Water Supply, Washington, D.C., pp. 43-45.

NCRP (National Council on Radiation Protection and Measuremments), 1975. Natural Background Radiation in the United States, NCRP Report No. 45, Washington, D.C.

National Defense University, February 1978. Climate Change to the Year 2000, A Survey of Expert Opinions, Defense Documentation Center, Alexandria, Va., pp. xvii-xx.

NMDFA (New Mexico Department of Finance and Administration), 1970a. Annual Report, New Mexico Municipal Governments, various years.

NMDFA (New Mexico Department of Finance and Administration), 1970b. Annual Report, New Mexico County Governments, various years.

NMDFA (New Mexico Department of Finance and Administration), 1978a. Annual Report, New Mexico Municipal Governments, various years.

NMDFA (New Mexico Department of Finance and Administration), 1978b. Annual Report, New Mexico Municipal Governments, various years.

NMDFA (New Mexico Department of Finance and Administration), 1978c. Statistics, Public School Finance, various years.

NMDFA (New Mexico Department of Finance and Administration), 1978d. Municipal Quarterly Cash Reports.

NOAA (National Oceanic and Atmospheric Administration), 1972-1976. Climatological Data, National Climatic Center.

NOAA (National Oceanic and Atmospheric Administration), 1974. Climates of the United States, Vol. 2--Western States, Roswell, New Mexico, Water Information Center, Inc., Port Washington, N.Y., p. 883.

NOAA (National Oceanic and Atmospheric Administration), 1977. Local Climatological Data, Annual Summary (1977) with Comparative Data, Roswell, New Mexico, National Climatic Center, Asheville, N.C.

NOAA (National Oceanic and Atmospheric Administration), 1978. Local Climatological Data, Annual Summaries for 1977, Roswell, New Mexico, National Climatic Center, Asheville, N.C.

Norwine, J., 1977, "A Question of Climate," Environment, 19(8), pp. 6-2.

NRC (U.S. Nuclear Regulatory Commission), 1976. "Preparation of Environmental Reports for Nuclear Power Stations," Regulatory Guide 4.2, NUREG-0099, July.

Pautz, M. E., ed., 1969. "Severe Local Storm Occurrences, 1955-1967," Technical Memorandum WBTM FCST 12, Environmental Sciences and Services Administration (ESSA), U.S. Department of Commerce, Silver Spring, Md.

1789 254

Powers, D. W., S. J. Lambert, S.-E. Shaffer, L. R. Hill, and W. D. Weart, eds., 1978. Geological Characterization Report for the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, in two volumes, SAND78-1596, Sandia Laboratories, Albuquerque, N.M.

Richmond, G. M., 1965. "Glaciations of the Rocky Mountains," The Quaternary of the United States, H. E. Wright, Jr., and D. E. Grey (eds.), Princeton University Press, Princeton, N.J.

Richmond, G. M., 1972. "Appraisal of the Future Climate of the Holocene in the Rocky Mountains," Quaternary Research, 2, pp. 315-322.

Robbins, C. S., B. Bruun, and H. Zim, 1966. Birds of North America, Golden Press, New York.

Sauer, C. O., 1950. "Grassland Climax, Fire, and Man," Journal of Range Management, 3, pp. 16-21.

Schwarzbach, M., 1963. Climates of the Past, An Introduction to Paleoclimatology, R. O. Muih (trans. and ed.), D. Van Nostrand Company, Ltd., Princeton, N.J.

SCS (U.S. Soil Conservation Service), 1971. Soil Survey of Eddy Area, New Mexico, U.S. Department of Agriculture, Government Printing Office, Washington, D.C.

SCS (U.S. Soil Conservation Service), 1974. Soil Survey of Lea County, New Mexico, Department of Agriculture, Government Printing Office, Washington, D.C.

SCS (U.S. Soil Conservation Service), 1975. Sureste Resource Conservation and Development Project, Department of Agriculture Program Action, prepared by the Resource Conservation and Development Council.

Sellers, W. D., 1965. Physical Climatology, University of Chicago Press, Chicago, Ill.

Shantz, H. L., 1917. "Plant Succession on Abandoned Roads in Eastern Colorado," J. Ecology, 5, pp. 19-42.

SSAR (Society for the Study of Amphibians and Reptiles), 1978. Standard Common and Current Scientific Names for North American Amphibians and Reptiles, No. 7.

Spellenberg, R., 1977. "A Synopsis of Federally Proposed Threatened or Endangered Plant Species in New Mexico," prepared for the U.S. Bureau of Reclamation, El Paso, Tex.

Start, G. E., and L. L. Wendell, 1974. Regional Effluent Dispersion Calculations Considering Spatial and Temporal Meteorological Variations, NOAA TM ERL ARL-44, Air Resources Laboratories, Idaho Falls, Idaho.

Stebbins, R. C., 1954. Amphibians and Reptiles of Western North America, McGraw Hill Co., New York.

Stebbins, R. C., 1966. A Field Guide to Western Reptiles and Amphibians, Houghton Mifflin, Boston, Mass.

Sublette, J. E., 1975. A Survey of the Fishes of the Pecos, Canadian and Arkansas Drainage in New Mexico, unpublished report to Endangered Species Program, New Mexico Department of Game and Fish.

Sublette, J. E., 1978. Quarterly Progress Reports-Aquatic Ecosystems, RFQ07-1489 (December 15, 1977-February 15, 1978), unpublished.

Thom, H. C. S., 1963. Tornado Probabilities, Monthly Weather Review, October-December, pp. 730-736.

Thom, H. C. S., 1968. New Distributions of Extreme Winds in the United States, American Society of Civil Engineers.

Tiebout, C., 1962. "The Community Economic Base Study," Supplementary Paper 16, p. 74, Committee for Economic Development.

Turner, D. B., 1964. "A Diffusion Model for an Urban Area," J. Appl. Meteorology, 3, pp. 83-91.

U.S. Army, Quartermaster Research and Engineering Center, 1958. Hail Size and Distribution, Technical Report EP-83.

USBM (U.S. Bureau of Mines), 1978. Annual Mineral Industry Survey Department of the Interior, Washington, D.C.

U.S. Department of Agriculture, 1975. Sureste Resource Conservation and Development Project, Program Action, prepared by the Resource Conservation and Development Council.

U.S. Department of Commerce, Bureau of the Census, 1970a. Census of Housing.

U.S. Department of Commerce, Bureau of the Census, 1970b. Census of Population, 4th County Summary (Computer) Tapes for New Mexico.

U.S. Department of Commerce, Bureau of the Census, 1970c. Census of Population, Series PC(1)-A33.

U.S. Department of Commerce, Bureau of Economic Analysis, 1975-1978. Regional Measurement Division, unpublished data (computer printouts).

U.S. Department of Commerce, Bureau of the Census, 1977a. "Gross Migration by County 1965 to 1970," Current Population Reports, Series P-25, No. 701, May.

U.S. Department of Commerce, Bureau of the Census, 1977b. "Population Estimates," Current Population Reports, Federal State Cooperative Program, Series P-26, No. 76-31.

U.S. Department of the Interior, National Park Service, Southwest Region, 1970-1978. Public Use in the Southwest Region, various monthly issues.

Wallmo, O. C., 1975. "Important Game Animals and Related Recreation in Arid Shrublands of the United States," Arid Shrublands, Proceedings of the Third Workshop of the United States/Australia Rangelands Panel, pp. 98-107, Tucson, Ariz.

Weaver, J. E., and F. W. Albertson, 1956. Grasslands of the Great Plains, Johnsen Publishing Company, Lincoln, Nebr.

Webb, O., 1954. "Perognathus nelsoni canescens in New Mexico," J. Mammalogy, 35, pp. 453.

Whitfield, C. J., and H. L. Anderson, 1938. "Secondary Succession in the Desert Plains Grassland," Ecology, 19(2), pp. 171-180.

Whitfield, C. J., and E. L. Beuther, 1938. "Natural Vegetation in the Desert Plains Grassland," Ecology, 19, pp. 26-37.

Wingfield, D. W., 1955. "Trees Versus Water and Grass," J. Range Management, 4, pp. 149-150.

Wolfe, H. G., et al. (eds.), 1977a. An Environmental Baseline Study of the Los Medanos Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report, SAND77-7017, Sandia Laboratories, Albuquerque, N.M.

Wolfe, H. G., et al. (eds.), 1977b. An Environmental Baseline Study of the Los Medanos Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report, An Addendum, SAND77-7018, Sandia Laboratories, Albuquerque, N.M.

Wolford, C. W., 1960. Tornado Occurrences in the United States, Technical Paper No. 20, U.S. Department of Commerce.

York, J. C., and W. A. Dick-Peddie, 1969. "Vegetation Changes in Southern New Mexico During the Past One Hundred Years," Arid Lands in Perspective, W. G. McGinnies and B. J. Goldman (eds.), University of Arizona Press, Tucson, Ariz.

1789 257

ANNEX 1

METEOROLOGICAL TABLES

Contents

<u>List of Tables</u>

1789 259

List of Tables (continued)

Table 1. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, June 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
								DIRECTION									
0.3- 1.4	1	3	2	5	5	10	1	2	1	1	1	1	1	5	2	2	43
(1)	0.3	0.9	0.6	1.6	1.6	3.2	0.3	0.6	0.3	0.3	0.3	0.3	0.3	1.6	0.6	0.6	13.6
(2)	0.3	0.9	0.6	1.6	1.6	3.2	0.3	0.6	0.3	0.3	0.3	0.3	0.3	1.6	0.6	0.6	13.6
1.5- 3.0	4	9	15	19	13	53	24	9	8	3	3	6	1	4	6	1	178
(1)	1.3	2.8	4.7	6.0	4.1	16.8	7.6	2.8	2.5	0.9	0.9	1.9	0.3	1.3	1.9	0.3	56.3
(2)	1.3	2.8	4.7	6.0	4.1	16.8	7.6	2.8	2.5	0.9	0.9	1.9	0.3	1.3	1.9	0.3	56.3
3.1- 5.0	1	2	2	2	6	36	15	10	3	0	0	1	0	1	0	0	79
(1)	0.3	0.6	0.6	0.6	1.9	11.4	4.7	3.2	0.9	0.0	0.0	0.3	0.0	0.3	0.0	0.0	25.0
(2)	0.3	0.6	0.6	0.6	1.9	11.4	4.7	3.2	0.9	0.0	0.0	0.3	0.0	0.3	0.0	0.0	25.0
5.1- 8.0	0	1	0	1	2	3	6	0	0	0	0	1	0	0	0	1	15
(1)	0.0	0.3	0.0	0.3	0.6	0.9	1.9	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	4.7
(2)	0.0	0.3	0.0	0.3	0.6	0.9	1.9	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	4.7
8.1-10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	6	15	19	27	26	102	46	21	12	4	4	9	2	10	9	4	316
(1)	1.9	4.7	6.0	8.5	8.2	32.3	14.6	6.6	3.8	1.3	1.3	2.8	0.6	3.2	2.8	1.3	100.0
(2)	1.9	4.7	6.0	8.5	8.2	32.3	14.6	6.6	3.8	1.3	1.3	2.8	0.6	3.2	2.8	1.3	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

316 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   43.9 PCT DATA RECOVERY

```
TID =TRC-65
ICR =   0   0   0   0   0   0
ITV =  77   6   1  78   5  31 365 408   3   3   3   1   1   0   0   0   3   0  17  24   3  23  23  66  89   0   0   0   0   0
NP  =  17
N1  =  31 N2 =  61 NL =   1SEAS =
NST =   0 NDT =   2 JCP =   1
```

Table 2. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, July 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
							DIRECTION										
0.3- 1.4	1	2	5	5	14	24	3	1	1	0	4	0	0	3	5	3	71
(1)	0.2	0.3	0.8	0.8	2.2	3.8	0.5	0.2	0.2	0.0	0.6	0.0	0.0	0.5	0.8	0.5	11.2
(2)	0.2	0.3	0.8	0.8	2.2	3.8	0.5	0.2	0.2	0.0	0.6	0.0	0.0	0.5	0.8	0.5	11.2
1.5- 3.0	5	4	11	7	45	139	48	23	4	3	4	3	1	5	4	2	308
(1)	0.8	0.6	1.7	1.1	7.1	22.0	7.6	3.6	0.6	0.5	0.6	0.5	0.2	0.8	0.6	0.3	48.7
(2)	0.8	0.6	1.7	1.1	7.1	22.0	7.6	3.6	0.6	0.5	0.6	0.5	0.2	0.8	0.6	0.3	48.7
3.1- 5.0	1	2	6	10	24	80	72	16	1	0	1	1	0	0	2	3	219
(1)	0.2	0.3	0.9	1.6	3.8	12.7	11.4	2.5	0.2	0.0	0.2	0.2	0.0	0.0	0.3	0.5	34.7
(2)	0.2	0.3	0.9	1.6	3.8	12.7	11.4	2.5	0.2	0.0	0.2	0.2	0.0	0.0	0.3	0.5	34.7
5.1- 8.0	0	2	0	3	0	14	11	3	0	0	0	0	0	0	0	1	34
(1)	0.0	0.3	0.0	0.5	0.0	2.2	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.4
(2)	0.0	0.3	0.0	0.5	0.0	2.2	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.4
8.1-10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	7	10	22	25	83	257	134	43	6	3	9	4	1	8	11	9	632
(1)	1.1	1.6	3.5	4.0	13.1	40.7	21.2	6.8	0.9	0.5	1.4	0.6	0.2	1.3	1.7	1.4	100.0
(2)	1.1	1.6	3.5	4.0	13.1	40.7	21.2	6.8	0.9	0.5	1.4	0.6	0.2	1.3	1.7	1.4	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

632 GOOD HRS 0 HRS (0.0 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 84.9 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 9
IIV = 77 6 1 78 5 31 365 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 62 N2 = 92 NL = ISEAS =
NST = 0 NDT = 2 JCP = 1

1789 2

Table 3. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, August 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	2	5	4	3	6	19	4	5	0	1	3	5	1	3	1	6	68
(1)	0.3	0.7	0.6	0.4	0.9	2.7	0.6	0.7	0.0	0.1	0.4	0.7	0.1	0.4	0.1	0.9	9.8
(2)	0.3	0.7	0.6	0.4	0.9	2.7	0.6	0.7	0.0	0.1	0.4	0.7	0.1	0.4	0.1	0.9	9.8
1.5- 3.0	5	14	7	18	32	109	41	30	12	13	7	7	1	5	7	11	319
(1)	0.7	2.0	1.0	2.6	4.6	15.6	5.9	4.3	1.7	1.9	1.0	1.0	0.1	0.7	1.0	1.6	45.8
(2)	0.7	2.0	1.0	2.6	4.6	15.6	5.9	4.3	1.7	1.9	1.0	1.0	0.1	0.7	1.0	1.6	45.8
3.1- 5.0	3	3	14	11	21	50	108	33	1	2	2	1	1	1	1	0	252
(1)	0.4	0.4	2.0	1.6	3.0	7.2	15.5	4.7	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.0	36.2
(2)	0.4	0.4	2.0	1.6	3.0	7.2	15.5	4.7	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.0	36.2
5.1- 8.0	0	3	3	12	3	9	18	2	0	0	0	0	1	0	0	1	52
(1)	0.0	0.4	0.4	1.7	0.4	1.3	2.6	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	7.5
(2)	0.0	0.4	0.4	1.7	0.4	1.3	2.6	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	7.5
8.1-10.4	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	6
(1)	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
(2)	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	10	25	28	48	64	187	171	70	13	16	12	13	4	9	9	18	697
(1)	1.4	3.6	4.0	6.9	9.2	26.8	24.5	10.0	1.9	2.3	1.7	1.9	0.6	1.3	1.3	2.6	100.0
(2)	1.4	3.6	4.0	6.9	9.2	26.8	24.5	10.0	1.9	2.3	1.7	1.9	0.6	1.3	1.3	2.6	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

697 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   93.7 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 0
ITV =- 77 6 1 78 5 31 365 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 93 N2 = 122 NL = 1SEAS =
NST = 0 NDT = 2 JCP = 1

1789 263

Table 4. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, September 1977

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	3	7	4	14	9	18	6	7	0	2	2	1	1	3	3	6	86
(1)	0.5	1.2	0.7	2.4	1.5	3.1	1.0	1.2	0.0	0.3	0.3	0.2	0.2	0.5	0.5	1.0	14.8
(2)	0.5	1.2	0.7	2.4	1.5	3.1	1.0	1.2	0.0	0.3	0.3	0.2	0.2	0.5	0.5	1.0	14.8
1.5- 3.0	19	27	38	19	17	45	39	29	4	4	5	17	8	4	4	21	300
(1)	3.3	4.6	6.5	3.3	2.9	7.7	6.7	5.0	0.7	0.7	0.9	2.9	1.4	0.7	0.7	3.6	51.5
(2)	3.3	4.6	6.5	3.3	2.9	7.7	6.7	5.0	0.7	0.7	0.9	2.9	1.4	0.7	0.7	3.6	51.5
3.1- 5.0	5	6	8	1	2	9	30	32	4	2	7	15	5	8	4	16	154
(1)	0.9	1.0	1.4	0.2	0.3	1.5	5.2	5.5	0.7	0.3	1.2	2.6	0.9	1.4	0.7	2.7	26.5
(2)	0.9	1.0	1.4	0.2	0.3	1.5	5.2	5.5	0.7	0.3	1.2	2.6	0.9	1.4	0.7	2.7	26.5
5.1- 8.0	2	1	4	0	0	0	14	2	0	1	2	11	1	0	0	4	42
(1)	0.3	0.2	0.7	0.0	0.0	0.0	2.4	0.3	0.0	0.2	0.3	1.9	0.2	0.0	0.0	0.7	7.2
(2)	0.3	0.2	0.7	0.0	0.0	0.0	2.4	0.3	0.0	0.2	0.3	1.9	0.2	0.0	0.0	0.7	7.2
8.1-10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	29	41	54	34	28	72	89	70	8	9	16	44	15	15	11	47	582
(1)	5.0	7.0	9.3	5.8	4.8	12.4	15.3	12.0	1.4	1.5	2.7	7.6	2.6	2.6	1.9	8.1	100.0
(2)	5.0	7.0	9.3	5.8	4.8	12.4	15.3	12.0	1.4	1.5	2.7	7.6	2.6	2.6	1.9	8.1	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

582 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   80.8 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 0
ITV = 77 6 1 78 5 31 365 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 123 N2 = 153 NL = 1SEAS =
NST = 0 NOT = 2 JCP = 1

1789

264

Table 6. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, November 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	9	22	35	19	48	29	20	17	9	6	7	3	6	9	1	11	251
(1)	[illegible]	3.3	5.2	2.8	7.2	4.3	3.0	2.5	1.3	0.9	1.0	0.4	0.9	1.3	0.1	1.6	37.5
(2)	[illegible]	3.3	5.2	2.8	7.2	4.3	3.0	2.5	1.3	0.9	1.0	0.4	0.9	1.3	0.1	1.6	37.5
1.5- 3.0	14	24	15	22	25	32	17	29	11	9	8	5	11	4	6	14	246
(1)	2.1	3.6	2.2	3.3	3.7	4.8	2.5	4.3	1.6	1.3	1.2	0.7	1.6	0.6	0.9	2.1	36.7
(2)	2.1	3.6	2.2	3.3	3.7	4.8	2.5	4.3	1.6	1.3	1.2	0.7	1.6	0.6	0.9	2.1	36.7
3.1- 5.0	10	3	7	5	2	8	10	12	8	13	4	5	4	4	1	7	103
(1)	1.5	0.4	1.0	0.7	0.3	1.2	1.5	1.8	1.2	1.9	0.6	0.7	0.6	0.6	0.1	1.0	15.4
(2)	1.5	0.4	1.0	0.7	0.3	1.2	1.5	1.8	1.2	1.9	0.6	0.7	0.6	0.6	0.1	1.0	15.4
5.1- 8.0	1	1	7	6	0	0	1	0	0	3	2	13	1	1	4	8	48
(1)	0.1	0.1	1.0	0.9	0.0	0.0	0.1	0.0	0.0	0.4	0.3	1.9	0.1	0.1	0.6	1.2	7.2
(2)	0.1	0.1	1.0	0.9	0.0	0.0	0.1	0.0	0.0	0.4	0.3	1.9	0.1	0.1	0.6	1.2	7.2
8.1-10.4	0	0	4	1	0	0	0	0	0	2	0	1	0	0	0	4	12
(1)	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.6	1.8
(2)	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.6	1.8
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
ALL SPEEDS	34	50	68	53	75	69	48	58	28	33	21	27	22	18	12	46	662
(1)	5.1	7.5	10.1	7.9	11.2	10.3	7.2	8.7	4.2	4.9	3.1	4.0	3.3	2.7	1.8	6.9	98.8
(2)	5.1	7.5	10.1	7.9	11.2	10.3	7.2	8.7	4.2	4.9	3.1	4.0	3.3	2.7	1.8	6.9	98.8

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

670 GOOD HRS 8 HRS (1.2 PCT) LESS THAN 0.3 MPS 720 HRS IN THE TIME PERIOD 93.1 PCT DATA RECOVERY

1789 266

Table 5. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, October 1977

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	5	12	12	13	41	16	13	3	3	3	3	3	2	3	7	141
(1)	0.3	0.8	1.9	1.9	2.1	6.6	2.6	2.1	0.5	0.5	0.5	0.5	0.5	0.3	0.5	1.1	22.7
(2)	0.3	0.8	1.9	1.9	2.1	6.6	2.6	2.1	0.5	0.5	0.5	0.5	0.5	0.3	0.5	1.1	22.7
1.5- 3.0	7	18	16	21	26	51	48	37	14	5	12	15	13	3	12	8	306
(1)	1.1	2.9	2.6	3.4	4.2	8.2	7.7	5.9	2.3	0.8	1.9	2.4	2.1	0.5	1.9	1.3	49.2
(2)	1.1	2.9	2.6	3.4	4.2	8.2	7.7	5.9	2.3	0.8	1.9	2.4	2.1	0.5	1.9	1.3	49.2
3.1- 5.0	3	5	8	19	8	9	26	25	5	2	3	5	1	1	1	4	125
(1)	0.5	0.8	1.3	3.1	1.3	1.4	4.2	4.0	0.8	0.3	0.5	0.8	0.2	0.2	0.2	0.6	20.1
(2)	0.5	0.8	1.3	3.1	1.3	1.4	4.2	4.0	0.8	0.3	0.5	0.8	0.2	0.2	0.2	0.6	20.1
5.1- 8.0	1	3	5	13	0	0	5	0	0	3	4	7	1	1	0	1	44
(1)	0.2	0.5	0.8	2.1	0.0	0.0	0.8	0.0	0.0	0.5	0.6	1.1	0.2	0.2	0.0	0.2	7.1
(2)	0.2	0.5	0.8	2.1	0.0	0.0	0.8	0.0	0.0	0.5	0.6	1.1	0.2	0.2	0.0	0.2	7.1
8.1-10.4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
(1)	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5
(2)	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5
OVER 10.4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
(1)	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
(2)	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
ALL SPEEDS	16	33	41	65	47	101	95	75	22	13	22	30	18	7	16	21	622
(1)	2.6	5.3	6.6	10.5	7.6	16.2	15.3	12.1	3.5	2.1	3.5	4.8	2.9	1.1	2.6	3.4	100.0
(2)	2.6	5.3	6.6	10.5	7.6	16.2	15.3	12.1	3.5	2.1	3.5	4.8	2.9	1.1	2.6	3.4	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

622 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   83.6 PCT DATA RECOVERY

```
TID =IRC-65
ICR =   0   0   0   0   0   0
ITV =  77   6   1  78   5  31 365 408   3   3   3   1   1   0   0   0   3   0  17  24   3  23  23  66  89   0   0   0   0   0
NP =   17
N1 =  154 N2 =  183 NL =    ISEAS =
NST =   0 NDT =   2 JCP =    1
```


1789 265

Table 7. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, December 1977

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	7	14	40	16	39	36	13	13	9	9	4	5	4	10	9	12	240
(1)	1.0	2.0	5.6	2.2	5.5	5.0	1.8	1.8	1.3	1.3	0.6	0.7	0.6	1.4	1.3	1.7	33.7
(2)	1.0	2.0	5.6	2.2	5.5	5.0	1.8	1.8	1.3	1.3	0.6	0.7	0.6	1.4	1.3	1.7	33.7
1.5- 3.0	12	19	12	6	10	31	28	14	14	22	27	16	7	16	14	5	253
(1)	1.7	2.7	1.7	0.8	1.4	4.3	3.9	2.0	2.0	3.1	3.8	2.2	1.0	2.2	2.0	0.7	35.5
(2)	1.7	2.7	1.7	0.8	1.4	4.3	3.9	2.0	2.0	3.1	3.8	2.2	1.0	2.2	2.0	0.7	35.5
3.1- 5.0	5	5	5	6	6	7	21	14	9	6	16	26	12	7	8	7	160
(1)	0.7	0.7	0.7	0.8	0.8	1.0	2.9	2.0	1.3	0.8	2.2	3.6	1.7	1.0	1.1	1.0	22.4
(2)	0.7	0.7	0.7	0.8	0.8	1.0	2.9	2.0	1.3	0.8	2.2	3.6	1.7	1.0	1.1	1.0	22.4
5.1- 8.0	1	0	1	1	0	0	0	1	0	1	2	13	1	3	2	4	30
(1)	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.3	1.8	0.1	0.4	0.3	0.6	4.2
(2)	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.3	1.8	0.1	0.4	0.3	0.6	4.2
8.1-10.4	0	0	2	2	0	0	0	0	0	0	0	5	5	0	0	0	14
(1)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	0.0	0.0	2.0
(2)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	0.0	0.0	2.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	5
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.0	0.7
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.0	0.7
ALL SPEEDS	25	38	60	31	55	74	62	42	32	38	49	67	32	36	33	28	702
(1)	3.5	5.3	8.4	4.3	7.7	10.4	8.7	5.9	4.5	5.3	6.9	9.4	4.5	5.0	4.6	3.9	98.5
(2)	3.5	5.3	8.4	4.3	7.7	10.4	8.7	5.9	4.5	5.3	6.9	9.4	4.5	5.0	4.6	3.9	98.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

713 GOOD HRS   11 HRS (1.5 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   95.8 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 0
ITV = 77 6 1 78 5 31 355 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 215 N2 = 245 NL = 1SEAS =
NST = 0 NDT = 2 JCP = 1

1789 267

Table 8. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, January 1978

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	9	13	23	24	22	30	19	4	2	1	5	2	5	5	5	5	174
(1)	1.4	2.0	3.6	3.7	3.4	4.7	3.0	0.6	0.3	0.2	0.8	0.3	0.8	0.8	0.8	0.8	27.1
(2)	1.4	2.0	3.6	3.7	3.4	4.7	3.0	0.6	0.3	0.2	0.8	0.3	0.8	0.8	0.8	0.8	27.1
1.5- 3.0	11	15	11	24	37	60	49	21	18	5	4	3	4	4	7	6	279
(1)	1.7	2.3	1.7	3.7	5.8	9.3	7.6	3.3	2.8	0.8	0.6	0.5	0.6	0.6	1.1	0.9	43.4
	1.7	2.3	1.7	3.7	5.8	9.3	7.6	3.3	2.8	0.8	0.6	0.5	0.6	0.6	1.1	0.9	43.4
3.1- 5.0	8	5	6	13	16	5	26	21	6	2	8	3	3	3	4	11	140
(1)	1.2	0.8	0.9	2.0	2.5	0.8	4.0	3.3	0.9	0.3	1.2	0.5	0.5	0.5	0.6	1.7	21.8
(2)	1.2	0.8	0.9	2.0	2.5	0.8	4.0	3.3	0.9	0.3	1.2	0.5	0.5	0.5	0.6	1.7	21.8
5.1- 8.0	2	4	5	9	5	0	0	0	0	0	0	3	0	2	2	8	40
(1)	0.3	0.6	0.8	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.3	1.2	6.2
(2)	0.3	0.6	0.8	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.3	1.2	6.2
8.1-10.4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
(1)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
(2)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	30	37	47	70	80	95	94	46	26	8	17	11	12	14	18	30	635
(1)	4.7	5.8	7.3	10.9	12.4	14.8	14.6	7.2	4.0	1.2	2.6	1.7	1.9	2.2	2.8	4.7	98.8
(2)	4.7	5.8	7.3	10.9	12.4	14.8	14.6	7.2	4.0	1.2	2.6	1.7	1.9	2.2	2.8	4.7	98.8

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

643 GOOD HRS   8 HRS (1.2 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   86.4 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 0
ITV = 77 6 1 78 5 31 365 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 246 N2 = 273 NL = 1SEAS =
NST = 0 NDT = 2 JCP = 1

Table 9. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, February 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	5	6	9	8	21	26	12	11	5	5	12	7	6	10	5	6	154
(1)	0.9	1.1	1.6	1.5	3.8	4.8	2.2	2.0	0.9	0.9	2.2	1.3	1.1	1.8	0.9	1.1	28.2
(2)	0.9	1.1	1.6	1.5	3.8	4.8	2.2	2.0	0.9	0.9	2.2	1.3	1.1	1.8	0.9	1.1	28.2
1.5- 3.0	3	9	16	16	25	31	12	18	8	10	5	6	9	10	6	12	196
(1)	0.5	1.6	2.9	2.9	4.6	5.7	2.2	3.3	1.5	1.8	0.9	1.1	1.6	1.8	1.1	2.2	35.8
(2)	0.5	1.6	2.9	2.9	4.6	5.7	2.2	3.3	1.5	1.8	0.9	1.1	1.6	1.8	1.1	2.2	35.8
3.1- 5.0	8	9	9	21	17	13	20	6	0	6	2	6	4	4	2	8	135
(1)	1.5	1.6	1.6	3.8	3.1	2.4	3.7	1.1	0.0	1.1	0.4	1.1	0.7	0.7	0.4	1.5	24.7
(2)	1.5	1.6	1.6	3.8	3.1	2.4	3.7	1.1	0.0	1.1	0.4	1.1	0.7	0.7	0.4	1.5	24.7
5.1- 8.0	4	8	5	7	0	1	0	0	0	0	4	13	4	0	2	1	49
(1)	0.7	1.5	0.9	1.3	0.0	0.2	0.0	0.0	0.0	0.0	0.7	2.4	0.7	0.0	0.4	0.2	9.0
(2)	0.7	1.5	0.9	1.3	0.0	0.2	0.0	0.0	0.0	0.0	0.7	2.4	0.7	0.0	0.4	0.2	9.0
8.1-10.4	0	0	2	0	0	0	0	0	0	0	0	4	1	0	0	0	7
(1)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	1.3
(2)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	1.3
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	20	32	41	52	63	71	44	35	13	21	23	36	24	24	15	27	541
(1)	3.7	5.9	7.5	9.5	11.5	13.0	8.0	6.4	2.4	3.8	4.2	6.6	4.4	4.4	2.7	4.9	98.9
(2)	3.7	5.9	7.5	9.5	11.5	13.0	8.0	6.4	2.4	3.8	4.2	6.6	4.4	4.4	2.7	4.9	98.9

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

547 GOOD HRS   6 HRS (1.1 PCT) LESS THAN 0.3 MPS   672 HRS IN THE TIME PERIOD   81.4 PCT DATA RECOVERY

```
TID =TRC-65
ICR =   0   0   0   0   0   0
ITV =  77   6   1  78   5  31 365 408   3   3   3   1   1   0   0   0   3   0  17  24   3  23  23  66  89   0   0   0   0   0
NP =   17
N1 =  274 N2 =  304 NL =    1SEAS =
NST =   0 NDT =   2 JCP =    1
```


1789 269

Table 10. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, March 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
								DIRECTION									
0.3- 1.4	7	15	11	14	22	29	9	5	3	5	2	5	5	5	1	7	145
(1)	1.0	2.1	1.5	1.9	3.0	4.0	1.2	0.7	0.4	0.7	0.3	0.7	0.7	0.7	0.1	1.0	19.8
(2)	1.0	2.1	1.5	1.9	3.0	4.0	1.2	0.7	0.4	0.7	0.3	0.7	0.7	0.7	0.1	1.0	19.8
1.5- 3.0	8	11	14	16	26	63	27	26	17	13	10	9	14	14	13	7	288
(1)	1.1	1.5	1.9	2.2	3.6	8.6	3.7	3.6	2.3	1.8	1.4	1.2	1.9	1.9	1.8	1.0	39.4
(2)	1.1	1.5	1.9	2.2	3.6	8.6	3.7	3.6	2.3	1.8	1.4	1.2	1.9	1.9	1.8	1.0	39.4
3.1- 5.0	4	2	15	26	8	30	14	16	5	10	19	17	9	6	4	7	192
(1)	0.5	0.3	2.1	3.6	1.1	4.1	1.9	2.2	0.7	1.4	2.6	2.3	1.2	0.8	0.5	1.0	26.3
(2)	0.5	0.3	2.1	3.6	1.1	4.1	1.9	2.2	0.7	1.4	2.6	2.3	1.2	0.8	0.5	1.0	26.3
5.1- 8.0	6	1	8	12	2	4	8	1	1	2	7	19	6	3	7	5	92
(1)	0.8	0.1	1.1	1.6	0.3	0.5	1.1	0.1	0.1	0.3	1.0	2.6	0.8	0.4	1.0	0.7	12.6
(2)	0.8	0.1	1.1	1.6	0.3	0.5	1.1	0.1	0.1	0.3	1.0	2.6	0.8	0.4	1.0	0.7	12.6
8.1-10.4	0	0	0	1	0	0	0	2	0	0	0	4	1	0	2	0	10
(1)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.5	0.1	0.0	0.3	0.0	1.4
(2)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.5	0.1	0.0	0.3	0.0	1.4
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	25	29	48	69	58	126	58	50	26	30	38	54	35	28	27	26	727
(1)	3.4	4.0	6.6	9.4	7.9	17.2	7.9	6.8	3.6	4.1	5.2	7.4	4.8	3.8	3.7	3.6	99.5
(2)	3.4	4.0	6.6	9.4	7.9	17.2	7.9	6.8	3.6	4.1	5.2	7.4	4.8	3.8	3.7	3.6	99.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

731 GOOD HRS 4 HRS (0.5 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 98.3 PCT DATA RECOVERY

TID =TRC-65
ICR = 0 0 0 0 0 0
ITV = 77 6 1 73 5 31 365 408 3 3 3 1 1 0 0 0 3 0 17 24 3 23 23 66 89 0 0 0 0 0
NP = 17
N1 = 305 N2 = 334 NL = ISEAS =
NST = 0 NDT = 2 JCP = 1

Table 11. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, April 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	6	7	11	13	16	17	14	12	6	7	3	3	3	2	8	12	140
(1)	0.9	1.1	1.7	2.0	2.4	2.6	2.1	1.8	0.9	1.1	0.5	0.5	0.5	0.3	1.2	1.8	21.4
(2)	0.9	1.1	1.7	2.0	2.4	2.6	2.1	1.8	0.9	1.1	0.5	0.5	0.5	0.3	1.2	1.8	21.4
1.5- 3.0	10	19	11	4	20	27	12	13	16	10	16	13	8	10	7	26	222
(1)	1.5	2.9	1.7	0.6	3.1	4.1	1.8	2.0	2.4	1.5	2.4	2.0	1.2	1.5	1.1	4.0	33.9
(2)	1.5	2.9	1.7	0.6	3.1	4.1	1.8	2.0	2.4	1.5	2.4	2.0	1.2	1.5	1.1	4.0	33.9
3.1- 5.0	4	5	4	5	4	34	8	16	15	8	12	12	3	8	3	11	152
(1)	0.6	0.8	0.6	0.8	0.6	5.2	1.2	2.4	2.3	1.2	1.8	1.8	0.5	1.2	0.5	1.7	23.2
(2)	0.6	0.8	0.6	0.8	0.6	5.2	1.2	2.4	2.3	1.2	1.8	1.8	0.5	1.2	0.5	1.7	23.2
5.1- 8.0	1	4	5	6	1	12	7	6	8	8	24	28	4	6	1	12	133
(1)	0.2	0.6	0.8	0.9	0.2	1.8	1.1	0.9	1.2	1.2	3.7	4.3	0.6	0.9	0.2	1.8	20.3
(2)	0.2	0.6	0.8	0.9	0.2	1.8	1.1	0.9	1.2	1.2	3.7	4.3	0.6	0.9	0.2	1.8	20.3
8.1-10.4	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.6
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	21	35	31	28	41	90	41	47	45	33	57	58	18	26	19	61	651
(1)	3.2	5.4	4.7	4.3	6.3	13.8	6.3	7.2	6.9	5.0	8.7	8.9	2.8	4.0	2.9	9.3	99.5
(2)	3.2	5.4	4.7	4.3	6.3	13.8	6.3	7.2	6.9	5.0	8.7	8.9	2.8	4.0	2.9	9.3	99.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

654 GOOD HRS   3 HRS (0.5 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   90.8 PCT DATA RECOVERY

```
TID =TRC-65
ICR =   0   0   0   0   0   0
ITV =  77   6   1  78   5  31 365 408   3   3   3   1   1   0   0   0   3   0  17  24   3  23  23  66  89   0   0   0   0   0
NP =   17
N1 =  335 N2 =  365 NL =     ISEAS =
NST =   0 NDT =    2 JCP =     1
```


1789 271

Table 12. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, May 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	5	9	18	4	15	15	8	14	10	6	5	5	3	6	6	6	135
(1)	0.7	1.2	2.5	0.6	2.1	2.1	1.1	1.9	1.4	0.8	0.7	0.7	0.4	0.8	0.8	0.8	18.7
(2)	0.7	1.2	2.5	0.6	2.1	2.1	1.1	1.9	1.4	0.8	0.7	0.7	0.4	0.8	0.8	0.8	18.7
1.5- 3.0	8	5	12	2	29	34	19	13	11	10	9	10	8	8	10	15	203
(1)	1.1	0.7	1.7	0.3	4.0	4.7	2.6	1.8	1.5	1.4	1.2	1.4	1.1	1.1	1.4	2.1	28.2
(2)	1.1	0.7	1.7	0.3	4.0	4.7	2.6	1.8	1.5	1.4	1.2	1.4	1.1	1.1	1.4	2.1	28.2
3.1- 5.0	2	7	8	12	13	51	38	22	9	11	17	19	9	7	14	7	246
(1)	0.3	1.0	1.1	1.7	1.8	7.1	5.3	3.1	1.2	1.5	2.4	2.6	1.2	1.0	1.9	1.0	34.1
(2)	0.3	1.0	1.1	1.7	1.8	7.1	5.3	3.1	1.2	1.5	2.4	2.6	1.2	1.0	1.9	1.0	34.1
5.1- 8.0	2	1	5	9	2	25	10	6	2	12	14	16	1	5	2	5	117
(1)	0.3	0.1	0.7	1.2	0.3	3.5	1.4	0.8	0.3	1.7	1.9	2.2	0.1	0.7	0.3	0.7	16.2
(2)	0.3	0.1	0.7	1.2	0.3	3.5	1.4	0.8	0.3	1.7	1.9	2.2	0.1	0.7	0.3	0.7	16.2
8.1-10.4	0	0	2	0	0	0	0	0	0	2	1	2	0	0	0	0	7
(1)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.3	0.0	0.0	0.0	0.0	1.0
(2)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.3	0.0	0.0	0.0	0.0	1.0
OVER 10.4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
(1)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
(2)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
ALL SPEEDS	17	22	46	27	59	125	75	55	32	41	46	52	21	26	32	34	710
(1)	2.4	3.1	6.4	3.7	8.2	17.3	10.4	7.6	4.4	5.7	6.4	7.2	2.9	3.6	4.4	4.7	98.5
(2)	2.4	3.1	6.4	3.7	8.2	17.3	10.4	7.6	4.4	5.7	6.4	7.2	2.9	3.6	4.4	4.7	98.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

721 GOOD HRS   11 HRS (1.5 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   96.9 PCT DATA RECOVERY

Table 13. Distribution of Wind Directions and Speeds at the Reference Site, Stability A, June 1, 1977-May 31, 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	1	3	5	5	7	5	7	11	3	7	6	5	2	3	5	1	76
(1)	0.1	0.2	0.3	0.3	0.4	0.3	0.4	0.6	0.2	0.4	0.3	0.3	0.1	0.2	0.3	0.1	4.0
(2)	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.0	1.0
1.5- 3.0	8	15	15	23	53	88	80	112	50	41	34	28	27	27	24	33	658
(1)	0.4	0.8	0.8	1.2	2.8	4.6	4.2	5.8	2.6	2.1	1.8	1.5	1.4	1.4	1.2	1.7	34.3
(2)	0.1	0.2	0.2	0.3	0.7	1.2	1.1	1.5	0.7	0.5	0.5	0.4	0.4	0.4	0.3	0.4	8.7
3.1- 5.0	16	11	15	21	32	94	190	154	39	42	53	47	19	30	19	32	814
(1)	0.8	0.6	0.8	1.1	1.7	4.9	9.9	8.0	2.0	2.2	2.8	2.4	1.0	1.6	1.0	1.7	42.4
(2)	0.2	0.1	0.2	0.3	0.4	1.2	2.5	2.0	0.5	0.6	0.7	0.6	0.3	0.4	0.3	0.4	10.8
5.1- 8.0	8	12	11	6	4	19	38	17	10	18	42	89	12	12	15	23	336
(1)	0.4	0.6	0.6	0.3	0.2	1.0	2.0	0.9	0.5	0.9	2.2	4.6	0.6	0.6	0.8	1.2	17.5
(2)	0.1	0.2	0.1	0.1	0.1	0.3	0.5	0.2	0.1	0.2	0.6	1.2	0.2	0.2	0.2	0.3	4.5
8.1-10.4	0	1	0	0	2	0	0	2	0	3	3	13	2	0	3	2	31
(1)	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.2	0.7	0.1	0.0	0.2	0.1	1.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.4
OVER 10.4	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0	1	5
(1)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ALL SPEEDS	33	43	46	55	98	206	315	296	102	111	138	184	63	72	66	92	1920
(1)	1.7	2.2	2.4	2.9	5.1	10.7	16.4	15.4	5.3	5.8	7.2	9.6	3.3	3.7	3.4	4.8	100.0
(2)	0.4	0.6	0.6	0.7	1.3	2.7	4.2	3.9	1.4	1.5	1.8	2.4	0.8	1.0	0.9	1.2	25.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1920 HRS ON THIS PAGE   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   (0.0 PCT OF ALL HRS)

Table 14. Distribution of Wind Directions and Speeds at the Reference Site, Stability B, June 1, 1977-May 31, 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	1	1	1	1	1	1	2	2	2	1	5	0	0	4	1	2	25
(1)	0.4	0.4	0.4	0.4	0.4	0.4	0.8	0.8	0.8	0.4	2.0	0.0	0.0	1.6	0.4	0.8	10.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.3
1.5- 3.0	6	3	2	6	4	10	8	10	12	11	9	6	8	6	6	10	117
(1)	2.4	1.2	0.8	2.4	1.6	4.0	3.2	4.0	4.9	4.5	3.6	2.4	3.2	2.4	2.4	4.0	47.4
(2)	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.6
3.1- 5.0	2	4	4	6	4	7	19	10	10	3	3	2	3	1	1	6	85
(1)	0.8	1.6	1.6	2.4	1.6	2.8	7.7	4.0	4.0	1.2	1.2	0.8	1.2	0.4	0.4	2.4	34.4
(2)	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1
5.1- 8.0	0	1	0	1	0	2	1	0	1	0	4	2	1	0	0	2	15
(1)	0.0	0.4	0.0	0.4	0.0	0.8	0.4	0.0	0.4	0.0	1.6	0.8	0.4	0.0	0.0	0.8	6.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
8.1-10.4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
(1)	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.8
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	9	9	7	17	9	20	30	22	25	15	21	10	13	11	8	21	247
(1)	3.6	3.6	2.8	6.9	3.6	8.1	12.1	8.9	10.1	6.1	8.5	4.0	5.3	4.5	3.2	8.5	100.0
(2)	0.1	0.1	0.1	0.2	0.1	0.3	0.4	0.3	0.3	0.2	0.3	0.1	0.2	0.1	0.1	0.3	3.3

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

247 HRS ON THIS PAGE   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   (0.0 PCT OF ALL HRS)

1789 274

Table 15. Distribution of Wind Directions and Speeds at the Reference Site, Stability C, June 1, 1977–May 31, 1978

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	3	3	0	1	2	2	2	3	0	1	2	2	1	4	1	0	27
(1)	1.3	1.3	0.0	0.4	0.9	0.9	0.9	1.3	0.0	0.4	0.9	0.9	0.4	1.7	0.4	0.0	11.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4
1.5- 3.0	6	2	5	3	1	11	16	20	10	4	9	5	4	6	6	3	111
(1)	2.6	0.9	2.1	1.3	0.4	4.7	6.9	8.6	4.3	1.7	3.9	2.1	1.7	2.6	2.6	1.3	47.6
(2)	0.1	0.0	0.1	0.0	0.0	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	1.5
3.1- 5.0	1	2	8	3	2	10	13	13	3	2	2	6	5	2	1	2	75
(1)	0.4	0.9	3.4	1.3	0.9	4.3	5.6	5.6	1.3	0.9	0.9	2.6	2.1	0.9	0.4	0.9	32.2
(2)	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	1.0
5.1- 8.0	2	0	1	3	0	1	1	0	0	2	1	3	1	0	0	2	17
(1)	0.9	0.0	0.4	1.3	0.0	0.4	0.4	0.0	0.0	0.9	0.4	1.3	0.4	0.0	0.0	0.9	7.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
8.1-10.4	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	2
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.9
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	12	7	14	10	5	24	32	36	13	10	14	17	11	12	8	7	232
(1)	5.2	3.0	6.0	4.3	2.1	10.3	13.7	15.5	5.6	4.3	6.0	7.3	4.7	5.2	3.4	3.0	99.6
(2)	0.2	0.1	0.2	0.1	0.1	0.3	0.4	0.5	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.1	3.1

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

233 HRS ON THIS PAGE 1 HRS (0.4 PCT) LESS THAN 0.3 MPS (0.0 PCT OF ALL HRS)

1789 275

Table 16. Distribution of Wind Directions and Speeds at the Reference Site, Stability D, June 1, 1977-May 31, 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	7	7	7	7	8	9	10	12	6	12	11	10	9	15	10	10	150
(1)	0.7	0.7	0.7	0.7	0.8	0.9	1.0	1.2	0.6	1.2	1.1	1.0	0.9	1.5	1.0	1.0	14.8
(2)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	2.0
1.5- 3.0	16	17	14	11	35	65	63	46	40	18	18	23	17	12	19	21	435
(1)	1.6	1.7	1.4	1.1	3.5	6.4	6.2	4.5	3.9	1.8	1.8	2.3	1.7	1.2	1.9	2.1	42.9
(2)	0.2	0.2	0.2	0.1	0.5	0.9	0.8	0.6	0.5	0.2	0.2	0.3	0.2	0.2	0.3	0.3	5.8
3.1- 5.0	26	14	30	26	24	36	36	28	6	7	3	18	1	7	8	10	280
(1)	2.6	1.4	3.0	2.6	2.4	3.6	3.6	2.8	0.6	0.7	0.3	1.8	0.1	0.7	0.8	1.0	27.6
(2)	0.3	0.2	0.4	0.3	0.3	0.5	0.5	0.4	0.1	0.1	0.0	0.2	0.0	0.1	0.1	0.1	3.7
5.1- 8.0	8	11	17	22	1	8	5	3	0	8	9	12	1	4	4	8	121
(1)	0.8	1.1	1.7	2.2	0.1	0.8	0.5	0.3	0.0	0.8	0.9	1.2	0.1	0.4	0.4	0.8	11.9
(2)	0.1	0.1	0.2	0.3	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.0	0.1	0.1	0.1	1.6
8.1-10.4	0	0	10	2	0	0	0	0	0	0	0	1	0	0	0	2	15
(1)	0.0	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	1.5
(2)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
OVER 10.4	2	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	4
(1)	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ALL SPEEDS	59	49	79	68	68	118	114	89	52	45	41	64	29	38	41	51	1005
(1)	5.8	4.8	7.8	6.7	6.7	11.6	11.2	8.8	5.1	4.4	4.0	6.3	2.9	3.7	4.0	5.0	99.1
(2)	0.8	0.7	1.0	0.9	0.9	1.6	1.5	1.2	0.7	0.6	0.5	0.9	0.4	0.5	0.5	0.7	13.4

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1014 HRS ON THIS PAGE 9 HRS (0.9 PCT) LESS THAN 0.3 MPS (0.1 PCT OF ALL HRS)

1789 276

Table 17. Distribution of Wind Directions and Speeds at the Reference Site, Stability E, June 1, 1977–May 31, 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	9	5	10	15	16	26	16	22	8	9	10	9	11	13	8	16	203
(1)	0.6	0.3	0.6	1.0	1.0	1.7	1.0	1.4	0.5	0.6	0.6	0.6	0.7	0.8	0.5	1.0	12.9
(2)	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	2.7
1.5- 3.0	16	20	37	37	70	211	74	50	12	11	4	14	9	14	13	11	603
(1)	1.0	1.3	2.4	2.4	4.5	13.4	4.7	3.2	0.8	0.7	0.3	0.9	0.6	0.9	0.8	0.7	38.4
(2)	0.2	0.3	0.5	0.5	0.9	2.8	1.0	0.7	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.1	8.0
3.1- 5.0	7	19	22	57	62	168	109	12	3	3	14	23	10	8	12	18	547
(1)	0.4	1.2	1.4	3.6	4.0	10.7	6.9	0.8	0.2	0.2	0.9	1.5	0.6	0.5	0.8	1.1	34.9
(2)	0.1	0.3	0.3	0.8	0.8	2.2	1.4	0.2	0.0	0.0	0.2	0.3	0.1	0.1	0.2	0.2	7.3
5.1- 8.0	2	3	18	45	10	38	34	0	0	2	2	15	5	5	1	15	195
(1)	0.1	0.2	1.1	2.9	0.6	2.4	2.2	0.0	0.0	0.1	0.1	1.0	0.3	0.3	0.1	1.0	12.4
(2)	0.0	0.0	0.2	0.6	0.1	0.5	0.5	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.2	2.6
8.1-10.4	1	0	2	3	0	0	0	0	0	0	0	3	5	0	0	1	15
(1)	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.1	1.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	35	47	89	157	158	443	233	84	23	25	30	64	40	40	34	62	1564
(1)	2.2	3.0	5.7	10.0	10.1	28.2	14.9	5.4	1.5	1.6	1.9	4.1	2.5	2.5	2.2	4.0	99.7
(2)	0.5	0.6	1.2	2.1	2.1	5.9	3.1	1.1	0.3	0.3	0.4	0.9	0.5	0.5	0.5	0.8	20.8

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1569 HRS ON THIS PAGE 5 HRS (0.3 PCT) LESS THAN 0.3 MPS (0.1 PCT OF ALL HRS)

1789 277

Table 18. Distribution of Wind Directions and Speeds at the Reference Site, Stability F, June 1, 1977–May 31, 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	12	27	41	27	46	55	28	18	6	4	3	4	6	9	5	14	305
(1)	1.3	3.0	4.5	3.0	5.1	6.1	3.1	2.0	0.7	0.4	0.3	0.4	0.7	1.0	0.5	1.5	33.7
(2)	0.2	0.4	0.5	0.4	0.6	0.7	0.4	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	4.1
1.5- 3.0	15	16	23	22	59	154	75	11	4	6	14	14	6	8	12	14	453
(1)	1.7	1.8	2.5	2.4	6.5	17.0	8.3	1.2	0.4	0.7	1.5	1.5	0.7	0.9	1.3	1.5	50.0
(2)	0.2	0.2	0.3	0.3	0.8	2.0	1.0	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	6.0
3.1- 5.0	2	1	9	13	3	15	20	5	5	5	10	15	11	2	3	11	130
(1)	0.2	0.1	1.0	1.4	0.3	1.7	2.2	0.6	0.6	0.6	1.1	1.7	1.2	0.2	0.3	1.2	14.3
(2)	0.0	0.0	0.1	0.2	0.0	0.2	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1	1.7
5.1- 8.0	0	2	0	2	0	0	1	1	0	0	1	3	0	0	0	0	10
(1)	0.0	0.2	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	1.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
8.1-10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	29	46	73	64	108	224	124	35	15	15	28	36	23	19	20	39	898
(1)	3.2	5.1	8.1	7.1	11.9	24.7	13.7	3.9	1.7	1.7	3.1	4.0	2.5	2.1	2.2	4.3	99.1
(2)	0.4	0.6	1.0	0.9	1.4	3.0	1.6	0.5	0.2	0.2	0.4	0.5	0.3	0.3	0.3	0.5	11.9

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

906 HRS ON THIS PAGE   8 HRS (0.9 PCT) LESS THAN 0.3 MPS   (0.1 PCT OF ALL HRS)

Table 19. Distribution of Wind Directions and Speeds at the Reference Site, Stability G, June 1, 1977–May 31, 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	24	62	110	81	150	196	60	36	24	12	14	10	9	15	19	40	862
(1)	1.5	3.8	6.7	4.9	9.2	12.0	3.7	2.2	1.5	0.7	0.9	0.6	0.5	0.9	1.2	2.4	52.6
(2)	0.3	0.8	1.5	1.1	2.0	2.6	0.8	0.5	0.3	0.2	0.2	0.1	0.1	0.2	0.3	0.5	11.5
1.5- 3.0	39	101	82	72	83	136	48	13	9	16	22	20	14	14	16	36	721
(1)	2.4	6.2	5.0	4.4	5.1	8.3	2.9	0.8	0.5	1.0	1.3	1.2	0.9	0.9	1.0	2.2	44.0
(2)	0.5	1.3	1.1	1.0	1.1	1.8	0.6	0.2	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.5	9.6
3.1- 5.0	0	3	4	5	0	2	1	1	0	0	6	0	2	0	0	2	26
(1)	0.0	0.2	0.2	0.3	0.0	0.1	0.1	0.1	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.1	1.6
(2)	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3
5.1- 8.0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
(1)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1-10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	63	166	197	158	233	334	109	50	33	28	42	30	25	29	35	79	1611
(1)	3.8	10.1	12.0	9.6	14.2	20.4	6.7	3.1	2.0	1.7	2.6	1.8	1.5	1.8	2.1	4.8	98.3
(2)	0.8	2.2	2.6	2.1	3.1	4.4	1.4	0.7	0.4	0.4	0.6	0.4	0.3	0.4	0.5	1.0	21.4

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1639 HRS ON THIS PAGE   28 HRS (1.7 PCT) LESS THAN 0.3 MPS   (0.4 PCT OF ALL HRS)

1789 279

Table 20. Distribution of Wind Directions and Speeds at the Reference Site, All Stabilities Combined, June 1, 1977–May 31, 1978

SPEED (MPS)		DIRECTION															
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		57	108	174	137	230	294	125	104	49	46	51	40	38	63	49	83	1698
	(1)	0.8	1.4	2.3	1.8	3.1	3.9	1.7	1.4	0.7	0.6	0.7	0.5	0.5	0.8	0.7	1.1	21.9
	(2)	0.8	1.4	2.3	1.8	3.1	3.9	1.7	1.4	0.7	0.6	0.7	0.5	0.5	0.8	0.7	1.1	21.9
1.5- 3.0		106	174	178	174	305	675	364	262	137	107	110	110	85	87	96	128	3098
	(1)	1.4	2.3	2.4	2.3	4.1	9.0	4.8	3.5	1.8	1.4	1.5	1.5	1.1	1.2	1.3	1.7	41.2
	(2)	1.4	2.3	2.4	2.3	4.1	9.0	4.8	3.5	1.8	1.4	1.5	1.5	1.1	1.2	1.3	1.7	41.2
3.1- 5.0		54	54	92	131	127	332	388	225	66	62	91	111	51	50	44	81	1957
	(1)	0.7	0.7	1.2	1.7	1.7	4.4	5.2	3.0	0.9	0.8	1.2	1.5	0.7	0.7	0.6	1.1	26.0
	(2)	0.7	0.7	1.2	1.7	1.7	4.4	5.2	3.0	0.9	0.8	1.2	1.5	0.7	0.7	0.6	1.1	26.0
5.1- 8.0		20	29	48	79	15	68	80	21	11	30	59	124	20	21	20	51	696
	(1)	0.3	0.4	0.6	1.0	0.2	0.9	1.1	0.3	0.1	0.4	0.8	1.6	0.3	0.3	0.3	0.7	9.2
	(2)	0.3	0.4	0.6	1.0	0.2	0.9	1.1	0.3	0.1	0.4	0.8	1.6	0.3	0.3	0.3	0.7	9.2
8.1-10.4		1	1	12	8	2	0	0	2	0	4	3	18	7	0	3	5	66
	(1)	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.1	0.9
	(2)	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.1	0.9
OVER 10.4		2	1	1	0	0	0	0	0	0	0	0	2	3	0	0	3	12
	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
ALL SPEEDS		240	367	505	529	679	1369	957	612	263	249	314	405	204	221	212	351	7477
	(1)	3.2	4.9	6.7	7.0	9.0	18.2	12.7	8.1	3.5	3.3	4.2	5.4	2.7	2.9	2.8	4.7	99.3
	(2)	3.2	4.9	6.7	7.0	9.0	18.2	12.7	8.1	3.5	3.3	4.2	5.4	2.7	2.9	2.8	4.7	99.3

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

7528 GOOD HRS   51 HRS (0.7 PCT) LESS THAN 0.3 MPS   8760 HRS IN THE TIME PERIOD   85.9 PCT DATA RECOVERY

1789 280

Table 21. One-Hour Frequency Distribution of χ/Q Values for the Reference Site

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	805	0.718E-03	0.289E-03	0.613E-04
SW	805	0.110E-02	0.298E-03	0.776E-04
WSW	805	0.822E-03	0.291E-03	0.601E-04
W	805	0.110E-02	0.296E-03	0.608E-04
WNW	805	0.110E-02	0.429E-03	0.703E-04
NW	805	0.110E-02	0.288E-03	0.627E-04
NNW	805	0.110E-02	0.250E-03	0.596E-04
N	805	0.110E-02	0.233E-03	0.266E-04
NNE	805	0.110E-02	0.277E-03	0.248E-04
NE	805	0.110E-02	0.319E-03	0.322E-04
ENE	805	0.110E-02	0.274E-03	0.240E-04
E	805	0.822E-03	0.258E-03	0.279E-04
ESE	805	0.822E-03	0.274E-03	0.487E-04
SE	805	0.110E-02	0.283E-03	0.543E-04
SSE	805	0.110E-02	0.299E-03	0.597E-04
S	805	0.110E-02	0.255E-03	0.496E-04
ALL		0.110E-02	0.284E-03	0.599E-04
SSW	2414	0.270E-03	0.108E-03	0.143E-04
SW	2414	0.450E-03	0.968E-04	0.227E-04
WSW	2414	0.338E-03	0.115E-03	0.130E-04
W	2414	0.450E-03	0.959E-04	0.128E-04
WNW	2414	0.450E-03	0.181E-03	0.715E-04
NW	2414	0.450E-03	0.116E-03	0.173E-04
NNW	2414	0.450E-03	0.769E-04	0.117E-04
N	2414	0.450E-03	0.867E-04	0.385E-05
NNE	2414	0.450E-03	0.102E-03	0.405E-05
NE	2414	0.450E-03	0.122E-03	0.549E-05
ENE	2414	0.450E-03	0.848E-04	0.405E-05
E	2414	0.338E-03	0.879E-04	0.478E-05
ESE	2414	0.338E-03	0.908E-04	0.106E-04
SE	2414	0.450E-03	0.819E-04	0.119E-04
SSE	2414	0.450E-03	0.977E-04	0.139E-04
S	2414	0.450E-03	0.773E-04	0.103E-04
ALL		0.450E-03	0.109E-03	0.127E-04

1789 281

Table 21. One-Hour Frequency Distribution of X/Q Values for the Reference Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	4023	0.176E-03	0.705E-04	0.734E-05
SW	4023	0.293E-03	0.630E-04	0.115E-04
WSW	4023	0.220E-03	0.720E-04	0.641E-05
W	4023	0.293E-03	0.596E-04	0.642E-05
WNW	4023	0.293E-03	0.112E-03	0.118E-04
NW	4023	0.293E-03	0.724E-04	0.941E-05
NNW	4023	0.293E-03	0.485E-04	0.567E-05
N	4023	0.293E-03	0.563E-04	0.161E-05
NNE	4023	0.293E-03	0.646E-04	0.175E-05
NE	4023	0.293E-03	0.737E-04	0.260E-05
ENE	4023	0.293E-03	0.552E-04	0.175E-05
E	4023	0.220E-03	0.570E-04	0.220E-05
ESE	4023	0.220E-03	0.560E-04	0.518E-05
SE	4023	0.293E-03	0.527E-04	0.588E-05
SSE	4023	0.293E-03	0.597E-04	0.705E-05
S	4023	0.293E-03	0.479E-04	0.503E-05
ALL		0.293E-03	0.691E-04	0.627E-05
SSW	4828	0.150E-03	0.569E-04	0.580E-05
SW	4828	0.251E-03	0.522E-04	0.896E-05
WSW	4828	0.198E-03	0.597E-04	0.506E-05
W	4828	0.251E-03	0.520E-04	0.500E-05
WNW	4828	0.251E-03	0.925E-04	0.925E-05
NW	4828	0.251E-03	0.606E-04	0.752E-05
NNW	4828	0.251E-03	0.403E-04	0.443E-05
N	4828	0.251E-03	0.491E-04	0.122E-05
NNE	4828	0.251E-03	0.542E-04	0.127E-05
NE	4828	0.251E-03	0.600E-04	0.193E-05
ENE	4828	0.251E-03	0.450E-04	0.135E-05
E	4828	0.188E-03	0.486E-04	0.169E-05
ESE	4828	0.188E-03	0.488E-04	0.401E-05
SE	4828	0.251E-03	0.452E-04	0.442E-05
SSE	4828	0.251E-03	0.527E-04	0.562E-05
S	4828	0.251E-03	0.395E-04	0.385E-05
ALL		0.251E-03	0.567E-04	0.492E-05

Table 21. One-Hour Frequency Distribution of X/Q Values for the Reference Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	5633	0.131E-03	0.507E-04	0.473E-05
SW	5633	0.219E-03	0.455E-04	0.790E-05
WSW	5633	0.164E-03	0.541E-04	0.395E-05
W	5633	0.219E-03	0.445E-04	0.396E-05
WNW	5633	0.219E-03	0.854E-04	0.793E-05
NW	5633	0.219E-03	0.551E-04	0.624E-05
NNW	5633	0.219E-03	0.352E-04	0.359E-05
N	5633	0.219E-03	0.423E-04	0.936E-06
NNE	5633	0.219E-03	0.462E-04	0.987E-06
NE	5633	0.219E-03	0.544E-04	0.154E-05
ENE	5633	0.219E-03	0.400E-04	0.106E-05
E	5633	0.164E-03	0.418E-04	0.133E-05
ESE	5633	0.164E-03	0.421E-04	0.329E-05
SE	5633	0.219E-03	0.391E-04	0.358E-05
SSE	5633	0.219E-03	0.460E-04	0.359E-05
S	5633	0.219E-03	0.345E-04	0.320E-05
ALL		0.219E-03	0.502E-04	0.393E-05
SSW	7242	0.105E-03	0.428E-04	0.335E-05
SW	7242	0.176E-03	0.385E-04	0.573E-05
WSW	7242	0.132E-03	0.432E-04	0.287E-05
W	7242	0.176E-03	0.348E-04	0.286E-05
WNW	7242	0.176E-03	0.656E-04	0.597E-05
NW	7242	0.176E-03	0.437E-04	0.460E-05
NNW	7242	0.176E-03	0.283E-04	0.254E-05
N	7242	0.176E-03	0.329E-04	0.621E-06
NNE	7242	0.176E-03	0.387E-04	0.621E-06
NE	7242	0.176E-03	0.435E-04	0.104E-05
ENE	7242	0.176E-03	0.311E-04	0.723E-06
E	7242	0.132E-03	0.325E-04	0.940E-06
ESE	7242	0.132E-03	0.328E-04	0.229E-05
SE	7242	0.176E-03	0.317E-04	0.260E-05
SSE	7242	0.176E-03	0.366E-04	0.329E-05
S	7242	0.176E-03	0.276E-04	0.223E-05
ALL		0.176E-03	0.418E-04	0.284E-05

Table 21. One-Hour Frequency Distribution of χ/Q Values for the Reference Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	12070	0.669E-04	0.268E-04	0.172E-05
SW	12070	0.111E-03	0.240E-04	0.317E-05
WSW	12070	0.836E-04	0.278E-04	0.144E-05
W	12070	0.111E-03	0.214E-04	0.150E-05
WNW	12070	0.111E-03	0.425E-04	0.323E-05
NW	12070	0.111E-03	0.286E-04	0.247E-05
NNW	12070	0.111E-03	0.178E-04	0.131E-05
N	12070	0.111E-03	0.216E-04	0.269E-06
NNE	12070	0.111E-03	0.241E-04	0.269E-06
NE	12070	0.111E-03	0.272E-04	0.502E-06
ENE	12070	0.111E-03	0.201E-04	0.317E-06
E	12070	0.836E-04	0.211E-04	0.432E-06
ESE	12070	0.836E-04	0.205E-04	0.115E-05
SE	12070	0.111E-03	0.201E-04	0.132E-05
SSE	12070	0.111E-03	0.229E-04	0.169E-05
S	12070	0.111E-03	0.177E-04	0.113E-05
ALL		0.111E-03	0.262E-04	0.145E-05
SSW	24140	0.360E-04	0.141E-04	0.725E-06
SW	24140	0.599E-04	0.126E-04	0.138E-05
WSW	24140	0.450E-04	0.146E-04	0.627E-06
W	24140	0.599E-04	0.112E-04	0.624E-06
WNW	24140	0.599E-04	0.223E-04	0.145E-05
NW	24140	0.599E-04	0.149E-04	0.107E-05
NNW	24140	0.599E-04	0.913E-05	0.547E-06
N	24140	0.599E-04	0.113E-04	0.912E-07
NNE	24140	0.599E-04	0.126E-04	0.956E-07
NE	24140	0.599E-04	0.143E-04	0.188E-06
ENE	24140	0.599E-04	0.105E-04	0.105E-06
E	24140	0.450E-04	0.111E-04	0.166E-06
ESE	24140	0.450E-04	0.108E-04	0.465E-06
SE	24140	0.599E-04	0.103E-04	0.555E-06
SSE	24140	0.599E-04	0.119E-04	0.703E-06
S	24140	0.599E-04	0.929E-05	0.460E-06
ALL		0.599E-04	0.137E-04	0.608E-06

1789 284

Table 21. One-Hour Frequency Distribution of X/Q Values for the Reference Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	40233	0.230E-04	0.887E-05	0.381E-06
SW	40233	0.383E-04	0.806E-05	0.795E-06
WSW	40233	0.287E-04	0.917E-05	0.352E-06
W	40233	0.383E-04	0.724E-05	0.347E-06
WNW	40233	0.383E-04	0.138E-04	0.832E-06
NW	40233	0.383E-04	0.938E-05	0.607E-06
NNW	40233	0.383E-04	0.578E-05	0.301E-06
N	40233	0.383E-04	0.737E-05	0.424E-07
NNE	40233	0.383E-04	0.811E-05	0.417E-07
NE	40233	0.383E-04	0.902E-05	0.972E-07
ENE	40233	0.383E-04	0.717E-05	0.497E-07
E	40233	0.287E-04	0.700E-05	0.845E-07
ESE	40233	0.287E-04	0.680E-05	0.244E-06
SE	40233	0.383E-04	0.652E-05	0.297E-06
SSE	40233	0.383E-04	0.795E-05	0.372E-06
S	40233	0.383E-04	0.617E-05	0.245E-06
ALL		0.383E-04	0.862E-05	0.332E-06
SSW	56327	0.173E-04	0.681E-05	0.259E-06
SW	56327	0.288E-04	0.611E-05	0.558E-06
WSW	56327	0.216E-04	0.703E-05	0.243E-06
W	56327	0.288E-04	0.529E-05	0.243E-06
WNW	56327	0.288E-04	0.108E-04	0.581E-06
NW	56327	0.288E-04	0.716E-05	0.417E-06
NNW	56327	0.288E-04	0.444E-05	0.204E-06
N	56327	0.288E-04	0.537E-05	0.249E-07
NNE	56327	0.288E-04	0.611E-05	0.260E-07
NE	56327	0.288E-04	0.691E-05	0.646E-07
ENE	56327	0.288E-04	0.518E-05	0.282E-07
E	56327	0.216E-04	0.519E-05	0.547E-07
ESE	56327	0.216E-04	0.528E-05	0.167E-06
SE	56327	0.288E-04	0.481E-05	0.202E-06
SSE	56327	0.288E-04	0.576E-05	0.241E-06
S	56327	0.288E-04	0.457E-05	0.162E-06
ALL		0.288E-04	0.657E-05	0.227E-06

1789 285

Table 21. One-Hour Frequency Distribution of χ/Q Values for the Reference Site (Concluded)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	72420	0.141E-04	0.534E-05	0.200E-06
SW	72420	0.234E-04	0.511E-05	0.435E-06
WSW	72420	0.176E-04	0.548E-05	0.179E-06
W	72420	0.234E-04	0.424E-05	0.179E-06
WNW	72420	0.234E-04	0.838E-05	0.440E-06
NW	72420	0.234E-04	0.558E-05	0.325E-06
NNW	72420	0.234E-04	0.360E-05	0.154E-06
N	72420	0.234E-04	0.450E-05	0.174E-07
NNE	72420	0.234E-04	0.505E-05	0.172E-07
NE	72420	0.234E-04	0.541E-05	0.464E-07
ENE	72420	0.234E-04	0.418E-05	0.202E-07
E	72420	0.176E-04	0.429E-05	0.404E-07
ESE	72420	0.176E-04	0.418E-05	0.120E-06
SE	72420	0.234E-04	0.403E-05	0.149E-06
SSE	72420	0.234E-04	0.488E-05	0.176E-06
S	72420	0.234E-04	0.366E-05	0.120E-06
ALL		0.234E-04	0.529E-05	0.170E-06

1789 286

ANNEX 2

ECOLOGICAL DATA

Contents

List of Tables

Table 1. Vegetation Potentially Present but Not Observed at, or in the Vicinity of, the Reference Site

Taxon[a]

Acanthaceae
- *Carlowrightia linearifolia*
- *Stenandrium barbatum*

Amaranthaceae
- *Acanthochiton wrightii*
- *Amaranthus graecizans**
- *Amaranthus palmeri*
- *Cycloloma atriplicifolia*
- *Tidestromia lanuginosa*
- *Tidestromia suffruticosa*

Amaryllidaceae
- *Agave lechuguilla*
- *Zephranthes longifolia*

Anacardiaceae
- *Rhus choriophylla*
- *Rhus copallina lanceolata*
- *Rhus microphylla*
- *Rhus trilobata pilosissima*

Asclepiadaceae
- *Asclepias arenaria*
- *Asclepias brachystephana*
- *Asclepias elata*
- *Asclepias subverticillata*
- *Funastrum crispum*

Berberidaceae
- *Berberis trifoliata*

Bignoniaceae
- *Chilopsis linearis*

Boraginaceae
- *Coldenia canescens*
- *Coldenia greggii*
- *Coldenia hispidissima*
- *Cryptantha angustifolia*
- *Cryptantha crassisepala crassisepala*
- *Cryptantha jamesii*
- *Cryptantha mexicana*
- *Cryptantha minima*
- *Cryptantha oblata*
- *Heliotropium convolvulaceum*
- *Heliotropium curassivicum obovatum*
- *Heliotropium greggii*
- *Lappula redowskii*

Cactaceae
- *Echinocactus horizontalonius*
- *Echinocereus pectinatus neomexicanus*
- *Echinocereus triglochidiatus fendleri*
- *Echinocereus viridiflorus*
- *Epithelantha micromeris*
- *Mammillaria lasiacantha*
- *Opuntia imbricata*
- *Opuntia macrorhiza*
- *Opuntia violacea violacea*
- *Opuntia violacea macrocentra*

Chenopodiaceae
- *Allenrolfea occidentalis*
- *Bassia hyssopifolia*
- *Chenopodium incanum*
- *Salicornia bigelovii*
- *Suaeda suffrutescens*

Compositae
- *Aphanostephus riddellii*
- *Aphanostephus skirrhobasis*
- *Baccharis pteronioides*
- *Baccharis wrightii*
- *Bahia pedata*
- *Bahia absinthifolia dealbata*
- *Berlandiera lyrata*
- *Brickellia californica*
- *Brickellia laciniata*
- *Chrysopsis villosa*
- *Conyza canadensis*
- *Conyza coulteri*
- *Dicranocarpus parviflorus*
- *Dyssodia acerosa*
- *Dyssodia pentachaeta*
- *Evax multicaulis*
- *Franseria acanthicarpa*
- *Franseria confertiflora*
- *Gaillardia pinnatifida*
- *Grindelia aphanactis*
- *Grindelia havardii*
- *Gutierrezia glutinosa*

1789 289

Table 1. Vegetation Potentially Present but Not Observed at, or in the Vicinity of, the Reference Site (continued)

Taxon[a]
Compositae (continued)
Gutierrezia microcephala
Helenium microcephalum
Helianthus neglectus
Helianthus ciliaris
Heterotheca latifolia
Hymenoxys linearifolia
Hymenoxys odorata
Haplopappus havardii
Haplopappus heterophyllus
Haplopappus pluriflorus
Haplopappus spinulosus spinulosus
Haplopappus spinulosus australis
Haplopappus spinulosus laevis
Haplopappus spinulosus scabrellus
Iva ambrosiaefolia
Iva dealbata
Lygodesmia texana
Machaeranthera tanacetifolia
Parthenium lyratum
Perezia wrightii
Sanvitallia abertii
Sartwellia flaveriae
Selloa glutinosa
Stephanomeria exigua
Stephanomeria pauciflora
Townsendia exscapa
Trixis californica
Verbesina encelioides encelioides
Verbesina encelioides exauriculata
Verbesina nana
Viguiera stenoloba
Zinnia grandiflora
Convolvulaceae
Convolvulus sepium*
Ipomoea costellata
Ipomoea hirsutula
Ipomoea leptotoma
Cruciferae
Brassica juncea*
Capsella bursa-pastoris*
Descurainia pinnata halictorum
Greggia camporum
Lesquerella gordonii
Lesquerella fendleri

Taxon[a]
Cruciferae (continued)
Sisymbrium irio*
Streptanthus carinatus
Cucurbitaceae
Cucurbita foetidissima
Ibervillea tenuisecta
Ephedraceae
Ephedra antisyphilitica
Ephedra torreyana
Euphorbiaceae
Acalypha lindheimeri
Acalypha neomexicana
Bernardia myricaefolia
Croton corymbulosus
Croton fruticulosus
Ditaxis laevis
Euphorbia acuta
Euphorbia albomarginata
Euphorbia lata
Euphorbia serpens
Euphorbia serpyllifolia
Euphorbia spathulata
Euphorbia stictospora
Stillingia sylvatica
Fagaceae
Quercus pungens
Fouquieriaceae
Fouquieria splendens
Geraniaceae
Erodium cicutarium
Erodium texanum
Gramineae (Poaceae)
Aristida fendleriana
Aristida pansa
Bouteloua breviseta
Bouteloua gracilis
Bouteloua trifida
Bromus catharticus
Bromus tectorum
Cenchrus echinatus

1789 290

Table 1. Vegetation Potentially Present but Not Observed at, or in the Vicinity of, the Reference Site (continued)

Taxon[a]

Gramineae (Poaceae) (continued)
- *Chloris virgata*
- *Digitaria sanguinalis*
- *Enneapogon desvauxii*
- *Eragrostis arida*
- *Eragrostis erosa*
- *Eragrostis lugens*
- *Eragrostis neomexicana*
- *Hilaria mutica*
- *Hordeum pusillum*
- *Leptochloa dubia*
- *Leptochloa fascicularis*
- *Leptochloa filiformis*
- *Muhlenbergia arenacea*
- *Muhlenbergia arinicola*
- *Muhlenbergia asperifolia*
- *Muhlenbergia pungens*
- *Muhlenbergia setifolia*
- *Panicum capillare occidentale*
- *Panicum hallii*
- *Panicum hirticaule*
- *Piptochaetium fimbriatum*
- *Scleropogon brevifolius*
- *Setaria viridis**
- *Setaria macrostachya*
- *Sitanion hystrix*
- *Sorghum halapense**
- *Sorghastrum nutans*
- *Sporobolus giganteus*
- *Sporobolus texanus*

Hydrophyllaceae
- *Nama carnosum*
- *Nama hispidum*
- *Nama xylopodum*
- *Phacelia corrugata*
- *Phacelia coerulea*
- *Phacelia popei*

Labiatae
- *Hedeoma drummondii*
- *Hedeoma nana*
- *Scutellaria drummondii*

Leguminosae
- *Acacia angustissima cuspidata*
- *Acacia constricta*

Leguminosae (continued)
- *Acacia greggii*
- *Acacia roemeriana*
- *Astragalus nuttallianus austrinus*
- *Astragalus waterfallii*
- *Astragalus wootonii*
- *Cassia bauhinioides*
- *Cassia lindheimeriana*
- *Cassia roemeriana*
- *Dalea nana*
- *Dalea pogonathera*
- *Dalea scoparia*
- *Dalea terminalis*
- *Desmanthus illinoensis*
- *Desmanthus cooleyi*
- *Hoffmanseggia densiflora*
- *Hoffmanseggia drepanocarpa*
- *Krameria parvifolia*
- *Krameria lanceolata*
- *Phaseolus leiospermus*
- *Rhynchosia texana*
- *Sophora nuttalliana*
- *Sophora secundiflora*

Liliaceae
- *Dasylirion leiophyllum*
- *Dasylirion wheeleri*
- *Schoenocaulon texanum*
- *Yucca baccata*
- *Yucca elata*

Linaceae
- *Linum aristatum*
- *Linum vernale*

Loasaceae
- *Cevallia sinuata*
- *Mentzelia pumila*

Malvaceae
- *Abutilon malacum*
- *Abutilon parvulum*
- *Abutilon theophrastii**
- *Abutilon wrightii*
- *Hibuscus denudatus involucellatus*
- *Sida physocalyx*
- *Sida procumbens*

Table 1. Vegetation Potentially Present but Not Observed at, or in the Vicinity of, the Reference Site (continued)

Taxon[a]
Malvaceae (continued)
Sphaeralcea angustifolia cuspidata
Sphaeralcea angustifolia lobata
Sphaeralcea coccinea
Sphaeralcea incana
Sphaeralcea subhastata
Martyniaceae
Proboscidea arenaria
Proboscidea louisianica
Proboscidea parviflora
Moraceae
Morus microphylla
Nyctaginaceae
Allionia choisyi
Allionia incarnata
Anulocaulis gypsogenus
Anulocaulis leisolenus
Acleisanthes longiflora
Boerhaavia linearifolia
Boerhaavia tenuifolia
Cyphomeris gypsophiloides
Mirabilis multiflora
Oxybaphus comatus
Nyctaginea capitata
Oleaceae
Forestiera pubescens
Menodora longiflora
Menodora scabra
Onagraceae
Calylophus hartwegii hartwegii
Calylophus hartwegii fendleri
Calylophus hartwegii filifolius
Calylophus serrulatus
Calylophus tubiculus
Gaura coccinea
Gaura parviflora
Gaura suffulta neallii
Oenothera brachycarpa
Papaveraceae
Argemone squarrosa
Plantaginaceae
Plantago heterophylla
Plantago purshii
Plumbaginaceae
Limonium limbatum
Polemoniaceae
Gilia rigidula acerosa
Polygalaceae
Polygala hemipterocarpa
Polygala longa
Polygala macradenia
Polygala obscura
Polygonaceae
Eriogonum gypsophilum
Eriogonum leucophyllum
Eriogonum havardii
Polygonum persicaria*
Rumex crispus*
Rumex hymenosepalus
Portulacaceae
Portulaca oleracea*
Sessuvium verrucosum
Talinum angustissima
Talinum aurantiacum
Talinum pulchellum
Rhamnaceae
Ceanothus greggii
Microrhamnus ericoides
Rubicaceae
Galium microphyllum
Galium proliferum
Houstonia acerosa
Houstonia polypremoides
Scrophulariaceae
Castilleja integra
Leucophyllum minus
Linaria texana
Maurandya antirrihiniflora
Penstemon ambiguus

Table 1. Vegetation Potentially Present but Not Observed at, or in the Vicinity of, the Reference Site (concluded)

Taxon[a]	Taxon[a]
Solanaceae	Verbenaceae
Chamaesaracha conioides	*Aloysia lycioides*
Chamaesaracha coronopus	*Aloysia wrightii*
Datura metelioides	*Phyla cuneifolia*
Datura quercifolia	*Tetraclea coulteri*
Lycium berlandieri	*Verbena bracteata*
Physalis hederaefolia	*Verbena ciliata*
Physalis lobata	*Verbena perennis*
Physalis viscosa	*Verbena plicata*
Ulmaceae	Zygophyllaceae
Celtis reticulata	*Kallstroemia hirsutissima*
	Kallstroemia parviflora

[a]An asterisk is used to indicate nonnative plant species that have become naturalized in the area.

Table 2. Mammalian Species Potentially Inhabiting but Not Observed at, or in the Vicinity of, the Reference Site[a]

Common name	Scientific name
Desert shrew	*Notiosorex crawfordi*
Cave myotis	*Myotis velifer*
Fringed myotis	*Myotis thysanodes*
California myotis	*Myotis californicus*
Yuma myotis	*Myotis yumanensis*
Long-legged myotis	*Myotis volans*
Small-footed myotis	*Myotis leibii*
Silver-haired bat	*Lasionycteris noctivagans*
Western pipistrelle	*Pipistrellus hesperus*
Big brown bat	*Eptesicus fuscus*
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Townsend's big-eared bat	*Plecotus townsendii*
Pallid bat	*Antrozous pallidus*
Brazilian free-tailed bat	*Tadarida brasiliensis*
Big free-tailed bat	*Tadarida macrotis*
Eastern cottontail	*Sylvilagus floridanus*
Desert cottontail	*Sylvilagus audubonii*
Black-tailed jack rabbit	*Lepus californicus*
White-tailed antelope squirrel	*Ammospermophilus leucurus*
Mexican ground squirrel	*Spermophilus mexicanus*
Spotted ground squirrel	*Spermophilus spilosoma*
Rock squirrel	*Spermophilus variegatus*
Black-tailed prairie dog	*Cynomys ludovicianus*
Botta's pocket gopher	*Thomomys bottae*
Plains pocket gopher	*Geomys bursarius*
Yellow-faced pocket gopher	*Pappogeomys castanops*
Plains pocket mouse	*Perognathus flavescens*
Silky pocket mouse	*Perognathus flavus*
Hispid pocket mouse	*Perognathus hispidus*
Desert pocket mouse	*Perognathus penicillatus*
Ord's kangaroo rat	*Dipodomys ordii*
Merriam's kangaroo rat	*Dipodomys merriami*
Plains harvest mouse	*Reithrodontomys montanus*
Western harvest mouse	*Reithrodontomys megalotis*
Cactus mouse	*Peromyscus erimicus*
Deer mouse	*Peromyscus maniculatus*
White-footed mouse	*Peromyscus leucopus*
Brush mouse	*Peromyscus boylii*
Rock mouse	*Peromyscus difficilis*
Northern grasshopper mouse	*Onychomys leucogaster*
Southern grasshopper mouse	*Onychomys torridus*
Hispid cotton rat	*Sigmodon hispidus*
Southern plains woodrat	*Neotoma micropus*
White-throated woodrat	*Neotoma albigula*
Mexican woodrat	*Neotoma mexicana*
Porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Kit fox	*Vulpes macrotis*

1789 294

Table 2. Mammalian Species Potentially Inhabiting but Not Observed at, or in the Vicinity of, the Reference Site[a] (concluded)

Common name	Scientific name
Gray fox	*Urocyon cinereoargenteus*
Ringtail	*Bassericus astutus*
Long-tailed weasel	*Mustela frenata*
Badger	*Taxidea taxus*
Western spotted skunk	*Spilogale gracilis*
Striped skunk	*Mephitis mephitis*
Hog-nosed skunk	*Conepatus mesoleucus*
Mountain lion	*Felis concolor*
Bobcat	*Felis rufus*
Pronghorn	*Antilocapra americana*
Mule deer	*Odocoileus hemionus*
White-tailed deer	*Odocoileus virginianus*

[a]Common and scientific names follow Jones et al. (1975).

Table 3. Estimated Densities of Bird Species at, and in the Vicinity of, the Reference Site

Species	Density (number per 100 hectares) 1975 S	O	N	D	1976 J	F	M	J	J	A	1977 M	A	M	J	J	A
<u>Ducks</u>																
Mallard	<1															
Green-winged teal		<1														
Blue-winged teal		<1														
<u>Hawks and allies</u>																
Turkey vulture	<1	<1						<1	<1	<1			<1	<1		
Red-tailed hawk					<1	<1		<1								
Swainson's hawk	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1
Ferruginous hawk					<1	<1								<1		
Harris' hawk		<1							<1	<1	<1	<1	<1	<1	<1	<1
Marsh hawk	<1	<1	<1	<1	<1	<1	<1				<1	<1	<1			
American kestrel	<1	<1	<1	<1	<1	<1	<1		<1							<1
<u>Quails</u>																
Bobwhite									<1	<1						
Scaled quail	4	3	7	4	3	3	6	3	1	7	3	2	2	2	3	7
<u>Cranes</u>																
Sandhill crane		<1														
<u>Doves</u>																
Mourning dove	19	7	5	4	1			<1	1	2	<1	<1	<1	<1	2	2
<u>Cuckoos</u>																
Yellow-billed cuckoo	<1															
Roadrunner	<1	<1			<1	<1		<1	<1	<1		<1	<1	<1	<1	<1
<u>Owls</u>																
Greated horned owl										<1						<1
Burrowing owl								<1	<1	<1						

Table 3. Estimated Densities of Bird Species at, and in the Vicinity of, the Reference Site (continued)

Species	Density (number per 100 hectares)															
	1975				1976						1977					
	S	O	N	D	J	F	M	J	J	A	M	A	M	J	J	A
Nighthawks																
Common nighthawk								1	1	1						
Lesser nighthawk								3	1	1			1	2		<1
Woodpeckers																
Ladder-backed woodpecker						<1	1		<1	<1				<1	<1	
Red-shafted flicker											<1					
Perching birds																
Western kingbird	<1							1		<1		<1	<1		1	
Scissor-tailed flycatcher	<1								<1				<1			
Ash-throated flycatcher								<1				<1		<1	<1	
Say's phoebe	<1	<1										<1				<1
Western empidonax flycatcher	<1	1														
Western wood pewee	<1												<1			
Cliff swallow	<1															
Blue jay		<1														
White-necked raven	1	<1				<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
House wren		<1				1										
Carolina wren		<1			1											
Cactus wren				1		1	1	1	2	2	<1			<1	<1	<1
Rock wren										<1						
Mockingbird	1	<1						4	1	<1	<1	<1	4	2	<1	<1
Brown thrasher		<1										<1	<1			
Curve-billed thrasher		<1												<1		
Crissal thrasher		<1						<1	<1	<1			<1	<1	<1	<1
Sage thrasher		<1														
Loggerhead shrike	4	3	3	2	4	3	4	3	3	4	5	4	4	5	6	3
Myrtle warbler	<1	<1														
Audubon's warbler		<1														
Wilson's warbler	2															

Table 3. Estimated Densities of Bird Species at, and in the Vicinity of, the Reference Site (concluded)

Species	Density (number per 100 hectares)															
	1975				1976						1977					
	S	O	N	D	J	F	M	J	J	A	M	A	M	J	J	A
Perching birds (continued)																
Eastern meadowlark		<1	1	1		1										
Western meadowlark	<1	2	12	5	12	11	6	<1		<1	5		<1			
Bullock's oriole	<1								<1				<1			
Brewer's blackbird								<1								
Brown-headed cowbird	<1								[illegible]				<1	<1		<1
Pyrrhuloxia	1	4	7	10	4	4	6	10	9	5	4	8	4	10	10	6
House-finch				1												
Lark bunting	10	9	7	21	9	12	25	1	1	10			<1			<1
Pine siskin				1	31	2	19									
American goldfinch				3		2										
Green-tailed towhee		1	2													
Rufous-sided towhee		1	1													
Baird's sparrow		<1														
Vesper sparrow	1	8	9	6	3	1	10									
Lark sparrow	<1											<1	<1	<1		
Cassin's sparrow	11	6	5	3	1	1		<1								
Black-throated sparrow	1	1	1		4	1	3	2	3	1	4	2	3	2	<1	<1
Sage sparrow					<1	4		<1	1	<1						
Chipping sparrow																<1
Oregon junco				1		1										
Clay-colored sparrow	<1	<1														
Brewer's sparrow		<1														
White-crowned sparrow		9	9	18	16	12	8					<1				

Table 4. Amphibians and Reptiles Potentially Inhabiting but Not Observed at, or in the Vicinity of, the Reference Site

Common name[a]	Scientific name[a]
AMPHIBIANS	
Tiger salamander	Ambystoma tigrinum
Plains spadefoot	Scaphiopus bombifrons
Western spadefoot	Scaphiopus hammondi
Green plains toad	Bufo cognatus
Green toad	Bufo debilis
Red-spotted toad	Bufo punctatus
Canyon treefrog	Hyla arenicolor
Bullfrog	Rana catesbeiana
REPTILES	
Snapping turtle	Chelydra serpentina
Western box turtle	Terrapene ornata
Yellow mud turtle	Kinosternon flavescens
Lesser earless lizard	Holbrookia maculata
Greater earless lizard	Cophosaurus texanus
Longnose leopard lizard	Gambelia wislizenii
Collared lizard	Crotaphytus collaris
Eastern fence lizard	Sceloporus undulatus
Sagebrush lizard	Sceloporus graciosus
Tree lizard	Urosaurus ornatus
Side-blotched lizard	Uta stansburiana
Texas horned lizard	Phrynosoma cornutum
Roundtail horned lizard	Phynosoma modestum
Great Plains skink	Eumeces obsoletus
Many-lined skink	Eumeces multivirgatus
Colorado checkered whiptail	Cnemidophorus tesselatus
Six-lined racerunner	Cnemidophorus sexlineatus
Western whiptail	Cnemidophorus tigris
Little striped whiptail	Cnemidophorus inornatus
Texas spotted whiptail	Cnemidophorus gularis
Texas blind snake	Leptotyphlops dulcis
Western hognose snake	Heterodon nasicus
Ringneck snake	Diadophis punctatus
Coachwhip snake	Masticophis flagellum
Striped whipsnake	Masticophis taeniatus
Gopher snake	Pituophis melanoleucus
Glossy snake	Arizona elegans
Corn snake	Elaphe guttata
Trans-Pecos rat snake	Elaphe subocularis
Common kingsnake	Lampropeltis getulus
Long-nosed snake	Rhinocheilus lecontei
Checkered garter snake	Thamnophis marcianus
Blackneck garter snake	Thamnophis cyrtopsis
Common garter snake	Thamnophis sirtalis
Ground snake	Sonora episcopa
Western hooknose snake	Gyalopion canum
Plains blackhead snake	Tantilla nigriceps
Night snake	Hypsiglena torquata

Table 4. Amphibians and Reptiles Potentially Inhabiting but Not Observed at, or in the Vicinity of, the Reference Site (concluded)

Common name[a]	Scientific name[a]
REPTILES (continued)	
Rock rattlesnake	Crotalus lepidus
Western rattlesnake	Crotalus viridis
Western diamondback rattlesnake	Crotalus atrox
Massasauga	Sistrus catenatus

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

Table 5. Range Condition of the Land at the Reference Site[a]

Soil mapping unit	Range site	Annual production (lb)[b]	Potential vegetation: Key decreases	Potential vegetation: Key increases	Potential vegetation: Key invaders
Berino complex, 0-3% slopes, eroded	Deep sand	400-2400	Little bluestem Sand bluestem Black grama Bush muhly Side-oats grama Plains bristle grass	Blue grama Hairy grama Sand dropseed Three-awn Mesquite Shinnery oak	Broom snakewood Annuals
Kermit-Berino sand, 0-3% slopes:					
Kermit fine sand	Sand hill	800-3000	Bush muhly Little bluestem Black grama Sand bluestem Plains bristle grass Indian rice grass Switchgrass	Blue grama Red lovegrass Halls panicum Sand dropseed Tall dropseed Sand muhly Mesquite Little soaptree yucca Shinnery oak Sand sage brush Catclaw mimosa	Broom snakewood Ring muhly Annuals
Berino fine sand	Deep sand	400-2400	See Berino complex above	See Berino complex above	See Berino complex above

[a]Based on data from the Soil Conservation Service (SCS, 1971).

[b]Low numbers indicate average annual production of air-dry grazable forage on sites in poor condition; high numbers indicate production on sites in excellent condition.

Table 6. **Water-Quality Physical and Chemical Parameters**, February 5, 1978

Parameter	Windmill tank	Laguna Grande de la Sal	Pecos River: Harroum crossing	Pecos River: Pipeline crossing	Red Bluff Reservoir: Upper	Red Bluff Reservoir: Lower
Air temperature, °C	15	19	15	15	16	19
Water temperature, °C	10	15	13	10	12	10
Dissolved oxygen, mg/l	13.6	1.4	11	12	12.4	13.2
Specific conductance, μohm/cm	1,600	400,000	10,000	20,000	12,000	12,000
Nitrate, mg/l				2	1.2	
Nitrite, mg/l				16.4	8.4	
Hardness (as $CaCO_3$), mg/l			220	320	289	340
Chloride, mg/l	590	232,000	3000		3500	4200
Turbidity, Jackson turbidity units	9	3	14	14	3	14
Sulfates, mg/l	542.5	4160	1500	2150	2150	2276
Orthophosphate (as P), mg/l				0.11		

Table 7. Checklist of Fish from the Lower Pecos Drainage[a]

Species	Before 1972	1974-75	1977-78
BELOW 6-MILE DAM STATION			
Family Centrarchidae			
Lepomis cyanellus Rafinesque		x	
Lepomis machrochirus (Rafinesque)		x	
Micropterus salmoides (Lacepede)		x	
Pomoxis annularis (Rafinesque)		x	
Family Clupeidae			
Dorosoma cepedianum (Lesueur)		x	
Family Cyprinidae			
Cyprinus carpio (Linnaeus		x	
Hybognathus placitus Girard			
Notropis lutrensis (Baird & Girard)		x	
Pimephales promelas (Rafinesque)		x	
Family Ictaluridae			
Ictalurus melas (Rafinesque)		x	
Ictalurus punctatus (Rafinesque)		x	
Family Poeciliidae			
Gambusia affinis (Baird & Girard)		x	
BELOW 10-MILE DAM STATION			
Family Catostomidae			
Carpiodes carpio (Rafinesque)		x	
Cycleptus elongatus (Lesueur)	x		
Moxostoma congestum (Baird & Girard)	x	x	
Family Centrarchidae			
Chaenobryttus gulosus (Cuvier)			x
Lepomis cyanellus (Rafinesque)		x	x
Lepomis machrochirus (Rafinesque)			x
Lepomis megalotis X *L. machrochirus*			x
Lepomis megalotis (Rafinesque)	x		
Micropterus punctulatus (Rafinesque)	x		
Family Clupeidae			
Dorosoma depediaum (Lesueur)			x
Family Cyprinidae			
Cyprinus carpio (Linnaeus)	x	x	
Notropis lutrensis (Baird & Girard)			x
Pimephales promelas (Rafinesque)			x

1789 303

Table 7. Checklist of Fish from the Lower Pecos Drainage[a] (continued)

Species	Before 1972	1974-75	1977-78
Family Cyprinodontidae			
Lucania parva Baird	x		x
Fundulus zebrinus (Jordan & Gilbert)	x		
Family Ictaluridae			
Ictalurus punctatus (Rafinesque)	x		
Family Peocilliidae			
Gambusia affinis (Baird & Girard)	x		
BLACK RIVER AND PECOS CONFLUENCE			
Family Atherinidae			
Menidia berylina (Cope)		x	x
Family Catostomidae			
Carpiodes carpio (Rafinesque)	x		x
Cycleptus elongatus (Lesueur)	x		x
Ictiobus bubalus (Rafinesque)			x
Moxostoma congestum (Baird & Girard)	x		x
Family Centrarchidae			
Lepomis cynaellus (Rafinesque)			x
Lepomis gulcosus (Cuvier)			x
Lepomis machrochirus (Rafinesque)		x	x
Lepomis megalotis (Rafinesque)			
Micropterus punctulatus (Rafinesque)	x		x
Micropterus salmoides (Lacepede)			x
Family Clupeidae			
Dorosoma cepedianum (Lesueur)			x
Family Cypridae			
Cyprinus carpio (Linnaeus)			x
Hybognathus placitus Girard		x	
Notropis lutrensis (Baird & Girard)	x	x	x
Notrophis stramineus (Cope)	x		
Pimephales promelas (Rafinesque)	x	x	x
Family Cyprinodontidae			
Cyprinodon pecosensis (Eschelle)	x		
Fundulus zebrinus (Jordan & Gilbert)	x	x	
Lucania parva (Baird)	x		x
Family Ictaluridae			
Ictalurus punctatus (Rafinesque)			x
Family Lepisoteidae			
Lepisosteus osseus (Linnaeus)			x

Table 7. Checklist of Fish from the Lower Pecos Drainage[a] (continued)

Species	Before 1972	1974-75	1977-78
Family Percidae			
Etheostoma lepidum (Baird & Girard)	x		
Family Poeciliidae			
Gambusia affinis (Baird & Girard)	x		x
EL PASO NATURAL GAS PIPELINE CROSSING			
Family Atherinidae			
Menidia berylina (Cope)		x	x
Family Catostomidae			
Carpiodes carpio (Rafinesque)	x	x	
Cycleptus elongatus (Lesueur)	x		
Family Centrarchidae			
Lepomis cyanellus (Rafinesque)			x
Lepomis machrochirus (Rafinesque)			x
Lepomis megalotis (Rafinesque)		x	x
Micropterus punctulatus (Rafinesque)	x		x
Micropterus salmoides (Lacepede)			x
Family Clupeidae			
Dorosoma cepedianum (Lesueur)	x	x	x
Family Cyprinidae			
Cyprinus carpio (Linnaeus)		x	
Hybopsis aestivalis (Griard)	x		
Notropis lutrensis (Baird & Girard)	x	x	
Notropis stramineus (Cope)	x		
Pimephales promelas (Rafinesque)	x	x	
Family Cyprinodontidae			
Cyprinodon pecsenis (Eschelle)		x	x
Fundulus zebrinus (Jordan & Gilbert)	x	x	
Lucania parva Baird		x	x
Family Ictaluridae			
Ictalurus punctatus (Rafinesque)	x		
Family Percidae			
Etheostoma lepidum (Baird & Girard)	x		
Family Peociliidae			
Gambusia affinis (Baird & Girard)	x	x	x
UPPER RED BLUFF RESERVOIR			
Family Atherinidae			
Menidia berylina (Cope)		x	x

Table 7. Checklist of Fish from the Lower Pecos Drainage[a] (concluded)

Species	Before 1972	1974-75	1977-78
Family Catostomidae			
Carpiodes carpio (Rafinesque)	x	x	
Ictiobus niger (Rafinesque)		x	
Ictiobus bubalus (Rafinesque)	x	x	
Moxostoma congestum (Baird & Girard)	x		
Family Centrarchidae			
Lepomis cyanellus (Rafinesque)		x	
Lepomis machrochirus (Rafinesque)		x	
Lepomis megalotis (Rafinesque)	x		
Micropterus punctulatus (Rafinesque)	x		
Micropterus salmoides (Lacepede)	x		
Family Clupeidae			
Dorosoma cepedianum (Lesueur)	x	x	x
Family Cyprinidae			
Cyprinus carpio (Linnaeus)	x	x	
Hybognathus placitus Girard		x	
Notropis lutrensis (Baird & Girard)	x	x	
Pimephales promelas (Rafinesque)	x		
Family Cyprinodontidae			
Fundulus zebrinus (Jordan & Gilbert)	x		
Lucania parva Baird		x	x
Family Ictaluridae			
Ictalurus punctatus (Rafinesque)	x	x	
Pylodictus olivaris (Rafinesque)	x		
Family Lepisosteidae			
Lepisosteus osseus (Linnaeus)	x	x	
Family Percichthyidae			
Morone chrysops (Rafinesque)	x	x	x
Family Percidae			
Etheostoma lepidum (Baird & Girard)	x		
PUPFISH SPRINGS ABOVE SALT LAKE			
Family Cyprinodontidae			
Cyprinodon pecosensis (Eschelle)		x	x

[a]See Section H.5 for map and description of sampling stations.

1789 306

Table 8. Macrobenthic Invertebrates: Preliminary Results Based on Collection of Spring 1978[a]

Taxon	Sampling station[b]												
	1	2	3[c]	4	5	6	7	8	9[c]	10	11	12	13
Nematoda									48				20
Oligochaeta			746			65			3,714				601
Gastropoda													
Physidae									33				
Pelecypoda													
Sphaeriidae			1,148										
Archoidea													
Acari			287										
Crustace													
Amphipoda													
Talitridae						11							
Ostracoda			35,421		43								
Copepoda			631										
Insecta													
Odonata													
Coenagrionidae									81				
Ephemeroptera													
Bactidae									(d)				
Diptera													
Chironomidae			15,328			2,648			5,263			3,6600	200
Ceratopogonidae			1,378		3,703	517							86
Dolichopodidae			57		86								
Muscidae						11							43
Ephydridae				(d)									
Tabanidae						11							
Simuliidae						15,071							
Coleoptera													
Dryopidae						11			193				
Hydrophilidae						32			81				
Trichoptera													
Hydropsychidae									26,419				
Hydroptilidae									33				

Table 8. Macrobenthic Invertebrates: Preliminary Results Based on Collection of Spring 1978[a] (concluded)

	Sampling station[b]												
Taxon	1	2	3[c]	4	5	6	7	8	9[c]	10	11	12	13
Lepidoptera													
Pyralidae									193				

[a]Data from Sublette (1978). Organisms recorded as number per square meter.
[b]See Appendix H, Section H.5, for map and description of locations.
[c]This sample estimated from an aliquot.
[d]This group has been in qualitative samples.

Table 9. Checklist of the Chironomidae (Diptera) of the Lower Pecos Valley, Chaves and Eddy Counties, New Mexico[a]

Chironominae

Chironomini

- *Chironomus crassicaudatus* Malloch
- *Chironomus decorus* Johannsen
- *Chironomus stigmaterus* Say
- *Chironomus whitseli* Sublette & Sublette
- *Cryptochironomus fulvus* (Johannsen)
- *Cyphomella gibbera* Saether
- *Dicrotendipes californicus* (Johannsen)
- *Dicrotendipes neomodestus* (Malloch)
- *Glyptotendipes (Phytotendipes) barbipes* Staeger
- *Goeldichironomus holoprasinus* (Geoldi)
- *Microchironomus nigrovittatus* (Malloch)
- *Parachironomus monochromus* (Wulp)
- *Parachironomus potamogeti* (Townes)
- *Paralauterborniella elachista* (Townes)
- *Paralauterborniella subcincta* (Townes)
- *Phaenopsectra* new species
- *Polypedilum digitifer* Townes
- *Polypedilum scalaenum* (Schrank)
- *Polypedilum sulaceps* Townes
- *Polypedilum* species 1
- *Polypedilum* species 2
- *Pseudochironomus richardsoni* (Malloch)

Tanytarsini

- *Micropsectra nigripila* (Johannsen)
- *Paratanytarsus* new species 2
- *Rheotanytarsus exiguus* (Johannsen)
- *Tanytarsus* new species 1
- *Tanytarsus* new species 2
- *Tanytarsus* new species 3
- *Tanytarsus* new species 4
- *Tanytarsus* new species 5
- *Tanytarsus (Calopsectra)* new species 6

Diamesinae

- *Diamesa heteropus* (Coquillett)

Orthocladinae

- *Cricotopus bicinctus* (Meigen)
- *Cricotopus irwini* Sublette & Sublette
- *Cricotopus infuscatus* (Malloch)
- *Cricotopus sylvestris* (Meigen)
- *Cricotopus* new species 1
- *Cricotopus* new species 2
- *Cricotopus* new species 3
- *Cricotopus* new species 4
- *Cricotopus* new species 5
- *Eukiefferiella* species 12
- *Nanoladius distinctus* (Malloch)
- *Parakiefferiella* new species 1
- *Parakiefferiella* new species 2
- *Parametriocnemus lundbecki* Johannsen
- *Thienemanniella similis* (Malloch)
- *Thienemanniella species* 3
- Genus and species new

Tanypodinae

- *Ablabesmyia cinctipes* Johannsen
- *Ablabesmyia mallochi* (Walley)
- *Ablabesmyia* species 1
- *Ablabesmyia* species 5
- *Labrundinia pilosella* (Loew)
- *Procladius (Psilotanypus) bellus* (Loew)
- *Procladius denticulatus* (Sublette)2
- *Paramerina smithae* (Sublette)
- *Tanypus grodhausi* Sublette
- *Tanypus neopunctipennis* Sublette
- *Telopelopia okoboji* (Walley)

[a]Data from Sublette (1978).

1789 309

Table 10. Windmill Fauna of Eastern New Mexico and Western Texas[a]

- Oligochaeta
  - Naididae
    - Undetermined species
- Gastropoda
  - Lymnaeidae
    - *Lymnaea bulimoides* Say
  - Planorbidae
    - *Helisoma trivolvis* Say
- Insecta
  - Hemiptera
    - Corixidae
      - *Corisella tarsalis* (Fieber)
      - *Corisella edulis* (Champion)
      - *Sigara (Vermicorixa) alternata* (Say)
    - Notonectidae
      - *Notonecta undulata* (Say)
- Odonata
  - *Lestes alacer* Hagen
  - *Lestes sigma* Calvert
  - *Enmallagma civile* Hagen
  - *Ischnura demorsa* Hagen
  - *Libellula saturata* Uhler
  - *Libellula pulchella* Drury
  - *Platyhemis lydia* Drury
  - *Celithemis eponina* Drury
  - *Tarnetrum corruptum* Hagen
  - *Pantala flavescens* Fabricius
- Ephemeroptera
  - *Cloeon* species
- Diptera
  - Chironomidae
    - *Chironomus* (s.s.) *decorus* Johannsen
    - *Chironomus* (s.s.) *stigmaterus* Say
    - *Chironomus* (s.s.) new species
    - *Tanypus grodhausi* Sublette
    - *Procladius sublettei* Roback
  - Culicidae
    - *Culex tarsalis* Coquillett
  - Ceratopogonidae
    - *Culicoides variipennis sonorensis* (Wirth and Stone)
- Coleoptera
  - Dytiscidae
    - *Thermonectes nigrofasciatus ornaticollis* Aube
    - *Laccophilus fasciatus terminalis* Sharp
  - Hydrophilidae
    - *Tropisternus lateralis nimbatus* (Say)
    - *Berosus styliferus* Horn

[a]Data from Sublette (1978).

Table 11. Playa Lake Fauna of Eastern New Mexico and Texas[a]

Turbellaria
  Undetermined species

Oligochaeta
  Naididae
    Undetermined species

Hirudinea
  Undetermined species

Gastropoda
  Helisoma trivolvis Say
  Lymnaea bulimoides Lea

Crustacea
  Anostraca
    Streptocephalus texanus (Packard)
    Streptocephalus dorothae Mackin
    Thamnocephalus platyurus Packard
    Branchinecta campestris Lynch
    Branchinella new species
  Notostraca
    Triops longicaudatus LeConte
  Conchostraca
    Leptestheria compleximanus (Packard)
    Lynceus brevifrons (Packard)
    Eocyzicus concavus (Mackin)
    Caenesteriella setosa (Pearse)
    Eulimnadia inflecta Mattox
    Cyzicus new species
  Ostracoda
    Cypriconcha gnathostomata Ferguson

Insecta
  Odonata
    Zygoptera
      Lestes alcer Hagen
    Anisoptera
      Tarnetrum corruptum (Hagen)
      Pantala flavescens Fabricius
  Ephemeroptera
    Cloeon species
  Hemiptera
    Corixidae
      Corisella tarsalis (Fieber)
      Corisella edulis (Champion)
      Sigara (Vermicorixa) species near *modesta* (Abbott)
      Rhamphocorixa acuminata (Uhler)
  Belostomatidae
    Undetermined species

1789 311

Table 11. Playa Lake Fauna of Eastern New Mexico and Texas[a] (concluded)

- Insecta (continued)
  - Notonectidae
    - *Notonecta undulata* Say
    - *Notonecta* species

- Coleoptera
  - Dytiscidae
    - *Copelatus glyphicus* (Say)
    - *Thermonectes nigrofasciatus ornaticollis* Aube
    - *Laccophilus fasciatus terminalis* Sharp
    - *Hygrotus nubilus* (LeConte)
    - *Eretes sticticus* (Linnaeus
  - Hydrophilidae
    - *Tropisternus lateralis nimbatus* (Say)
    - *Hydrophilus triangularis* Say
    - *Berosus styliferus* Horn
    - *Berosus miles* LeConte
    - *Berosus stramineus* Knisch
    - *Berosus exiguus* Say?
    - *Berosus rugulosus* Horn
    - *Helophorus* species
    - *Octhebius* species

- Trichoptera
  - Undetermined species

- Diptera
  - Ceratopogonidae
    - Undetermined species
  - Chironomidae
    - *Tanypus grodhausi* Sublette
    - *Procladius sublettei* Roback
    - *Chironomus* (s.s.) *decorus* Johannsen
    - *Chironomus* (s.s.) *stigmaterus* Say
    - *Cryptotendipes darbyi* (Sublette)
    - *Glyptotendipes (Phytotendipes) barbipes* Staeger
  - Culcidae
    - *Culex tarsalis* Coquillett
  - Syrphidae
    - *Tubifera* species

- Acarina
  - Undetermined species

- Amphibia
  - *Scaphiopus* species

---

[a]Data from Sublette (1978).

Table 12. Preliminary Microbiology Survey of the Reference-Site Region[a]

Sampling location	Chlorophyll a (μg/l)	Chlorophyll b (μg/l)	Protein (mg/l)	Phycocyanin (μg/l)	Diatoms (cells/l x 10^{-6})	Bacteria (cells/l x 10^{-9})	Temperature (°C)	pH	Conductivity (μmhos x 10^{-3})	Alkalinity (mg/l $CaCO_3$)
Pupfish Spring (Laguna Grande de la Sal)	--	--	--	--	--	--	10	7.0	45	--
Windmill water tank (reference site)	1.3	0.072	3.6	10	0.084	2.5	5	8.7	1	160
Pecos River and Highway 31	--	--	--	--	5.7	2.5	11	8.4	4.5	110
Harroun (Pecos River)	15.6	0.24	3.3	10	1.8	2.3	10	8.2	3.4	130
Pipeline road (Pecos River)	9.1	0.12	2.3	10	6.2	0.82	10	8.2	15	120
Red Bluff Reservoir	4.9	0.11	2.6	10	5.6	2.3	10	8.4	15	100
Subsurface spring (Laguna Grande de la Sal)	--	--	--	--	--	--	10	7.0	200	--
Solar pond (Laguna Grande de la Sal)	1.6	0.08	1.2	10	0.005	--	15	7.0	200	--
Subterranean salt deposits (site)										
White	0.13[b]		--	--	--	--	--	--	--	--
Colored	0.10[b]		--	--	--	--	--	--	--	--

[a]All values are for phytoplankton and exclude epipelon, epilithon, and streamers of macroalgae, which were occasionally abundant. Data were collected on February 4, 1978.
[b]In micrograms per gram.

1789 313

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a]

Pteridophyta

Equisetaceae

Equisetum laevigatum A. Br. (E. kansanum J. H. Schaffn., synonym)
Throughout New Mexico. Along streams and lake banks, seepage areas.

Marsileaceae

Marsilea mucronata A. Br.
Eddy, Lea Counties. Shallow water in ponds, lakes, streams, or ditches.

Marsilea fournieri C. Chr.
Lea County. Playa lakes, ponds, and intermittent streams.

Polypodiaceae

Adiantum capillus-veneris L.
Eddy and Chaves Counties. Shaded areas, often among rocks, on damp soil near streams.

Spermatophyta

Monocotyledoneae

Typhaceae

Typha latifolia L.
Throughout most of Texas and New Mexico. Marshes or shallow water along streams.

Typha domingensis Pers.
Throughout most of Texas and New Mexico. Brackish or freshwater marshes and pools.

Potamogetonaceae

Potamogeton pectinatus L.
Eddy and Chaves Counties. Fresh and saline waters.

Potamogeton diversifolius Raf.
Eddy County. Ponds and lakes.

Potamogeton foliosus Rob. var. foliosus
Eddy County. Lakes and ponds.

Potamogeton gramineus L. var. gramineus
Eddy County. Lakes and ponds.

Potamogeton illinoensis Morong.
Eddy County. Lakes and ponds.

Zannichelliaceae

Zannichellia palustris L.
Chaves County. Quiet fresh or brackish water.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Ruppiaceae

Ruppia maritima L.
Chaves County. Fresh or saline water.

Gramineae

Agropyron smithii Rydb.
Trans-Pecos, Texas, to Grant and Colfax Counties, New Mexico. Marshes and edges of lakes, along streams and ponds, occasionally in flowing water.

Agrostis semiverticillata (Forsk.) C. Chr.
Eddy County. Stream banks.

Andropogon glomeratus (Walt.) B.S.P.
Eddy County. Marshy areas.

Distichlis stricta (Torr.) Rybd.
Lea and Chaves Counties. Alkaline or alkaline-saline areas in marshes, lakes, irrigation ditches.

Echinochloa colonum (L.) Link
Lea and Chaves Counties. Moist ground.

Echinochloa crusgalli var. *mitis* (Pursh.) Peterm.
Chaves County. Along ditches and in moist waste ground.

Elmus canadensis L.
Nearly throughout Texas and widespread in New Mexico. Wet mud along sluggish streams, in seepage areas, and marshes, along streams.

Eragrostis cilianensis (All.) E. Mosher
Trans-Pecos, Texas. Edges of playa lakes and ponds, in wettish sandy alkaline soil.

Hordeum jubatum L.
Trans-Pecos, Texas, to DeBaca, Colfax, San Juan, Valencia, McKinley, and Taos Counties, New Mexico. Moist open ground along ditches, in marshes and seepage areas, in shallow-water streams; often on alkaline or saline soils.

Leptochloa fascicularis (Lam.) Gray
Lea, Chaves, and Eddy Counties, New Mexico; Trans-Pecos, Texas. Muddy, sometimes alkaline or subsaline mud, about playa lakes, in seepage areas, and in shallow water of ponds and streams.

Leptochloa univervia (Presl.) Hitchc.
Lea, Eddy, and Chaves Counties, New Mexico; Trans-Pecos, Texas. Mud, sometimes alkaline or subalkaline, in ditches, along and in sloughs and river sandbars.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Muhlenbergia andina (Nutt.) Hitchc.
Trans-Pecos, Texas; San Miguel County, New Mexico. Wet meadows, moist thickets, river beds.

Muhlenbergia asperifolia (Nees and Mey.) Parodi
Trans-Pecos, Texas. Moist soil near streams and ditches, occasionally in marshy, wet or alkaline soil, in water of cattail swamps, and mud about pools and lakes.

Panicum capillare L.
Trans-Pecos, Texas; San Miguel and Sierra Counties, New Mexico. Moist soil along irrigation ditches and in wet sandy places along streams, about playa lakes.

Panicum hians Ell.
Eddy County. Damp ground around ponds or streams.

Panicum lanuginosum Ell.
Eddy County. Damp ground near lakes and streams.

Panicum tennesseense Ashe.
Eddy County. Moist ground, rare.

Panicum virgatum L.
Trans-Pecos, Texas; Colfax, Quay, and Guadalupe Counties, New Mexico. Moist, open places, fresh or brackish marshes, seepage areas, swamps, about lakes, edge of ponds and in shallow water of pools.

Paspalum dilatalum Poir
Trans-Pecos, Texas, infrequent. Disturbed soils in marshy meadows, along streams and irrigation ditches, mud and waters of marshes, lakes and ponds.

Paspalum distichum L.
Trans-Pecos, Texas. Margins of fresh ponds, streams and lakes, in marshes and on mud and in shallow water, sometimes in brackish areas.

Phalaris arundinacea L.
Chaves County. Moist ground.

Phragmites communis Trin.
Chaves, County. Wet ground, marshes, seeps, along rivers, at stream sides and canal banks.

Polypogon monspeliensis (L.) Desf.
Eddy and Chaves Counties. Moist soil near fresh or brackish ponds, along streams, seepage and boggy areas.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Setaria geniculata (Lam.) Beauv.
Throughout Texas, New Mexico, and Arizona. Disturbed moist areas, in mud along streams, salt and freshwater marshes, in mud and shallow water about ponds and lakes.

Setaria glauca (L.)
Trans-Pecos, Texas (rare); Sierra County, New Mexico. Wet soil on edges, lakes, and streams, in wet meadows, in ditches, and on gravel bars along streams.

Spartina pectinata Link.
Trans-Pecos, Texas. Freshwater or salt marshes, seepage areas, edges of ponds and streams.

Sphenopholis obtusata (Michx.) Scribn.
Eddy County. Water of creeks and seepage areas, wet soil.

Sporobolus flexuosus (Thurb.)
Trans-Pecos, Texas; widespread in New Mexico. Wet seepage areas.

Sporobolus texanus Vasey
Eddy and Chaves Counties. In moist, somewhat saline or alkaline soils.

Trichloris crinita (Lag.) Parodi
Trans-Pecos, Texas. Along or near intermittent creeks and along ditches.

Tridens albescens (Vasey) Wooten and Standl.
Lea County. Roadside ditches, streamsides, overflows, playa lakes.

Cyperaceae

Bulbostylis capillaris (L.) Clarke
Trans-Pecos, Texas; Dona Ana, Grant, and Socorro Counties, New Mexico. Seepage areas.

Carex frankii Kunth
Eddy County. Wet ground, usually near streams.

Cladium jamaicense Crantz.
Eddy and Chaves Counties; Trans-Pecos, Texas.Abundant in fresh water, on margins of streams, ponds, and lakes.

Cyperus albomarginatus Mart. & Schrad.
Trans-Pecos, Texas. Washes and along streams.

Cyperus aristatus Rottb.
Throughout Texas to Arizona. In wet soils, on edges of lakes, ponds, and marshes.

1789 317

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Cyperus difformis L.
Eddy County. Damp ground.

Cyperus elegans L.
Trans-Pecos, Texas (rare). Moist calcareous soil, edges of lakes, ponds, and tanks, in wet gravel sand of creek beds.

Cyperus esculentus L.
Chaves County. Wet ground (widespread).

Cyperus huarmensis (H.B.K.) M. C. Johnst.
Eddy County. Damp ground.

Cyperus laevigatus L.
Trans-Pecos, Texas. Infrequent in fresh or subsaline or gypseous mud, in water on edges of canals and streams, and in wet sandy flats.

Cyperus odoratus L.
Abundant in all parts of Texas and San Juan County, New Mexico. Mud of swamps, ditches, and streams; at edges of lakes and creeks.

Cyperus seslerioides H.B.K.
Eddy County. Damp ground.

Eleocharis engelmannii Steud.
Eddy County. Wet ground.

Eleocharis macrostachya Britt.
Eddy County. Marshes, vernal pools, wet meadows, ditches, flooded lands and alkaline mud.

Eleocharis montana (H.B.K.) R.& S.
Eddy County. Damp ground.

Eleocharis montevidensis Kunth.
Eddy County. Damp sandy soils; in shallow water of streams and ponds.

Eleocharis obtusa (Willd.) Schult.
Eddy County. Locally abundant in moist, sandy soils in wet meadows, shallow water of ponds, and at edges of lakes.

Eleocharis parvula (R.& S.) Link var. anachaeta (Torr.) Svenson.
Eddy and Chaves Counties; throughout Texas. Mud and shallow water of lakes, ponds and stream banks, occasionally in salt marshes.

Eleocharis radicans (Poir) Kunth.
Eddy County. Damp ground.

Eleocharis rostelleta Torr.
Eddy County. Mud in upland areas, springs, alkaline marshes and seeping wet meadows, often in saline ground.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Fuirena simplex Vahl.
Eddy County. Wet areas about springs, in shallow water on edges of ponds and lakes.

Scirpus acutus (Wats.) Chase
Eddy County; Trans-Pecos, Texas. Marshy ground, widespread; alkaline or calcareous mud, usually in water.

Scirpus americanus Pers. var. longispicatus Britt.
Throughout Texas and New Mexico. Moist ground in water and about seepage areas.

Scirpus californicus (C. A. Mey.) Steud.
Throughout Texas except Plains County; McKinley and Rio Arriba Counties, New Mexico. Mud and shallow water of ponds and lakes.

Scirpus olneyi Gray
Eddy County; Trans-Pecos, Texas. Salt marshes.

Scirpus paludosus A. Nels.
Chaves and Eddy Counties; Trans-Pecos, Texas. Marshes, salt flats; in mud about ponds and lakes; along streams.

Hemicarpha micrantha (Vahl.) Pax var. minor (Schrad.) Friedland.
Eddy County. Along streams.

Juncaceae

Juncus effusus L. var. solutus Fern. & Wieg.
Eddy County. Marshy areas around ponds, lakes, and streams.

Juncus interior Weig.
Trans-Pecos, Texas. Marshes; wet meadows; water in ditches, pools, and depressions, seepage areas.

Juncus torreyi Cov.
Eddy County. Damp or wet ground, fairly common; marshy margins of lakes, ponds, and streams, wet meadows, ditches, seepage areas.

Irdiaceae

Sisyrinchium dimorphum R. Oliv.
Trans-Pecos, Texas. Along streams.

Dicotyledoneae

Urticaceae

Urtica dioica L. ssp. gracilis (Ait.) Seland. var. gracilis
Trans-Pecos, Texas; throughout New Mexico. Along streams.

Salicaceae

Populus wislizenii
Common cottonwood along the Rio Grande in extreme western Texas and in New Mexico. Along rivers, streams, and irrigation canals.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Salix amygdaloides Anderss.
Trans-Pecos, Texas; Chaves County, New Mexico. Along streams and near water bodies.

Juglandaceae

Juglans major (Torr.) Heller
Trans-Pecos, Texas; southwestern New Mexico. Scattered along streams and in canyons.

Polygonaceae

Polygonum argyrocoleon Steud. ex Kunze
Lea County. Seasonally moist places such as temporary pools and playa lakes; in marshy ground.

Polygonum lapathifolia (L.) Gray
Chaves County, New Mexico; throughout Texas. Marshes, wet meadows; in and about water of ponds, lakes, and streams.

Polygonum persicaria L.
Throughout Texas; widespread in New Mexico.

Rumex crispus L.
Trans-Pecos, Texas; widespread in New Mexico. In shallow water of streams, about ponds and lakes and marshy areas, commonly in seasonally wet places.

Chenopodiaceae

Allenrolfea occidentalis (Wats.) Kuntze
Chaves County. In strongly alkaline places such as floodplains and in marshes.

Salicornia bigelovii Torr.
Chaves County. Salt marshes.

Salicornia utahensis Tides.
Chaves County. Damp alkaline soil near saline lakes and ponds.

Salsola kali L.
Through western North America. In mud about drying ponds and in salt marshes and alkaline floodplains.

Sarcobatus vermiculatus (Hook.) Torr.
Chaves County. Moist alkaline soil, salt marshes.

Suaeda nigrescens I. M. Johnst. var. glabra I. M. Johnst.
Chaves County. Saline soil on plains, flats, and stream banks.

Suaeda torreyana Wats.
Western Texas; rather general in New Mexico. Salt marshes and alkaline soil in mud of drying ponds.

1789 320

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Amaranthaceae

Amaranthus crassipes Schlecht

Trans-Pecos, Texas; not reported in New Mexico. On mud and gravel bars in rivers, along creeks, and in playa lakes.

Amaranthus palmeri Wats.

Throughout most of Texas and widespread in New Mexico. River banks, irrigation ditches, swamps along streams, and about ponds.

Aizoaceae

Sesuvium verrucosum Raf.

Chaves and Eddy Counties. In alkaline soil in river valleys or near lakes.

Caryophyllaceae

Drymaria pachyphylla Woot. & Standl.

Trans-Pecos, Texas; Dona Ana and Otero Counties, New Mexico. On sand-gravel bars and in wet silty areas along streams.

Ranunculaceae

Mysurus minimus L. subsp. montanus (Campbell) Stone.

Eddy County. Wet ground.

Cruciferae

Rorippa nasturtium-aquaticum (L.) Schinz & Thell.

Chaves and Eddy Counties. Streams.

Sisymbrium altissimum L.

Throughout most of Texas and New Mexico. Wet meadows, edges of ponds and streams.

Capparidaceae

Cleomella longipes Hook.

Trans-Pecos, Texas; Grant County. New Mexico. Saline or alkaline soils or sands of semidesert, salt playas, and wet soil on alkaline flats.

Wislizenia refracta Engelm.

Trans-Pecos, Texas; Dona Ana County, New Mexico. Alkaline sandy or loamy soils of semideserts, on edges of playas, in seepage, stream beds, river banks.

Leguminosae

Acacia greggi Gray var. arizonica Isely

Eddy, Lea, and Chaves Counties. Along streams and washes.

Malvaceae

Anoda cristata (L.) Schlecht var. cristata L.

Eddy County. Moist ground, especially in open areas near streams.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Anoda cristata var. digitata (Gray) Hochr.
Chaves County. Moist ground, often near streams.

Sida hederacea (Dougl.) Torr.
Chaves County. Damp, alkaline soils, often near streams.

Tamaricaceae

Tamarix gallica L.
Widespread in New Mexico. Near streams and washes.

Tamarix parviflora DC
Widespread in Canada and the United States. Along streams and washes.

Lythraceae

Ammannia auriculata Willd.
Eddy, Lea, and Chaves Counties. Wet ground near streams and marshes.

Lythrum californicum Torr. & Gray
Chaves County. Wet ground, often near springs, streams and marshes.

Onagraceae

Ludwigia palustris (L.) Ell.
Eddy County. Marshy ground or water.

Ludwigia repens Forst.
Eddy and Chaves Counties. Along streams, and near ponds.

Oenothera jamesii Torr. & Gray
Eddy County. Stream banks and wet places.

Umbelliferae

Berula erecta (Huds.) Cov.
Chaves County, New Mexico; Trans-Pecos, Texas. Near streams.

Hydrocotyle verticillata Thumb.
Eddy County. Marshy ground.

Samolus cuneatus Small
Chaves and Eddy Counties. Wet ground.

Samolus floribundus H.B.K.
Eddy and Chaves Counties. Wet ground.

Oleaceae

Forestiera neomexicana Gray
Eddy and Lea Counties. Mostly in damp groud near streams and river valleys.

Fraxinus velutina Torr.
Eddy and Chaves Counties, New Mexico; Trans-Pecos, Texas. Borders of lakes and springs, along streams.

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Gentianaceae

Centaurium calycosum (Buckl.) Fern.
Eddy and Chaves Counties. Moist ground, often in boggy or marshy places.

Eustoma exaltatum (L.) G. Don
Chaves and Eddy Counties. Damp meadows, along streams.

Apocynaceae

Apocynum sibiricum Jacq.
Eddy County, New Mexico; Trans-Pecos, Texas. In sandy soil along creeks and on dunes, in marshes about lakes, in seepage along streams, and about springs.

Asclepiadaceae

Asclepias incarnata L.
Chaves County. Moist and wet soil about water bodies and in marshes, water of lakes, and along and in sluggish or clearflowing streams.

Asclepias subverticillata (Gray) Vail.
Trans-Pecos, Texas; DeBaca, Dona Ana, Colfax, and Taos Counties, New Mexico. Marshes, seepage along streams, about springs, and along irrigation ditches.

Funastrum cynanchoides (Dcne.) Schlecht
Eddy and Chaves Counties. Near streams.

Funastrum heterophyllum (Engelm.) Standl.
Lea and Eddy Counties. Near water courses, usually climbing on small shrubs or trees.

Verbenaceae

Phyla cuneifolia (Torr.) Greene
Eddy County. Dry stream beds and playas.

Phyla lanceolata (Michx.)
Chaves County. Moist soil of river bottoms, lake shores, and coastal marshes; in swamps; in and about water of sloughs, ditches and ponds.

Verbena scabra Vahl.
Eddy County. Low ground, marshes, swamps, and edges of lakes and streams.

Labiatae

Lycopus americanus Muhl.
Chaves County. Damp meadows or wet ground.

Nicotiana attenuata Torr.
Eddy and Chaves Counties. Sandy ground near streams and washes.

1789 323

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (continued)

Nicotiana glauca Grah.
Trans-Pecos, Texas; Sierra County, New Mexico. Along stream banks, edges of lakes and canals, washes.

Physostegia praemorsa Shinners
Eddy County. Stream banks and arroyos.

Teucrium canadense L.
Chaves County. In water and mud along streams and canals, about lakes, in marshes, and in wet grassy swales.

Scrophulariaceae
Bacopa rotundifolia (Michx.) Wettst.
Eddy County. Shallow water.

Mimulus glabratus H.B.K.
Trans-Pecos, Texas; Otero, Mora, Lincoln, and Colfax Counties, New Mexico. In shallow water of streams or in muddy, places with stems often floating or creeping.

Veronica peregrina L.
Throughout most of Texas; Otero, San Miguel, Catron, Lincoln, Sandoval, Rio Arriba, Grant, and Taos Counties, New Mexico. The water of tanks and streams, swamps, marshes, about lakes and ponds.

Plantaginaceae
Plantago rhodosperma Dcne
Eddy County. Damp ground.

Campanulaceae
Lobelia cardinalis L. subsp. graminea (Tam.) McVaugh
Chaves and Eddy Counties; Trans-Pecos, Texas. Wet or moist soil, open places along streams, about springs and ponds.

Helenium autumnale L.
Chaves County, New Mexico. Moist, usually calcareous places, in marshes, along streams, and along irrigation ditches.

Helenium microcephalum DC
Eddy County, New Mexico; western half of Texas. Low, seasonally moist areas of clay soil, seepage areas, along streams.

Helianthus ciliaris DC
Trans-Pecos, Texas; Chaves and Eddy Counties. Near streams and canals, often in subalkaline desert soils.

Helianthus maximilliani Schrad.
Trans-Pecos, Texas (rare); Eddy County, New Mexico. Seasonally moist ditches, depressions, or prairies.

1789 324

Table 13. Aquatic Plants Reported from Chaves, Eddy, and Lea Counties, New Mexico, and Trans-Pecos, Texas[a] (concluded)

Liatris lancifolia (Greene) Kittell
Chaves County. On banks of spring-fed creeks and open slopes.

Pluchea purpurescens (Sw.) DC
Chaves County. Moist places, sometimes salt marshes and alkaline soil.

Pyrrhopappus multicaulis DC
Chaves and Eddy Counties. Wet ground.

Solidago altissima L.
Chaves and Eddy Counties. Stream margins and open low areas.

Vernonia marginata (Torr.)
Chaves County. Near ponds, along streams, about pools in washes, dunes, and shallow swales.

[a]Data from Sublette (1978).

REFERENCES

Jones, J. K., Jr., D. C. Carter, and H. H. Genoways, 1975. "Revised Checklist of North American Mammals North of Mexico," Occas. Papers Mus., Texas Technical University, 28, pp. 1-14.

SCS (U.S. Soil Conservation Service), 1971. Soil Survey of Eddy Area, New Mexico, U.S. Department of Agriculture, Government Printing Office, Washington, D.C.

Sublette, J. E., 1978. Quarterly Progress Reports-Aquatic Ecosystems, RFQ07-1489 (December 15, 1977-February 15, 1978), unpublished.

Appendix I

CORRESPONDENCE ON ARCHAEOLOGY,
HISTORIC SITES, AND PRIME FARM LAND

Appendix I

CORRESPONDENCE ON ARCHAEOLOGY, HISTORIC SITES, AND PRIME FARM LAND

Correspondence in this appendix is provided to confirm that there will be negligible impact on the archaeological, historical, and agricultural values of the lands affected by the construction of the WIPP.

Sandia Laboratories

Albuquerque, New Mexico 87115

November 15, 1976

Mr. Thomas W. Merlan
State Historic Preservation Officer
State Planning Office
505 Don Gaspar
Santa Fe, New Mexico 87503

Dear Sir:

I am working on the environmental assessment for the proposed Waste Isolation Pilot Plant east of Carlsbad. It has come to my attention that we need a determination from you as State Historic Preservation Officer on the existence of any cultural resources that may exist on or near the proposed project, and that the project may impact, and in particular we need to know about the existence of any sites on the State Register or being considered for the register on or near our location.

I enclose a xerox copy of the report on the archaeological survey of the central four sections of the area under consideration, made by the Agency of Conservation Archaeology, Eastern New Mexico University (ENMU), and will send you a copy of the formal report when it is printed. We have not yet had an archaeological survey made of the necessary rights of way, but intend to have one made in the near future.

I also enclose two maps of the area, showing the proposed withdrawal area for the projects and the rights of way that will be required for highway, railroad, and electric power line access (other utilities will be routed over one or the other of these rights of way). I should add that most of the 28 square miles of withdrawal area is to be used merely as a buffer zone with no change in surface use. Only in the central three square miles (included within the four square miles of the ENMU survey) will there be mining, and all surface facilities will be in a 100-acre plot on the edge of this core area.

Yours,

M. L. Merritt

M. L. Merritt, Supv.
Environmental Assessment
Division 1151

MLM:1151:vf
Enclosure
Copy to:
ALO W. P. Armstrong, wo/enc.
ALO J. D. Shaykin, wo/enc.
1140 W. D. Weart, wo/enc.

1789 329

STATE OF NEW MEXICO

STATE PLANNING OFFICE

GREER BUILDING
505 DON GASPER
SANTA FE, 87503
(505) 827-2073

GRACIELA (GRACE) OLIVAREZ
STATE PLANNING OFFICER

JERRY APODACA
GOVERNOR

February 16, 1977

Mr. M.L. Merritt, Supervisor
Environmental Assessment Division, 1115
Sandia Laboratories
Albuquerque, New Mexico 87115

Dear Mr. Merritt:

With reference to your request for comments on cultural resources which may be affected by the proposed Waste Isolation Pilot Plant east of Carlsbad the report: An Archaeological Reconnaissance of Sandia Laboratories' Los Medanos Nuclear Waste Disposal Facility, Eddy County, New Mexico by Jeffrey Nielsen has been reviewed by this office.

The recommendations for mitigation of adverse effects on cultural resources located by this survey should be followed and avoidance of sites accomplished whenever possible. Sites which cannot be avoided should be excavated or tested as indicated in these recommendations before clearance can be granted. Those rights of way which have not yet been surveyed should be surveyed as soon as possible so that recommendations for the mitigation of adverse effects on any resources located within these areas may be included in the overall mitigation proposal.

Several of the sites located by the survey may meet the criteria for eligibility for nomination to the National Register of Historic Places. However, there are currently no sites located within the 28 square mile withdrawal which are entered in either the National Register or the State Register of Cultural Properties.

Should you have any further questions regarding this matter, please do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan
State Historic
Preservation Officer

1789 330

TWM:jf

Department of Energy
Washington, D.C. 20545

Dr. William Murtagh
Keeper of the National Register
Heritage, Conservation and Recreation Service
U. S. Department of the Interior
Washington, D. C. 20240

Dear Dr. Murtagh:

Your opinion respecting the eligibility of certain sites associated with the proposed Waste Isolation Pilot Plant (WIPP), for inclusion in the National Register, is hereby requested under the provisions of 36 CFR 800.4(a)(2).

The Department of Energy (DOE) has been investigating a site in southeastern New Mexico for a deep geological repository. DOE will seek congressional authorization for the WIPP and legislative action to acquire land and rights-of-way needed. The WIPP will be licensed by the Nuclear Regulatory Commission.

The WIPP will be used for the demonstration of safe permanent disposal of transuranic wastes produced as a result of the United States defense program. The WIPP will also be used for experiments related to the permanent disposal of solidified high level radioactive wastes.

The WIPP plans call for the use of 17,200 acres of Federal land and 1760 acres of State land for the site (and 691 acres for rights-of-way). Construction would remove 487 acres of land from grazing temporarily and 448 acres for an extended period of time. Surface facilities for radioactive waste handling will require about 100 acres above ground. There will also be extensive underground handling and storage facilities in the salt formation at the WIPP site.

Mr. Thomas W. Merlan, State Historic Preservation Officer, State of New Mexico, State Planning Office, Greer Building, 505 Don Gaspar, Sante Fe, New Mexico, 87503, can be contacted for details concerning the review performed by the State of New Mexico. T. Merlan stated, in a letter to M. Merritt, Sandia Laboratories, on February 16, 1977 - "Several of the sites located by the survey may meet the criteria for eligibility for nomination to the National Register of Historic Places. However, there are currently no sites located within the 28 square mile withdrawal which are entered in either the National Register or the State Register of Cultural Properties."

1789 331

Report SAND77-7024, "An Archaeological Reconnaissance of a Proposed Site for the Waste Isolation Pilot Plant (WIPP)," October 1977, by Jeffrey Nielsen, Agency of Conservation Archaeology, Eastern New Mexico University, Portales, New Mexico, is enclosed for your use.

Your opinion concerning the eligibility of the sites associated with the WIPP will be included in the Draft Environmental Impact Statement now being prepared by DOE for issuance in October 1978. If there are any questions, we would be pleased to respond.

Sincerely,

Colin A. Heath
WIPP Program Manager
Division of Waste Management

Enclosure:
Report SAND77-7024

cc w/o encl:
T. W. Merlan, State Historic
Preservation Officer, NM

United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:
H32-880

Mr. Thomas W. Merlan, SHPO
State Planning Office
Santa Fe, New Mexico 87503

Dear State Historic Preservation Officer:

As you will note from the enclosed letter, we have received a request for a determination of eligibility for inclusion in the National Register, pursuant to Executive Order 11593 or the National Historic Preservation Act of 1966, as amended, as implemented by the procedures of the Advisory Council on Historic Preservation (36 CFR 800).

Since determinations of eligibility are made in consultation with the State Historic Preservation Officer, we would appreciate receiving your opinion on the eligibility of the property(s) which appear in the enclosed material along with any documentation which you have on it and its significance within three weeks of receipt of this letter. Copies of documentation submitted with the request(s) are enclosed for your review, as appropriate.

We look forward to hearing from you in the near future. Please do not hesitate to consult the National Register staff if you have any questions concerning this property.

We appreciate your assistance in this matter.

Sincerely yours,

William J. Murtagh
Keeper of the National Register

Enclosure(s)

1789 333

cc: Mr. Colin A. Heath
WIPP Program Manager
Division of Waste Management
Department of Energy
Washington, D.C. 20545

Mr. Gregory J. Cavanaugh, Director
Division of Real Estate and Facilities Management
Department of Energy
Washington, D.C. 20545
Attn: Mr. William R. Cochran

Advisory Council on Historic Preservation
Denver Office
Box 25085
Denver, Colorado 80225
Attn: Louis Wall

1789 334

HISTORIC PRESERVATION PROGRAM
Department of Educational Finance & Cultural Affairs
c/o New Mexico State Library
P.O. Box 1[illegible]0
Santa Fe, New Mexico 87503
(505) 827-2108

April 28, 1978

Dr. William J. Murtagh
Keeper of the National Register
National Park Service
1100 L Street, N.W. - Room 3209
Washington, D.C. 20005

Dear Dr. Murtagh:

This office has been requested by the Department of Energy to provide an opinion on the eligibility for nomination to the National Register of Historic Places of several archaeological sites located in southeastern New Mexico.

The sites in question were located by an archaeological survey of a four section area and related right-of-way which constitutes the core area of the proposed Waste Isolation Pilot Plant project. Information on the survey area, survey techniques, and descriptions of the individual sites is included in the report entitled An Archaeological Reconnaissance of a Proposed Site fro the Waste Isolation Pilot Plant (WIPP) By Jeffrey Nielsen, Agency of Conservation Archaeology, Eastern New Mexico University, July, 1976.

All of the 33 sites located by this survey appear, on the basis of survey data, to be associated culturally and temporally, and related to a specific economic activity. The archaeological investigation of this group of sites is in our opinion likely to yield significant information on the prehistoric occupation and utilization of the Los Medanos region. Some theoretical considerations for such a study are outlined in the above referenced report.

Therefore, we believe that the 33 sites because of their relationship, are contributing elements of an archaeological district meeting the criteria of eligibility for nomination to the National Register. The significance of the information which can be obtained through the scientific investigation of these sites becomes even more important in view of the so far poorly defined prehistory of this area.

The boundaries of the archaeological district can be arbitrarily defined as the approximately 2,600 acre, four section, core area and right-of-way covered by the archaeological survey. Indications from subsequent archaeological surveys of drill pad, access roads, and test plots are that similar archaeological sites can be expexted to occur throughout the 18,960 acre withdrawal area.

1789 335

Mr. William J. Murtagh
April 28, 1978
Page 2

Should you have any questions regarding our opinion regarding the significance of these archaeological sites, do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan

Thomas W. Merlan
State Historic Preservation Officer

TWM:jf

cc: Smokey O'Connor
Colin A. Heath

1789 336

United States Department of the Interior

HERITAGE CONSERVATION AND RECREATION SERVICE
WASHINGTON, D. C. 20240

IN REPLY REFER TO:
H32-NR

Mr. Colin A. Heath
WIPP Program Manager
Division of Waste Management
Department of Energy
Washington, D.C. 20545

Dear Mr. Heath:

Thank you for your letter requesting a determination of eligibility for inclusion in the National Register pursuant to Executive Order 11593 or the National Historic Preservation Act of 1966, as amended. Our determination appears on the enclosed material.

As you understand, your request for our professional judgment constitutes a part of the Federal planning process. We urge that this information be integrated into the National Environmental Policy Act analysis in order to bring about the best possible program decisions. This determination does not serve in any manner as a veto to uses of property, with or without Federal participation or assistance. Any decision on the property in question and the responsibility for program planning concerning such properties lie with the agency or block grant recipient after the Advisory Council on Historic Preservation has had an opportunity to comment.

We are pleased to be of assistance in the consideration of historic resources in the planning process.

Sincerely yours,

William J. Murtagh
Keeper of the National Register

Enclosure

1789 337

DETERMINATION OF ELIGIBILITY
NOTIFICATION DISTRIBUTION

:c: State Historic Preservation Officer: Mr. Thomas W. Merlan, New Mexico

Federal Representative: Mr. Gregory J. Cavanaugh

Bureau Liason:

Advisory Council on Historic Preservation: , Denver

Mr. George Sherwood
Acting Chief
Environmental Safety
& Effects Division
Reactor, Research and Technology
US. Department of Energy
Washington, D.C. 20545

1789 338

E.O.11593

DETERMINATION OF ELIGIBILITY NOTIFICATION

NATIONAL REGISTER OF HISTORIC PLACES

OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION

HERITAGE CONSERVATION AND RECREATION SERVICE

Request submitted by: DOE Colin A. Heath

Date request received: 2/24/78 additional information received 5/5/78

Name of property: Archeological Sites, Waste Isolation Pilot Plant State: New Mexico

Location: S.E. of Carlsbad, New Mexico

Opinion of the State Historic Preservation Officer:

(X) Eligible ( ) Not eligible ( ) No response

Comments: "All of the 33 sites located by this survey appear, on the basis of survey data, to be associated culturally and temporally, and related to a specific economic activity... (and are) likely to yield significant information on the prehistoric occupation and utilization of the Los Medanos region... we believe that the 33 sites, because of their relationship, are contributing elements of an archaeological district..."

The Secretary of the Interior has determined that this property is:

(x) Eligible Applicable criteria: D

Comments: 36 CFR Part 63.3 Determination

( ) Not eligible

Comments:

( ) Documentation insufficient (see accompanying eet explaining additional materials required)

William J. Murtagh (Sgd.)

Keeper of the National Register

Date: MAY 24 1978

WASO-183
9/75

1789 339

Sandia Laboratories

Albuquerque, New Mexico 87115

November 3, 1976

Mr. Albert W. Hamelstrom
517 Gold Avenue SW
P. O. Box 2007
Albuquerque, NM 87103

Dear Sir:

I am in the process of preparing inputs for a Draft Environmental Impact Statement on the proposed Waste Isolation Pilot Plant to be used for experiments related to the storage of low and intermediate level nuclear wastes in the bedded salt of the Delaware Basin, east of Carlsbad, New Mexico.

I have just been informed that I must solicit a determination from the USDA Rural Development Committee on whether there are any "prime or unique farmlands" located within the project area. I would be very much surprised if there were, but nevertheless I need a formal statement on the subject.

The area proposed includes all or part of Sections 7-11, 14-23, 26-35 of T. 22 S., R. 33 E.; Sections 2-6 of T. 23 S., R. 31 E.; Sections 12-13, 24-25, 36 of T. 22 S., R. 30 E.; and Section 1, T. 23 S., R. 30 E. Most of this land will merely be buffer zone; the area which would overlie the underground workings includes only Sections 20-21 and 28-29, T. 22 S., R. 31 E. All the land mentioned is in Eddy County, New Mexico--see map enclosed.

If there are any further questions, please phone me at 264-3540. Thank you for your cooperation.

Yours,

M. L. Merritt

M. L. Merritt, Supervisor
Environmental Assessment Div. 1151

MLM:1151:jeh

Enclosure

Copy to:
SAO L. P. Apodaca w/encl.
ALO W. P. Armstrong w/encl.
1140 W. D. Weart w/encl.

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Box 2007, Albuquerque, NM 87103

November 11, 1976

Mr. M. L. Merritt, Supervisor
Environmental Assessment Division 1151
Sandia Laboratories
Albuquerque, NM 87115

Dear Mr. Merritt:

In response to your request of November 3, 1976, the site and buffer zone for the proposed Waste Isolation Pilot Plant in Eddy County, New Mexico, does not include prime or unique farm lands according to Soil Conservation Service criteria. The area considered was that shown on the map provided with your letter.

Sincerely,

aw Hamelstrom

A. W. Hamelstrom
State Conservationist

1789 341

Appendix J

EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

CONTENTS

1789 343

LIST OF TABLES

LIST OF FIGURES

Appendix J

EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

This appendix discusses the materials and methods used to collect the data presented in this report. It also discusses the proposed monitoring programs for assessing the environmental impacts of the WIPP reference repository.

J.1 PREOPERATIONAL ENVIRONMENTAL PROGRAMS

The preoperational survey programs have been designed to describe the existing geologic, hydrologic, meteorologic, biologic, and radiologic characteristics of the region surrounding the site proposed for the WIPP reference repository in Eddy County, New Mexico.

J.1.1 Geology

The purposes of the site geologic studies and the geology sections presented in this report are given in Section 7.2. Investigation methods for geology and seismology are discussed in more detail in the Geological Characterization Report (Powers et al., 1978).

Geologic studies for the site fall into three different phases: preliminary site-selection activities, site characterization, and studies on long-range geologic processes affecting a repository. Site characterization at the present site began in 1975 with the drilling of a hole at the center of the site and the start of seismic reflection work. Site characterization is intended to provide data concerning the geologic acceptability of the site. It has been reported in the Geological Characterization Report (Powers et al., 1978). Studies of long-term processes that might affect the integrity of the repository are now the major geotechnical activity of the project personnel. These studies are concerned with the age of significant features and the rates and processes that have produced them.

This section summarizes the geophysical and geologic methods used in characterizing the New Mexico study area. Twelve stratigraphic holes have been drilled to date (March 1979) in support of this program; one (ERDA-9) is at the center of the present study area. Figure J-1 and Table J-1 show the location, purpose, and depth of all boreholes within 5 miles of the center of the site. These boreholes were extensively logged, cored, and drill-stem-tested in the evaporite section. The cores form the basis for several continuing laboratory studies important to an understanding of the physical and chemical phenomena associated with the site and contributing to general knowledge about the formation of evaporites. Two boreholes have been drilled well outside the immediate area to obtain data on salt dissolution.

Many line-miles of seismic reflection data were available for the study area from petroleum companies, and 26 line-miles of such data were initially obtained by the DOE (Figure J-2), using standard techniques for the petroleum

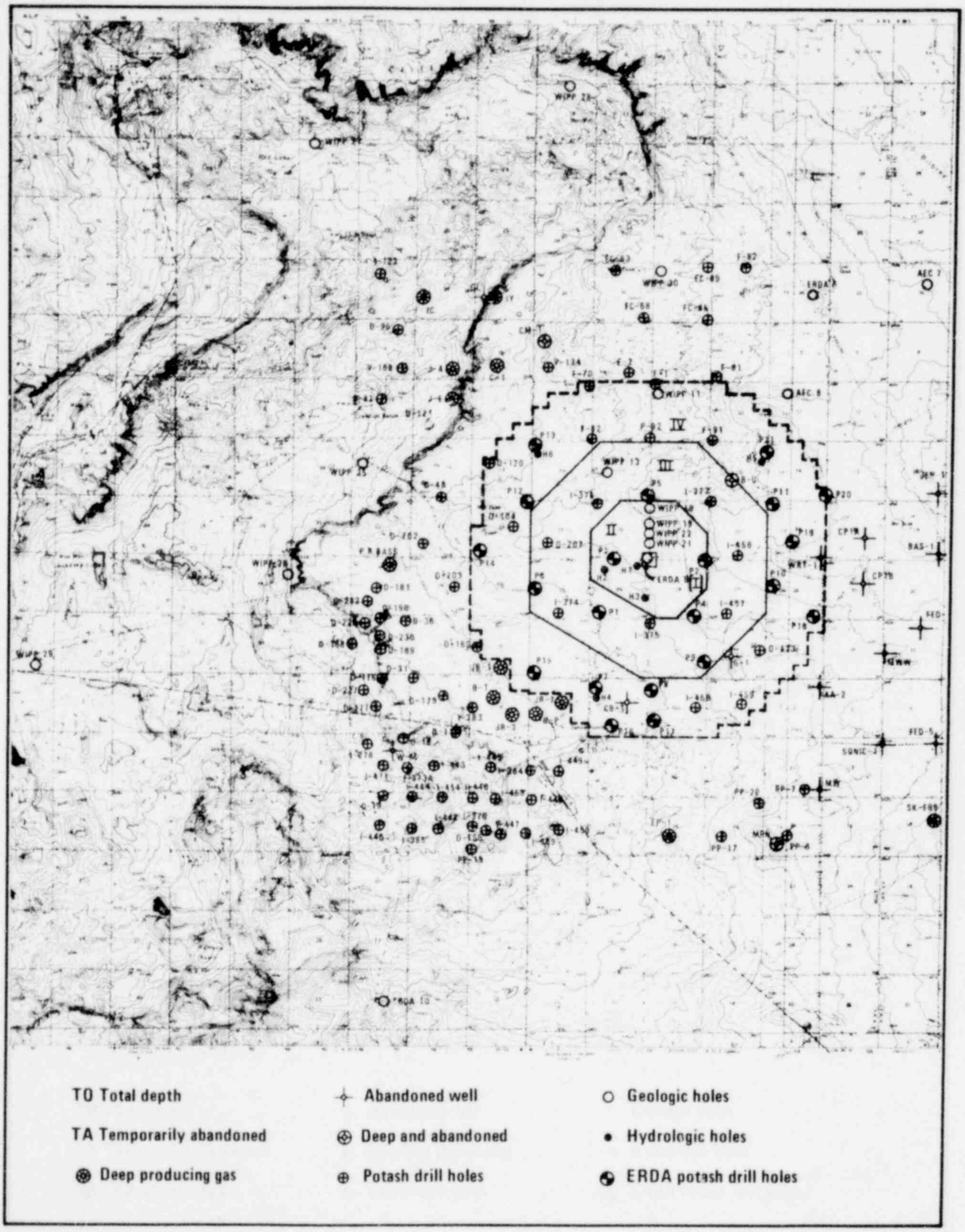


Figure J-1. Exploratory drill holes in the vicinity of the WIPP reference site.

Table J-1. Exploratory Drill Holes in the Vicinity of the Site

Designation	Start date	Purpose	Total depth (ft)
AEC-7	3-74	Stratigraphic	3918
AEC-7	3-74	Stratigraphic	3918
ABCD	5-74	Stratigraphic	
(deepened)	6-76	Deep hydrologic	4910
ERDA-6	6-13-75	Stratigraphic	2776
ERDA-9	4-28-76	Stratigraphic	2886
ERDA-10	8-18-77	Deep dissolution	4431.5
P-1	8-23-76	Potash	1591
P-2	8-25-76	Potash	1895
P-3	8-26-76	Potash	1676
P-4	8-27-76	Potash	1857
P-5	9-10-76	Potash	1830
P-6	9-3-76	Potash	1573
P-7	9-4-76	Potash	1574
P-8	9-8-76	Potash	1660
P-9	9-16-76	Potash	1796
P-10	9-24-76	Potash	2009
P-11	9-24-76	Potash	1940
P-12	9-17-76	Potash	1598
P-13	9-17-76	Potash	1576
P-14	9-24-76	Potash and hydrologic	1545
P-15	10-4-76	Potash and hydrologic	1465
P-16	9-27-76	Potash	1585
P-17	10-18-76	Potash and hydrologic	1660
P-18	10-19-76	Potash and hydrologic	1998
P-19	10-19-76	Potash	2000
P-20	10-6-76	Potash	1995
P-21	10-15-76	Potash	1915

Designation	Start date	Purpose	Total depth (ft)
H-1	5-20-76	Hydrologic	856
H-2A	2-14-77	Hydrologic	563
H-2B	2-7-77	Hydrologic	661
H-2C	2-28-77	Hydrologic	795
H-3	7-25-76	Hydrologic	902
H-4A	5-16-78	Hydrologic	415
H-4B	5-14-78	Hydrologic	529
H-4C	4-30-78	Hydrologic	661
H-5A	6-13-78	Hydrologic	824
H-5B	6-4-78	Hydrologic	925
H-5C	6-24-78	Hydrologic	1076
H-6A	7-7-78	Hydrologic	525
H-6B	6-28-78	Hydrologic	640
H-6C	6-21-78	Hydrologic	741
WIPP-11	2-5-78	Stratigraphic	3577
WIPP-13	7-26-78	Stratigraphic	1025
WIPP-15	2-8-78	Paleoclimate	810
WIPP-18	2-13-78	Stratigraphic	1060
WIPP-19	4-5-78	Stratigraphic	1038
WIPP-21	5-24-78	Stratigraphic	1045
WIPP-22	5-8-78	Stratigraphic	1450
WIPP-25		ND-1 Hydrologic	
WIPP-26		ND-2 Hydrologic	
WIPP-27		ND-3 Hydrologic	
WIPP-28	8-8-78	ND-4 Hydrologic	800
WIPP-29		ND-5 Hydrologic	
WIPP-30		ND-6 Hydrologic	

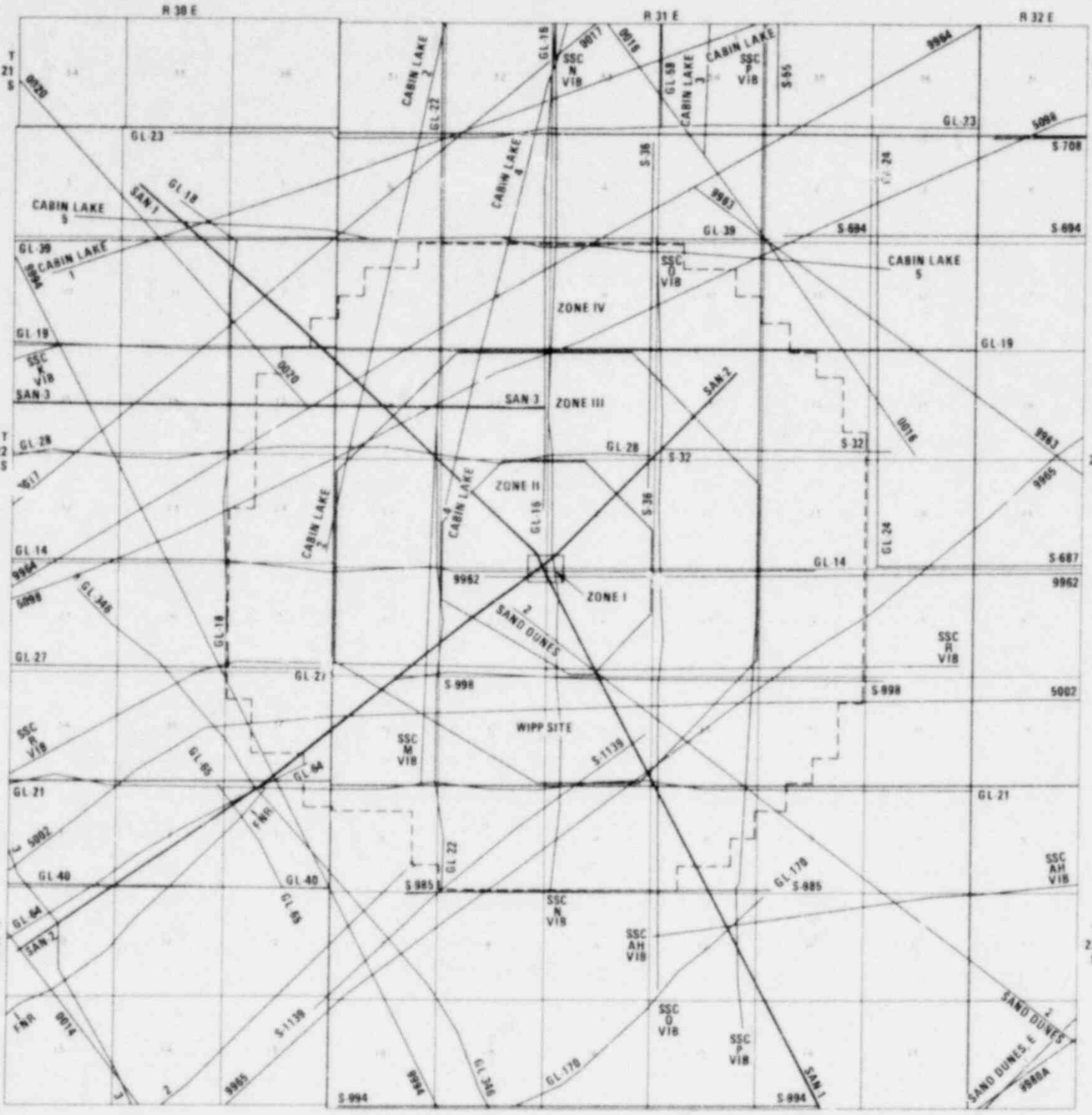


Figure J-2. Industry seismic data and WIPP data from 1976.

industry. The data are excellent for interpreting deeper structure, but are not as useful for showing reflecting interfaces in the upper 3000 feet. In 1977 about 48 line-miles of new data (Figure J-3) were obtained using shorter spacings for geophones, higher frequencies from Vibroseis units, and higher rates of data sampling. These data show much improved reflections from, and better resolution in, the shallow depths of interest. Resistivity has also been extensively used. Field tests indicate that resistivity can detect certain types of solution features; more than 9000 measurements have been taken in the study area to search for such features (Figure J-4). Additional measurements of resistivity using expander arrays have been made to study resistivity changes with depth and to help interpret the detailed measurements (Figure J-5).

Investigation methods used at the site fall into the major categories of field geology, geophysics, geochemistry, and rock mechanics. The application

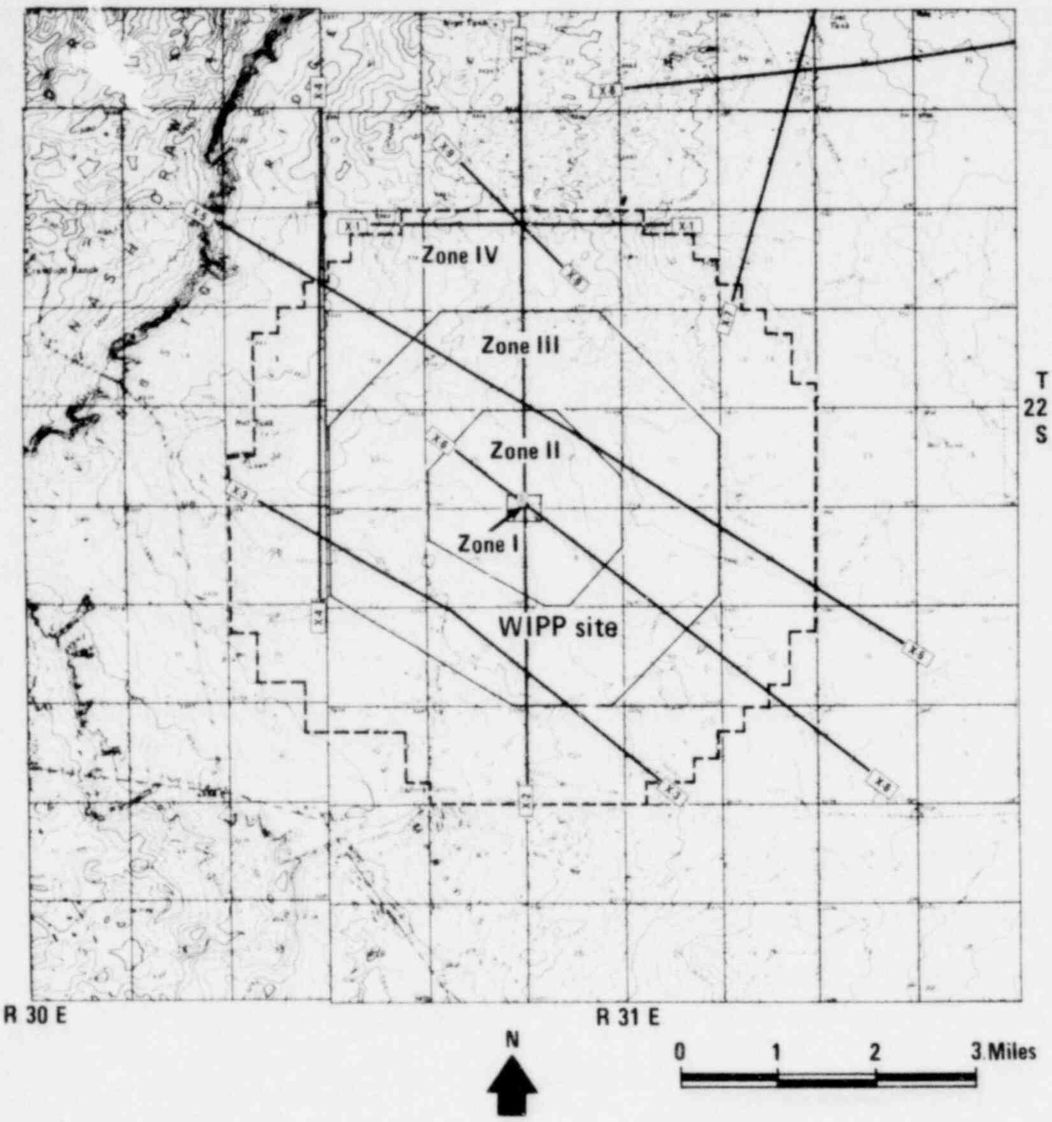


Figure J-3. Seismic program, 1977.

of these disciplines to studies relevant to the WIPP reference repository is outlined below.

Field geology

While all tne methods to be discussed may be considered fundamental in the geologic sciences, the term "field geology" is here restricted to the investigations and correlations of regional and local features that are available to the geologist through surface mapping, aerial photography, satellite imagery, and interpretation of borehole and other subsurface data.

The basic starting point of the present investigations was the preparation of a good base map on which the topographic, geomorphologic, and surface-geologic characteristics could be displayed. Existing USGS topographic quadrangle maps and aerial photographs were used for this purpose. Aerial photos, in both color and black and white, were used for the surface mapping of geologic features. Larger scale features were derived from satellite

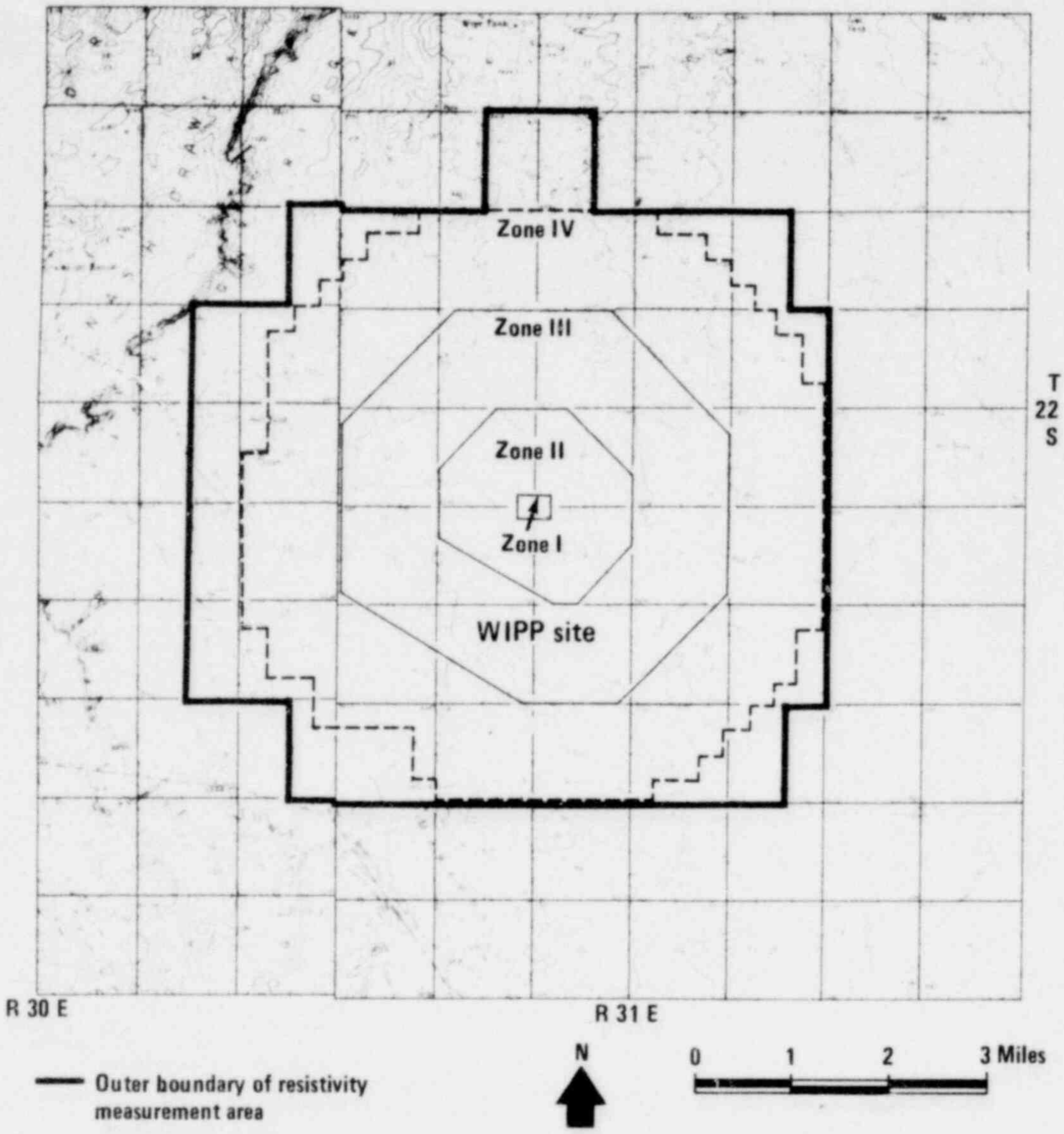


Figure J-4. Profile location map of gradient resistivity array.

imagery obtained for the southern New Mexico-west Texas area. Lineations, which can often only be discerned in aerial views, were investigated on the surface to determine whether they were geologically significant.

Data on surface geology were compiled starting with earlier investigations of the area reported in the literature. It was necessary to supplement this work with more detailed mapping of geologic units in the immediate vicinity of the proposed site. Visual inspection and identification of rock units is necessary at this stage and requires months of field work. Observations of geomorphology and vegetation changes were useful in identifying geologic features for mapping.

Subsurface geology was established using several lines of evidence. Data reported in the literature were the starting point. These were supplemented, and sometimes amended, by proprietary data from petroleum and potash companies that have conducted exploration in the region. Vast quantities of information exist on southeastern New Mexico, both from drill-hole and geophysical tests.

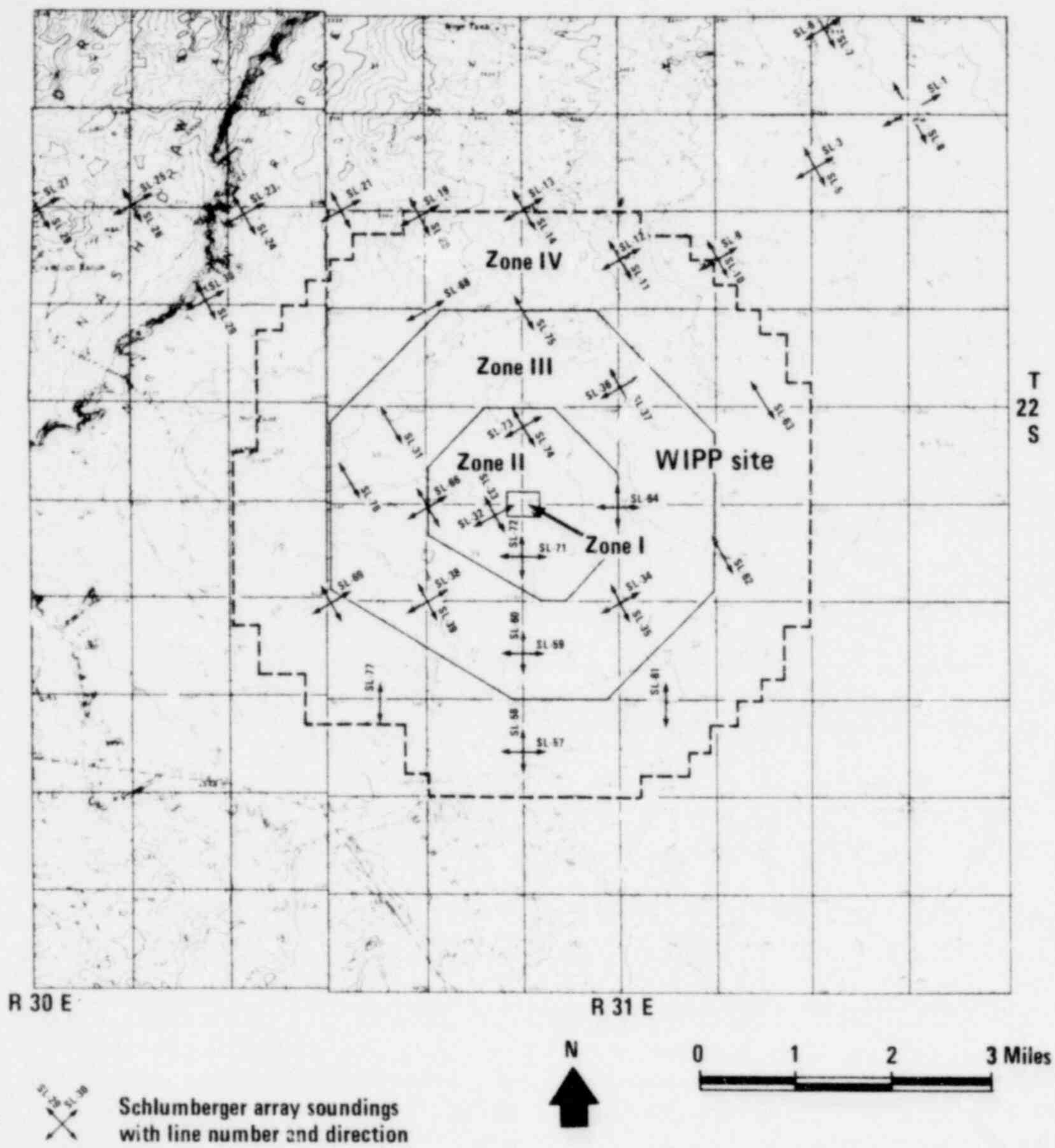


Figure J-5. Location map for resistivity soundings.

Final details were provided by drilling and coring holes for stratigraphic information and conducting geophysical studies to help map formations between boreholes. Cores from boreholes were measured and located relative to the ground surface, described and identified in field notes, and photographed. Lithologic and stratigraphic logs were prepared from examination of the samples. Portions not used in subsequent analyses and tests were sealed in plastic bags, labeled, and stored. All this information is assembled into structural contour and isopach maps for the different geologic formations of interest.

Geomorphologic, topographic, surface, and subsurface geologic maps are all used to interpret the geologic history and tectonic setting of the area. In certain instances, paleontological or paleobotanical information is useful in establishing chronology of events. Micropaleontology is being used to provide a more thorough understanding of solutioning processes and their rates since Pleistocene time. Samples are obtained by coring deposits in solution sinks

1789 351

in the Delaware basin. Coupled with the physical and geochemical studies, a chronology of events can be developed that allows an estimate of process rates and provides some confidence that forecasts into the near geologic future will not be unreasonable.

Geophysics

Early in the preliminary site evaluation, 1500 line-miles of petroleum-company reflection data were examined for evidence of major faults and other structures in the deep (over 4000 feet) formations. The nature of the data limited its usefulness for examination of shallow (less than 4000 feet) horizons. Information on shallow horizons was acquired by special seismic reflection surveys. Conventional oil-field gear (Vibroseis) was used, with geophone spacing and instrument recording adjusted to provide better resolution at depths of less than 5000 feet. Experience has shown that this technique can provide good information on reflectors in the Castile Formation and below but must be used with a great deal of caution in attempting to define the attitude of the top of the Salado. Reflections from this horizon and depth are erratic.

Only a limited amount of seismic refraction work was carried out to determine weathering conditions for the reflection work. Where possible, sonic logs or uphole surveys were preferred for this purpose.

Electrical resistivity proved to be a valuable tool in se rching for dissolution-related features in the Delaware basin. Resistivity surveys over known solution features, such as "breccia pipes," give characteristic signatures. Consequently, closely spaced resistivity surveys were made over the site to examine it for these anomalies. Indicated anomalies were then confirmed or denied by test drilling. The surveys were run along lines 500 feet apart over the entire 30 square miles of the site area and resulted in about 9000 data points. Two different measurement configurations were used. The modified Werner electrode placement was used for the areal survey described above, and an "expander" array was used to investigate changes in resistivity with depth at a given location. The latter configuration was used to determine whether low resistivities were associated with the presence of the shallow-dissolution zone.

Magnetic methods were employed to search for both regional and local features expected to show magnetic contrast. Existing aeromagnetics of the Delaware basin was examined for indications of major faulting or igneous instrusions. An igneous dike 9 miles northwest of the site was all that was observable in these data; a higher resolution survey will be used to examine the region near the site for similar but less evident instrusives. Ground surveys and detailed aeromagnetic surveys were tried but were found to be ambiguous in detecting solution-collapse features.

Gravity data for the Delaware basin were examined for indications of major geologic structures and for their utility in detecting collapse features. The absence of the former in the site and the failure of collapse features to exhibit significant density differentials limited the usefulness of the gravity technique.

First-order level line surveys tied into the national grid established by the National Oceanographic Survey (NOS) were made by NOS within the region and locally, in a more dense pattern, in and near the site. These permanent stations will be periodically reoccupied to detect tectonic movements and subsidence due to solutioning and potash mining.

Geochemistry

Geochemical measurements include techniques used to determine the mineral composition, chemical composition, fluid content and composition, age of rocks, and postdepositional history of recrystallization. Mineral composition has been determined through visual inspection, petrographic microscope examination, and X-ray diffraction. When large numbers of samples are involved, X-ray diffraction has been the preferred technique.

Chemical composition has been obtained by analytical-chemistry and atomic-absorption methods. For most purposes atomic absorption is satisfactory and more rapid than wet-chemistry techniques.

Fluid inclusions in salt are counted by microscopic examination. The mass of the fluid is determined by crushing, heating, and recording the weight loss of the sample. In favorable samples the effluent is analyzed by gas chromatography or mass spectrometry. Inferences on fluid-inclusion composition are also obtained by cooling the sample and observing the "freezing" point.

Brines are studied for clues to their past history by applying mass spectrometry to obtain oxygen-18/oxygen-16 and deuterium/hydrogen ratios.

Age dating of evaporites may be attempted by examining rubidium/strontium ratios. Dating of old brines has been attempted through analysis of the uranium-234/uranium-238 disequilibrium. Satisfactory age-dating techniques for old brines and evaporites are not well developed.

Rock mechanics

Rock-mechanics methods described here include both physical and thermal tests applied to rock specimens.

Elastic and strength properties of the salt and other rock samples are determined by stressing machined specimens under conditions of both uniaxial and triaxial stress. Special creep-test apparatus has been built to test rheological properties as a function of temperature and pressure applied over long periods of time.

Permeability of salt to various gases (helium, nitrogen, hydrogen) has been established by laboratory tests on single crystals and on rock cores. Variations in permeability as a function of pressure are also measured. In-situ tests will be conducted in potash mines in the future.

Thermal properties have been measured on laboratory samples and at bench scale. Parameters determined are thermal conductivity, thermal diffusivity, thermal expansion coefficient, and specific hea capacity. Radiant heat transfer has also been examined and found to be relatively minor. These properties are determined by standard laboratory techniques. On larger, bench-scale samples, holes are drilled into the block for heater elements, thermocouples, and strain gauges. These tests allow the determination of average properties more representative of in-situ conditions.

Radiation effects on salt have also been examined in laboratory tests. Induced crystal-lattice defects resulting in "stored energy" are found to be similar in magnitude to those described in the literature for other salts.

Seismology

Information about the regional seismicity around the site falls into two groups. The first includes information obtained before 1962, when no specialized instrumentation existed close to the area. During that period, there were not enough seismic stations in the southwestern United States to provide instrumental coverage of southeastern New Mexico. Therefore, these data describe earthquakes that people felt and that were reported in the technical literature, including the annual publication U.S. Earthquakes. Sanford and Toppozada (1974) gathered other information from newspaper accounts, recollections of long-time residents, records of museums, historical societies, and the like. The principal weakness of these early seismic data is that they are partly a function of population density.

The second group of data began to be collected after instrumentation was established in 1960 and 1962 at Socorro by the New Mexico Institute of Mining and Technology and at Sandia Base near Albuquerque by the Atomic Energy Commission and the Coast and Geodetic Survey. Additional Coast and Geodetic Survey stations, established in 1962 in Las Cruces, New Mexico; Payson, Arizona; and Fort Sill, Oklahoma, permitted epicenters to be determined for local events. Since April 1974, A. R. Sanford of the New Mexico Institute of Mining and Technology has operated a vertical, single-component, continuously recording seismograph station (CLN), 4 miles east-northeast of the site, to monitor seismicity near the site. Useful information is also available from a seismograph station operated at Fort Stockton, Texas, from June 21, 1964, to April 12, 1965, as part of the Federally sponsored Long Range Seismic Measurement (LRSM) system. Since November 1975, the USGS has operated a 10-station seismic array near Kermit, Texas, about 60 miles southeast of the site, to monitor seismicity in the Central Basin platform. Seismic information for the site and its vicinity is becoming much better because of the establishment of these stations.

J.1.2 Hydrology

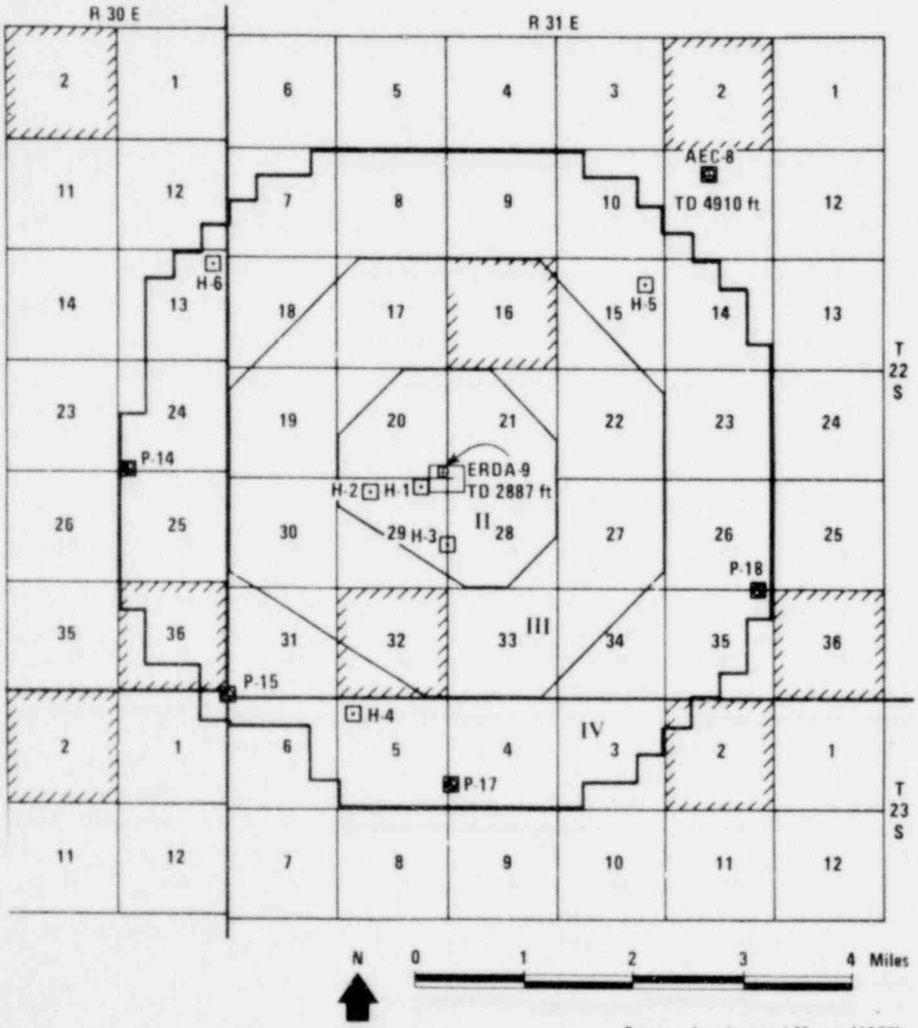
Hydrology is a major consideration in examining the feasibility of a site for nuclear-waste disposal. Two factors are directly related to hydrology: (1) the geologic stability of the formation in which the waste will be stored and (2) the presence of groundwater as a transport medium. Because unsaturated waters migrating along the surfaces of salt beds will dissolve salts, an examination of the integrity of the Salado Formation is directed into three study areas: (1) the Rustler-Salado contact beneath the site, to determine whether dissolution is presently occurring; (2) the front of the shallow-dissolution zone in Nash Draw, to more precisely map active dissolution boundaries; and (3) the estimated rates of dissolution at the top and the bottom of the salt, to refine analyses of hazards to the site. Further definition of the hydraulic gradients and rates of fluid movement in the fluid-bearing zones that overlie the Salado will aid in refining the estimates of potential groundwater transport of radionuclides.

Inventory of test holes

The objectives of the hydrologic testing program at the site selected for the reference case are to determine the static head or reservoir pressure, the water-yielding potential of the rock strata, and the chemistry of formation waters. These hydrologic tests are commonly made in exploratory test holes either during drilling or after the holes have been drilled to total depth.

As of February 1979, hydrologic tests had been conducted in 11 exploratory test holes at the site. Of the 11 holes tested so far, five were specifically designed for hydrologic testing: H-1, H-2 (a complex of three holes), and H-3 (Figure J-6). The configuration of these five holes was designed to allow data collection in a triangular array measuring approximately 0.5 mile on a side. The primary objective was to determine hydraulic gradients in the fluid-bearing zones above the Salado Formation.

The potash test holes P-14, P-15, P-17, and P-18 shown in Figure J-6 were not drilled specifically for hydrologic testing but for exploring potash mineral deposits. These holes were then used for hydrologic testing because they



Source: Lambert and Mercer (1977).

Figure J-6. Drill-hole status.

allow for static-head determinations and hydrologic testing in the fluid-bearing zones above the salt near the downgradient boundary of the site.

Two other holes (AEC-8 and ERDA-10) are deep test holes used for testing fluid-bearing zones below the Salado salt section. The AEC-8 hole, drilled 5 miles to the northeast before the WIPP project, was deepened for testing fluid-bearing zones below the salt. Hydrologic testing of these zones was also conducted in ERDA-10, a test hole drilled 14 miles to the southwest (at the Gnome site) for off-site geologic evaluations.

After drilling and testing holes H-1 and H-3, three triangular arrays--H-4, H-5, and H-6--were designed with a much closer spacing than that of the H-2 complex. A three-hole program, in addition to providing long-term open-hole testing, permits static fluid-level monitoring and pump testing to check for vertical or horizontal communications between fluid-bearing zones. Moreover, the more closely spaced array provides a hydraulic-testing base over distances of less than 100 feet.

The additional sets of triangular arrays (the H-4, H-5, and H-6 complexes) drilled for hydrologic testing have been completed and await testing. Together with P-14, P-15, P-17, P-18, and WIPP-11, the new arrays form part of a network of holes, 2 to 3 miles apart, completely encircling the site.

General methods used in drilling

Air-rotary drilling was used to drill the holes designed specifically for hydrologic testing at the site. This method differs from standard rotary drilling in that the fluid or mud gel usually used to cool the bit and remove cuttings is replaced by compressed air pumped down the drill pipe and back up the annular space between the drill pipe and the borehole wall. When moist zones or fluid are encountered, detergent and water are added to assist the air in removing the cuttings. The air method was used to make it easier to identify zones that might contain fluid and to prevent plugging of the aquifer test zones, which may occur when standard drilling fluids are used.

Detailed strategies for drilling and testing

The H-2 array consists of three holes spaced as shown in Figure J-7. Hole 2a penetrates the Magenta aquifer, hole 2b the Culebra aquifer, and hole 2c the Rustler-Salado contact (Figure J-8). This three-hole configuration makes possible three types of study: independent open-hole testing of the Magenta and Culebra aquifers and the Rustler-Salado contact without interference from the other zones; convenient monitoring of the three formations without the use of downhole hardware such as packers; and pump tests of low-yield formations in closely spaced holes. Each hole was drilled to within 10 feet of its intended depth, casing was set and cemented, and then the hole was cored to total depth. In hole 2c, the deepest of the three, the following logs were run: natural gamma and density, caliper, compensated density, compensated neutron gamma ray, dual-induction laterolog, microlaterolog, temperature, acoustic, and 16-inch electric. All holes were surveyed for lateral deviation with a Sperry-Sun directional survey.

Open-hole testing is preferred because it allows exposing the maximum surface area of the test interval. If, however, the test zones are of very low permeability, requiring long water-level-recovery times, cased-hole testing may be more feasible.

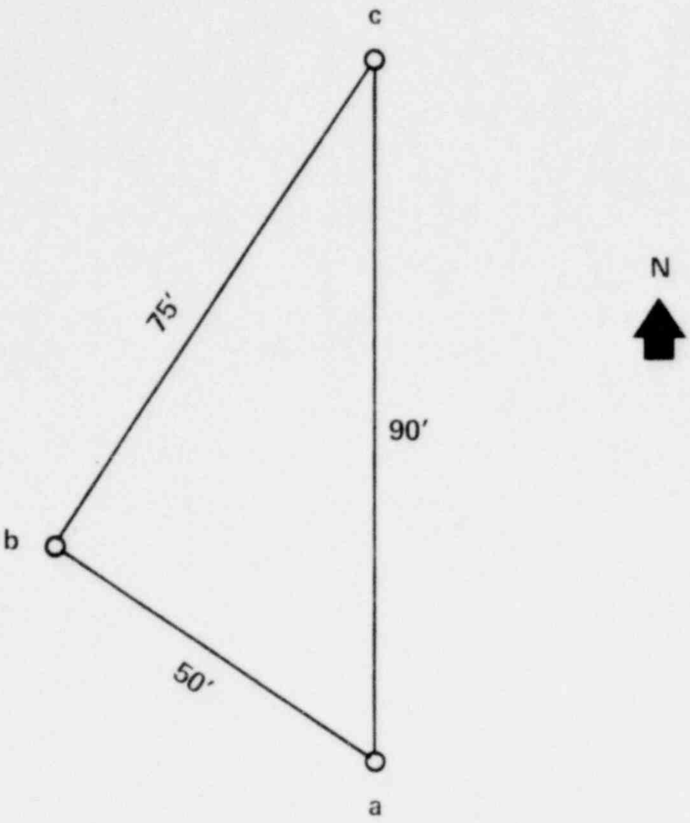


Figure J-7. Plan view showing the configuration of the H-2 three-hole array.

Investigations usually began with geophysical logging of the open borehole to obtain information on changes in rock strata, formational characteristics, potential zones of water yield, and borehole-diameter changes. These parameters aided in the selection of borehole intervals to be tested in detail and provided useful information on hole conditions needed in the selection of packer seats. A detailed discussion of logging and log interpretation has been published by Keys and MacCary (1971).

After logging, the proposed test zone was isolated by an inflatable packer or packers, and a preliminary drill-stem test (DST) was conducted. The DST is designed to provide such hydrologic data as representative samples of formational fluid, undisturbed formational pressures, and indications of formational permeability. Standard oil-field DSTs were run in AEC-8 and ERDA-10, but in the other holes the procedures were modified. The most common modification was in the method of recording formational pressures. In standard oil-field DSTs, pressures are recorded with a Bourdon-tube pressure-recording gauge (pressure bomb) placed near the bottom of the drill string. Data from this pressure bomb cannot be retrieved until the test has been completed. In the modified DSTs used in the site hydrologic investigations, the fluid was initially removed from the tubing and the stabilizing fluid levels were measured in the drill string. This modification allowed for continuous monitoring throughout the test. In addition, pressure monitors were placed above and below packers to determine the effective isolation of the tested zone from the rest of the borehole.

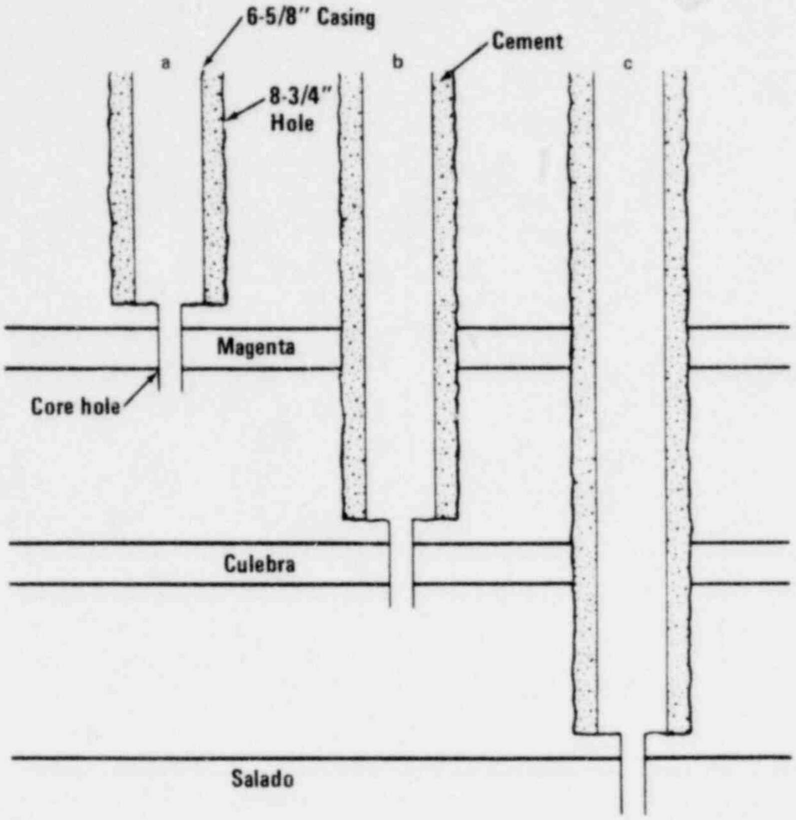


Figure J-8. Configuration of completed H-2 holes.

Hydrologic tests at the site--whether DSTs, open-hole tests, or cased-hole tests--generally consisted of bailing or swabbing a known volume of fluid and then observing the rate at which the water level recovered. Yields from test zones could then be calculated from the rate of change in water levels with time.

The bailing tests are conducted with a bailer, which is a hollow steel cylinder usually 20 feet long and slightly smaller than the borehole. The bailer is equipped with a dart-door valve (check valve) at the bottom. When the bailer is moved up and down in the borehole, the dart allows water to enter the bailer, and the water is entrapped. The bailer is then removed from the hole, and the fluid is dumped into a calibrated tank.

Swabbing tests are similar to bailing tests in that their purpose is to extract a known volume of fluid from the hole; they are used to remove mud and other fluids from the hole before testing. After the drill pipe or tubing is lowered into the hole, the swab is attached to a wire line and lowered into the tubing. The swab consists of a hollow supporting mandrel with an upward opening valve (check valve), sinker bar, and rubber cups. As the swab is lowered into the hole, the fluid in the hole passes up through the check valve and enters the space above. After depth is reached below the fluid Level, the swab is pulled out of the hole. The check valve keeps the fluid from again passing through the swab. The weight of the fluid flattens the rubber cups and expands their diameter until they press firmly against the pipe lining the hole. This expansion prevents fluid leakage around the swab and the pipe; the fluid is lifted to the surface and into a calibrated tank (Blankenagel, 1968, pp. 27-29).

Radioactive-tracer tests were conducted in some of the hydrologic test holes after they had been cased and perforated at selected intervals. The main objective of these tests, which used an aqueous solution of iodine-131, was to check for cement bonds between the casing and the borehole wall. These tests also yielded information on the vertical distribution of permeability across the test interval.

Several methods of running tracer tests are available; because of the low permeabilities, the depth-drive technique was used at the site (Blankenagel, 1968, p. 16). In this technique, water is pumped at a nearly constant rate into the borehole and a slug of iodine-131 is injected above the perforations. As this slug moves down the hole, it is followed with a scintillation gamma detector, which moves at timed intervals through the slug; at the ground surface the increase in gamma activity is recorded. The depth, direction, and rate of slug movement can be calculated by comparing successive gamma traces.

To insure that the tested fluids represented adequately the fluid in the formations, the test zones were bailed or swabbed until fluid temperature, conductivity, and density all stabilized. Samples were then collected and treated according to standard USGS techniques, as outlined by Brown et al. (1970). These samples were chemically analyzed for major and trace elements and for radiochemistry.

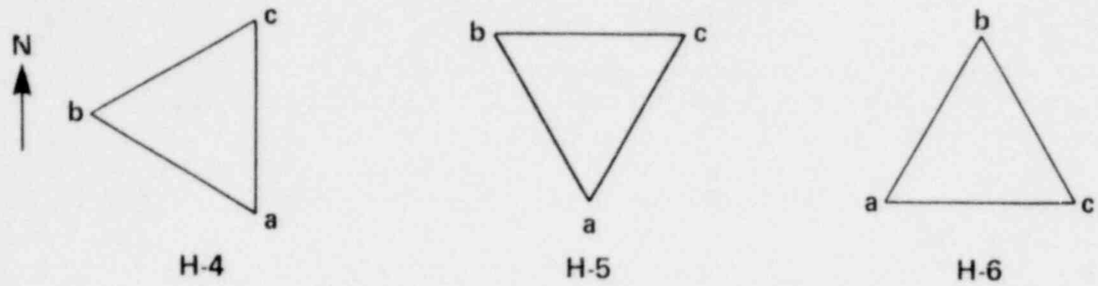
Rationale for establishing hydrologic test holes H-4, H-5, and H-6

Discussions between WIPP hydrologists and mathematical modelers have revealed special data requirements for hydrologic data collection. The general philosophy of hydrologic data collection for the reference repository is outlined in a report (Lambert and Mercer, 1977) that establishes a set of procedures for the collection of data describing the hydrogeologic system of the Rustler Formation at a certain point. The goal of the data collection is to determine a distribution of data values that can establish practical bounds on the spatial nonuniformity of hydrologic parameters and on the variations in experimental results.

Like tests in other hydrologic test holes, these tests are intended to add to the data bank describing the potentiometric surface, the hydraulic conductivity, and the water quality within the Magenta and Culebra aquifers of the Rustler Formation and the zone of contact between the Rustler and Salado Formations. A closely spaced system of holes like test hole H-2 is required for multihole testing of particular water-bearing, yet low-yielding, zones. Close spacing provides an opportunity for two-hole testing in a finite amount of time, even with the anticipated low water velocities in the Rustler Formation (Mercer and Orr, 1977).

Configurations. Test holes H-4, H-5, and H-6 are each resolved into three holes designated a, b, and c. Hole a penetrates the Magenta, hole b penetrates the Culebra, and hole c penetrates the Rustler-Salado contact. The holes are drilled at the corners of equilateral triangles, as shown on the next page.

1789 359



The triangles are nominally 100 feet on a side. The different orientations of the triangles test whether preferred directions of permeability exist in the zones to be tested (such preferred directions were observed in a test involving H-2 holes b and c). When a zone is injected or tapped in one well, a longer time is required to observe the resulting changes in a distant monitor well than in a nearby one. Since the deepest hole (hole c) is the first to be drilled in each cluster, higher water production than anticipated in the Culebra and/or Magenta aquifers might require that holes b and a be drilled more than 100 feet from hole c. While spacing significantly smaller than 100 feet is not desirable, a larger spacing might be warranted by conditions encountered in hole c. This decision must rely on experience gained as the field program is executed.

The final hole spacing is determined within a tolerance of less than 1 foot for precise calculation of hydrologic parameters from tests involving more than one hole. Surface elevations are also established for each hole within a tolerance of less than 1 foot.

Locations. The H-6 cluster of holes is near the northeast corner of Section 13, T 22 S, R 30 E, near existing potash hole P-13. This location was selected for the following reasons:

1. It is near the northwest boundary of the site, where there have been no hydrologic control data for the Rustler groundwater system.

2. It is 2 to 2.25 miles from both P-14 and WIPP-11, thereby filling a gap in a network of peripheral holes on a 2- to 3-mile spacing.

3. It is near the eastern margin of Nash Draw and thus provides an opportunity to investigate the stratigraphic and hydrologic relationships of the shallow dissolution below the Rustler Formation, where P-14 experience indicates that brine should be encountered.

4. The holes at the H-6 site, together with P-14, become members of a system of holes designed to investigate hydrologic relationships between the shallow dissolution and the Rustler in Nash Draw.

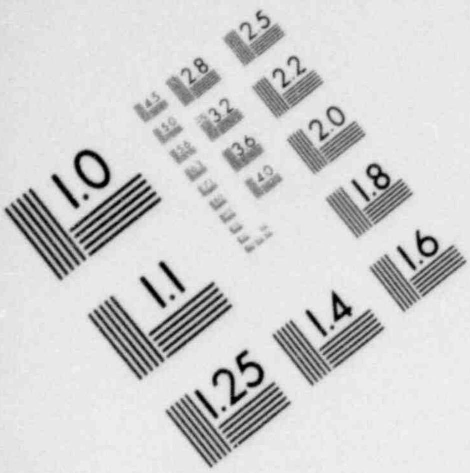
The H-5 cluster of holes is near the northeast corner of Section 15, T 22 S, R 31 E, near existing hole P-21. This location was selected for the following reasons:

1. It is near the northeast boundary of the site, where there have been no hydrologic control data for the Rustler groundwater system.

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART



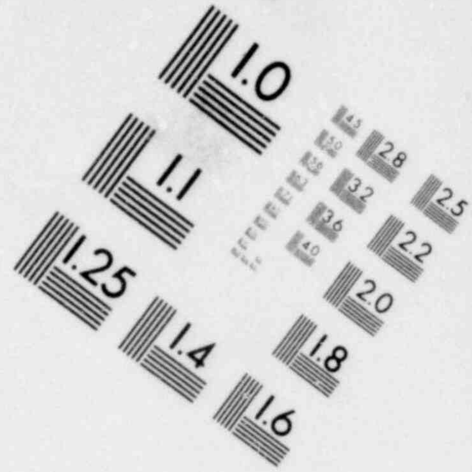
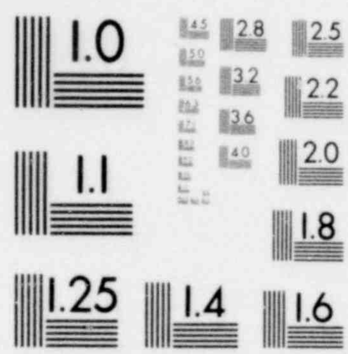
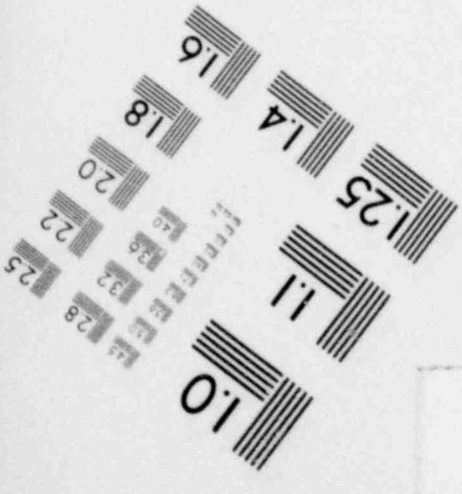


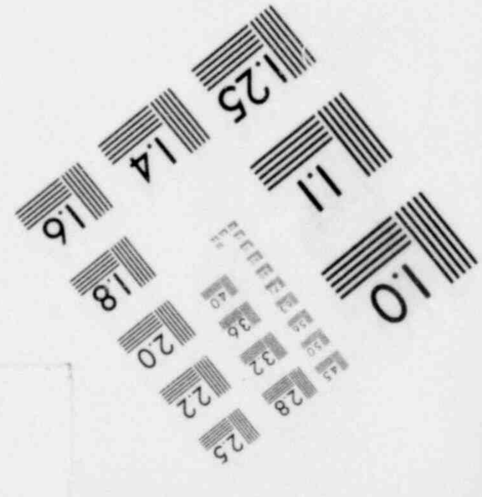
IMAGE EVALUATION TEST TARGET (MT-3)

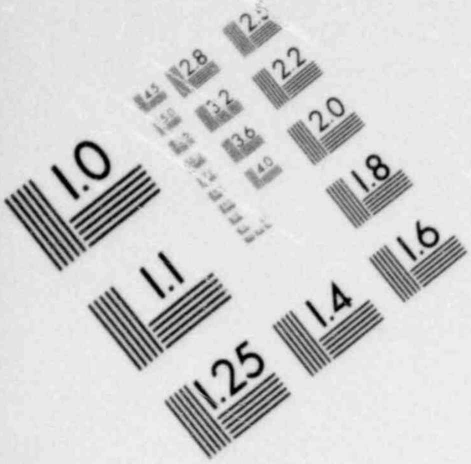


6"

MICROCOPY RESOLUTION TEST CHART







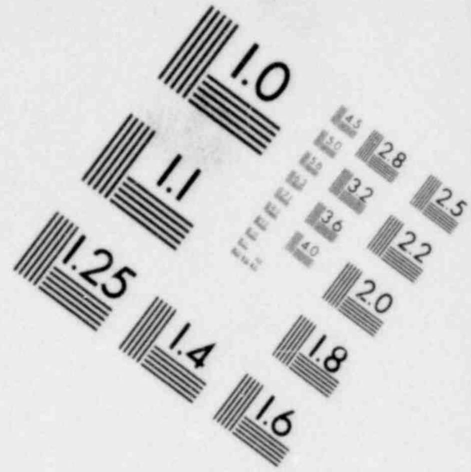
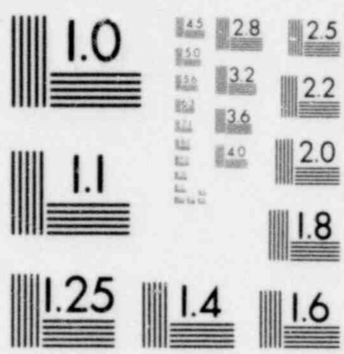
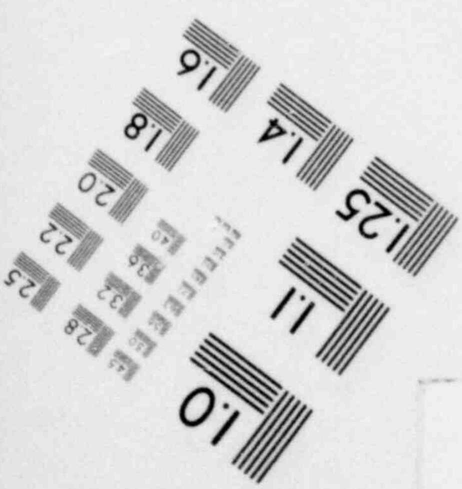


IMAGE EVALUATION TEST TARGET (MT-3)



6″

MICROCOPY RESOLUTION TEST CHART



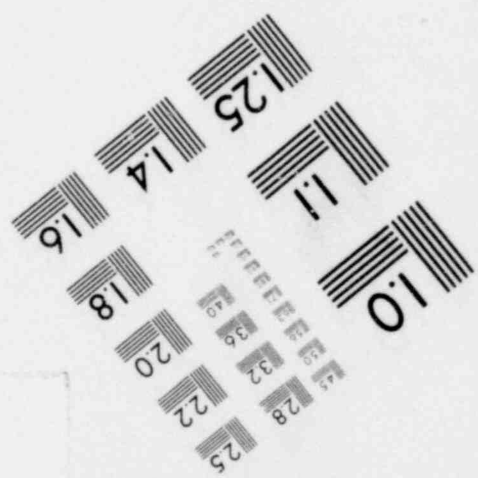
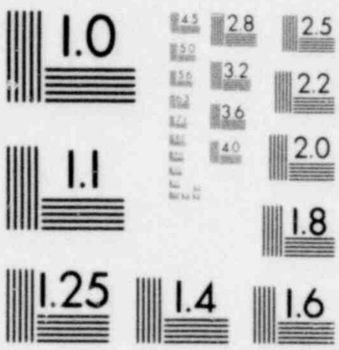


IMAGE EVALUATION
TEST TARGET (MT-3)



6"

MICROCOPY RESOLUTION TEST CHART

2. It is about 2.5 miles from WIPP-11 and thus complements the network of peripheral holes on a 2- to 3-mile spacing. It is also 3 miles north of hole P-18, similarly completed.

3. It is between the center of the site and the Divide, a topographic feature thought to be associated with a groundwater divide.

4. It serves as a monitoring station for estimating groundwater recharge flowing from the northeast across the site area, thereby providing a valuable boundary condition for safety-assessment modeling efforts.

The H-4 cluster of holes is near the northwest corner of Section 5, T 23 S, R 31 E, near existing hole P-7. The specific reason for this location is as follows: data acquired from previous testing indicated water movement across the area of the reference site in a south-to-southeast direction. A hole system located downgradient from the site is needed to verify this trend.

J.1.3 Meteorology

The primary source of meteorological data is the site meteorological station, which has been operating since mid-1976. The original and present locations of the station are shown in Figure J-9. Specifically, the present location, 26 miles east of Carlsbad in Section 21, T 22 S, R 31 E, is at

- Elevation 1050 meters
- Latitude 32 degrees 22.48 minutes N
- Longitude 103 degrees 47.24 minutes W

Until May 1977 the monitoring system consisted of the following sensors:

- Average wind speed, 10 meters
- Wind direction, 10 meters
- Humidity, 10 meters
- Pressure, 1 meter
- Precipitation, 1 meter
- Ionizing radiation, 1 meter
- Sky radiation, 3 meters
- Temperature, 10 meters

These sensors were interfaced with signal conditioners; their output was recorded by a data logger and a strip-chart recorder. The data logger sequentially sampled data at about three channels per second and displayed output voltages on paper tape. Appropriate calibrations were made to convert this information to engineering units. Computer programs were written to convert and store the data. Peak wind speed was obtained by visually scanning the wind-speed strip chart and finding the maximum wind speed during the hour preceding the report hour.

Since November 1977 the meteorological system has provided data as described in Table J-2. The on-site meteorological system was designed to comply with most of the criteria in NRC Regulatory Guide 1.23.

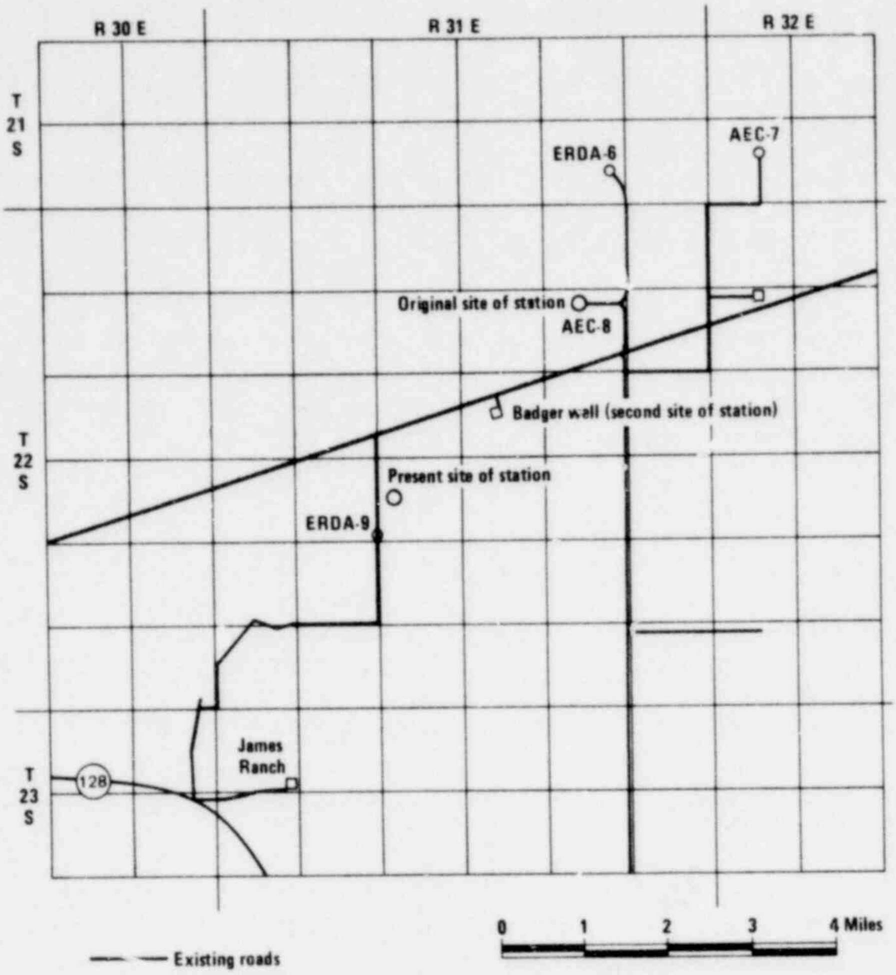


Figure J-9. Location of the meteorology and air-quality-monitoring station.

The 30-meter instruments have been raised (September 1978) to 40 meters to insure compliance with NRC Regulatory Guide 1.23.

The data are managed and processed with a redundant system of two PDP 11/03 minicomputers, each capable of managing 40 channels of information. Recording is made directly on a nine-track incremental magnetic tape. The wind speed and wind direction continue to be recorded on a strip chart for a redundant record.

The sensors in the present system are supplied by the Climatronics Corporation. An exception is the rain gauge, which is supplied by Texas Electronics. The sensors are described in Table J-3.

In addition to the above sensors, four solar and terrestrial radiation sensors have been added to the system at a height of 3 meters. Of two pyranometers, one measures the direct component of sunlight and the diffuse, short-wave component of the skylight; the other measures the reflected short-wave component from the surface. Of two pyrgeometers, one measures the long-wave skylight component from the downward emission of atmospheric gases; the other measures the upward emission and reflection by natural surfaces and atmospheric gases. These sensors are described below.

Pyranometer (Eppley Model PSP)

Sensitivity	9 mV/(W/m^2)
Impedance	650 ohms
Temperature dependence	±1% over -20 to +40°C
Linearity	±0.5% from 0 to 2800 W/m^2
Mechanical vibration	Tested to 20g

Pyrgeometer (Eppley Model PIR)

Sensitivity	3 mV (W/m^2)
Impedance	700 ohms
Temperature dependence	±2% over -20 to +40°C
Linearity	±1% from 0 to 700 W/m^2
Mechanical vibration	Tested to 20g

Maintenance and calibration of all the sensors is performed on a formal, periodic basis.

Additional sources of surface meteorological data used in the site meteorological analysis are the Carlsbad-airport, Hobbs, and Roswell stations that report to the National Climatic Center. Upper-air data have come from the Albuquerque, El Paso, Midland-Odessa, and Lubbock stations that report to the National Climatic Center.

Table J-2. Summary of Meteorological Measurements

Item	Height (meters)	Sampling interval	Recording interval	Units
Pressure	3	1 hour	1 hour	mb
Precipitation	1	1 hour	1 hour	cm
Dew point	3	1 hour	1 hour	°C
Temperature	3, 10, 30	15 sec	15 sec	°C
Wind speed	3, 10, 30	0.1 sec[a]	15 sec	m/sec
Wind direction	3, 10, 30	0.1 sec[a]	15 sec	degrees clockwise from north
Temperature difference	10-3	15 sec	15 sec	°C
Temperature difference	30-3	15 sec	15 sec	°C
Temperature difference	30-10	15 sec	15 sec	°C

[a]For each of the three levels of wind data, the 10-per-second samples are processed to produce 15-second values of mean component values (east-west, north-south), standard deviation of each component, correlation coefficient between the two components, standard deviations of downwind and crosswind components, and downwind and crosswind components of turbulence intensity.

Table J-3. Meteorological Sensors Used

WIND SPEED

Threshold	0.33 m/sec
Distance constant	1.5 meters
Accuracy	0.1 m/sec or ±1%, whichever greater
Range	0 to 50 mps
Linearity	±0.1% of full scale
Stability	±0.1% of full scale
Survivability	Gusts to 45 m/sec, sustained to 33 m/sec

WIND DIRECTION

Threshold	0.33 m/sec
Distance constant	1.5 meters
Accuracy	±2.5 degrees
Damping ratio	0.4 degree at 10-degree angle of attack
Range	0 to 540 degrees
Linearity	±0.1% of full scale
Stability	±0.1% of full scale
Survivability	Gusts to 45 m/sec, sustained to 33 m/sec

TEMPERATURE

Range	-30 to +50°C
Accuracy	±0.25°C
Linearity	±0.2°C

DEW POINT

Range	-40 to +42°C
Accuracy	±0.5°C
Response time	1°C/min

TEMPERATURE DIFFERENTIAL

Accuracy	0.1°C
Range	-[illegible] to + 10°C

STATION PRESSURE

Range	850 to 975 mb
Linearity	±0.3%
Sensitivity	0.2%

RAIN GAUGE

Type	Tipping bucket
Measurement	0.01-inch water per tip
Signal out	Momentary switch closure

1790 004

J.1.4 Air Quality

Air-quality measurements have been made at the meteorological station which has been at three locations since data collection began in early 1976 (Figure J-9). From January to June 1976 the measurements were made at the ERDA-8 drilling pad. The location was changed in June 1976 to the site of the old Badger well in Section 15, R 31 E, T 22 S, and in May 1977 to the present location in Section 21. The air-monitoring station consists of an instrument trailer, instrument towers, and portable diesel generators.

The air-quality data collected at the site and the methods of collection have been documented by Brewer and Metcalf (1977). Air-quality samples are analyzed for total suspended particulates, sulfur dioxide, nitrogen dioxide, hydrogen sulfide, carbon monoxide, and ozone. The program as operated before November 1977 is described below.

Total-suspended-particulate samples were taken with a high-volume air sampler that originally had its collector head attached to the instrument trailer tower 4 feet above the trailer roof. The samples were collected on glass fiber or on Whatman 41 4-inch-diameter filters. Samples were collected for 25 hours at a constant sampling rate of 18.5 ft^3/min. The sampling rate was maintained by electronic flow controllers. Each sample was analyzed for the concentration of sodium, potassium, calcium, magnesium, silicon, iron, aluminum, chloride, and sulfate. These elements and species were selected because they are effluents released by the nearby potash-refining plants. The water-soluble metals, sulfate, and chloride were extracted from the filter by heating in an aqueous solution for 2 hours. The metals were analyzed by atomic-absorption spectrophotometry.

Air samples for particle-size determination and mineralogical analysis were taken for periods of 5 to 7 days once a month. A Sierra Cascade impactor with five stages was used. The impactor was originally located on the trailer roof, about 12 feet above the ground. Sulfates and chlorides were analyzed by turbimetric and colorimetric methods, respectively. After extraction, the filters were dissolved in concentrated nitric acid, and the remaining elements were analyzed by atomic-absorption spectrophotometry.

Sulfur dioxide, hydrogen sulfide, and nitrogen dioxide were detected by wet-chemistry techniques. The sampling frequency was once a week on a random-day basis. The wet-chemistry sampler was located about 3 feet above the roof of the meteorological trailer. The sampling rate was 200 ml/min in high-efficiency bubblers. The sulfur dioxide and nitrogen dioxide samples were analyzed colorimetrically; the hydrogen sulfide samples were titrated. The methods used were standardized through the use of samples of known concentrations.

Carbon monoxide was detected with a continuous nondispersive infrared analyzer. An average concentration for each 24 hours was calculated. The monitor was calibrated weekly by means of a carbon monoxide-in-nitrogen gas standard. The monitor sampling inlet was inside the housing of the Sierra Cascade impactor.

Ozone was measured continuously with an automated ultraviolet-absorption detection technique. An average concentration for each 24 hours was calculated. The ozone monitor was calibrated weekly by electronic methods.

1790 005

Since November 1977 changes have been made to the original air-quality-monitoring system. The system was automated to reduce recording by personnel. Of primary importance was the introduction of a redundant system of PDP 11/03 minicomputers to manage data input from the sampling devices. The concentrations of all continuously monitored chemical species are monitored by the minicomputers. The data are averaged and recorded every 15 seconds. The chemical species continuously monitored are ozone, oxides of nitrogen, carbon monoxide, total hydrocarbons, sulfur dioxide, and hydrogen sulfide.

Changes in pollutant-detection techniques since November 1977 include new methods for sulfur dioxide and hydrogen sulfide, which are now measured with pulsed-ultraviolet-fluorescence detectors; total hydrocarbons, which are now measured with a flame-ionization detector; and oxides of nitrogen, which are now measured by a chemiluminescence technique. Total-particulate samples are now analyzed for lead in addition to the other elements measured before November 1977. All elements are analyzed by atomic-absorption spectrometry.

The location of some of the sampling equipment was also changed. The Sierra Cascade impactor is now 12 feet above the ground on a sampling platform. The high-volume sampler and the wet-chemistry sampler inlet, a chemical sampler now used as a backup system, are also on the platform at heights of 10 and 8 feet, respectively. The preoperational program samplers will remain at these levels.

J.1.5 Ecology

In 1975, the New Mexico Environmental Institute (NMEI) began an environmental baseline study for the DOE in the area of the reference site. The study was to provide baseline environmental data the for the assessment of environmental impacts. These investigations were conducted in a 72-square-mile study area, with intensive studies in a 3-mile intensive-study area over a 2-year period. The results were published in progress reports (Wolfe et al., 1977a, 1977b).

In 1977, the biological team was reorganized, and ecological studies were continued at, and in the vicinity of, the site. This team has issued several quarterly reports. An annual report summarizing data collected through 1978 will be completed in 1979. Field and laboratory methods and ecosystem-modeling plans are detailed in these reports and in Draft Biological Program (Best, 1978).

All of the major habitats at and near the site have been and are being sampled on a seasonal basis for plants, mammals, birds, reptiles, amphibians, terrestrial invertebrates, and aquatic species. Microbial flora, soils, and nutrient cycling have also been and are being studied at the site and in its vicinity.

Soil studies

The objective of soil studies is to give the physical and chemical descriptions of the major soil series at and near the site. Other objectives are better knowledge of nitrogen fixation; elemental composition, productivity, and nutrient cycling in selected plant species; and soils associated with existing mined-rock piles.

Microbiological studies

Terrestrial and aquatic microbial communities and processes are being studied quantitatively to determine inputs for an ecological prediction model. Other objectives are to determine soil and aquatic primary productivity and respiration, establish baseline mutagenic rates for terrestrial and aquatic microorganisms, and to investigate the relationship between the rate of soil erosion and the density of soil crust.

Botanical studies

The objectives of botanical studies are to produce as complete a species list as possible and to determine the density (numbers and biomass) and distribution of the principal plant species within the study area. Permanent transects, quadrats, and exclosures are established in conjunction with these studies. Also, reproductive and vegetative phenophases of selected plant species are being characterized.

Terrestrial-invertebrate studies (soil arthropods and decomposers)

These investigations focus on arthropods involved in the cycling of soil nutrients and detritus. The parameters of interest include spatial and temporal density distributions (numbers and biomass) and the feeding rates and habits of ants, termites, and tenebrionid beetles. In addition, estimates of the quantity and types of materials transported and/or consumed by these arthropods are being made.

Terrestrial-vertebrate studies

These studies monitor the species composition and density distribution (numbers and biomass) of terrestrial vertebrates within the study area. Feeding habits and population dynamics of selected species are studied for use in an ecological prediction model. The studies include the reproductive phenology of selected organisms.

Aquatic studies

Spatial and temporal density distributions (numbers and biomass) and the population dynamics of aquatic flora and fauna at major trophic levels are being studied for possible use in an ecological prediction model.

Baseline radioecology

In order to assess the radioecological impact of the reference repository, indicator organisms representative of the major terrestrial and aquatic trophic compartments need to be determined and baseline inventories of selected radionuclides in them determined. By applying a trophic level approach, instances of biomagnification may be identified.

The specific nuclides usually include cesium-137 as representative of nuclides similar to potassium in their mobility, strontium-90 as similar to calcium, and one of the actinides.

J.1.6 Radiation Monitoring

Since the levels of natural background radiation vary with time, a preoperational radiation-monitoring program has been established to assess the level of natural background radiation at the reference site and its excursions from average levels. The program will assess the variation in background radiation resulting from variations in soil composition, atmospheric conditions, and external events such as cosmic-ray cycles or atmospheric weapons testing. The monitoring program to be carried out during the operational phase of the repository can then evaluate the effects of the plant on the environment. The preoperational monitoring program will also be useful in training personnel and evaluating procedures and equipment for the later program.

The preoperational monitoring program has already started and will continue at its present level until 2 years before the anticipated issuance of the operating license for the repository. At that time, the program will be increased in scope so that its duration will be consistent with NRC Regulatory Guide 4.8, the most nearly applicable guide even though it applies to nuclear power plants. The 2-year period provides sufficient time to establish background levels. If regulations governing geologic repositories are developed in time to guide the program, they will be followed.

The environmental sampling program is designed around existing EPA guidelines for nuclear power plants (EPA ORD/SID 72-2). The guidelines are for a generic power plant, whose operation and discharges are not directly comparable to those of a nuclear-waste repository. The EPA guidelines were therefore used where applicable and modified as necessary to take into account the expected nuclide inventory at the site. The sampling locations were selected according to the recommendations of the EPA guide on the basis of local terrain, demography, and meteorology.

The preoperational program is characterized below, although it cannot be described in detail until the repository is closer to operation. Construction of the repository will have no effect on the radiological levels of the environment except that the accumulation of mined-salt piles, which contain naturally occurring potassium-40, radon-220, and radon-222, may increase the site background levels slightly. The following paragraphs describe sampling locations, types of samples, collection durations and frequencies, and the analyses to be performed. The proposed preoperational radiation-monitoring program is summarized in Table J-4. More detail will be added when the full program begins 2 years before the expected commencement of operation.

Air particulates

Air-particulate samples are presently being taken at the site meteorological station (Figure J-10). Samples are taken three times a week for 24 hours by a high-volume air sampler (18.5 ft^3/min) with high-efficiency filter media. Gross beta concentrations are measured by a beta proportional counter. If the beta activity is greater than 0.06 pCi/m^3, a gamma scan is also taken. Every 3 months samples will be analyzed for gross alpha activity and strontium-90, and isotope analyses (alpha and gamma spectra) will be performed.

1790 008

The present program will be continued until 2 years before repository operation. At that time, additional sampling locations will be established at

1. The James Ranch (the inhabitants nearest the site) near the perimeter of control zone IV to the south-southwest and 3 miles from the surface facilities.

2. Kerr-McGee potash mine, 9 miles north of the site.

3. International Minerals and Chemical Corporation (IMCC) potash mine, 10 miles west-northwest of the site.

4. Mississippi Chemical and Potash, Inc., potash mine, 12 miles northwest of the site.

5. A point on the northwest boundary of the site in the most prevalent wind direction.

6. A point on the north-northwest boundary of the site.

7. Town of Loving, approximately 19 miles west-southwest of the site.

8. City of Carlsbad, approximately 26 miles west of the site.

9. Town of Eunice, approximately 38 miles east of the site.

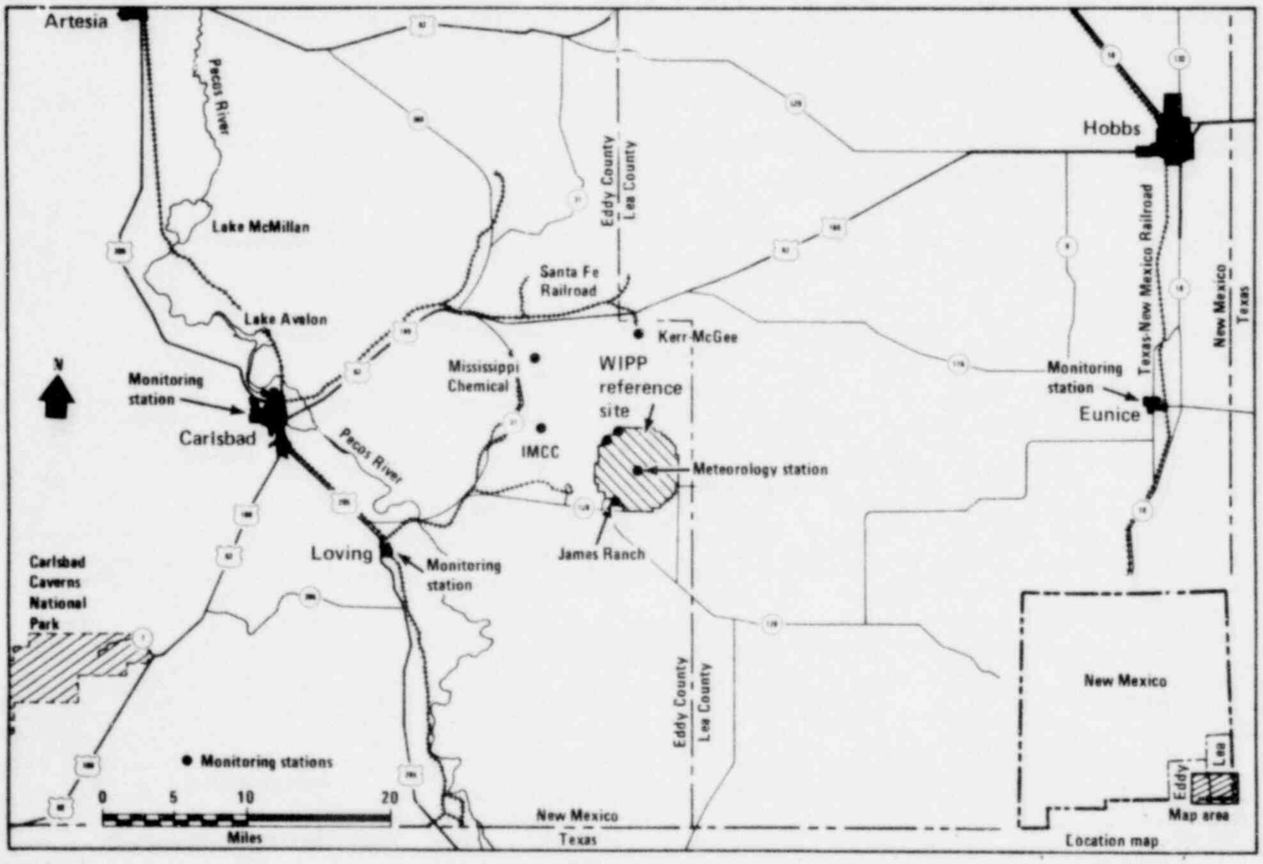


Figure J-10. Air-particulate-monitoring stations.

1790 009

Table J-4. Preoperational Radiation-Monitoring Program

Sample	Location	Sampling and collection frequency	Type of analysis
		AIRBORNE	
Particulates	Meteorological station[a] James Ranch Kerr-McGee potash mine IMCC potash mine Mississippi Chemical & Potash mine Northwest boundary of site North-northwest boundary of site Loving Eunice Carlsbad	24-hr samples taken 3 times per week	Gross beta[b] Gross alpha, Sr-90, alpha and gamma spectra
Soil	Same as air samplers	Semiannually	Alpha[c] and gamma spectra
		DIRECT RADIATION	
	Six TLDs on site in site area,[a] including the meteorological station Carlsbad All other air-sampling stations listed above	Quarterly	Gamma dose
		WATERBORNE	
Ground	13 locations at site	Semiannually	Gross beta, gamma spectra, tritium
Surface	Pecos River	Semiannually	Gamma spectra, tritium[d]
Drinking	James Ranch well	Semiannually	Gamma spectra, tritium, Sr-90, Pu isotopes, Am-241, Cm-244
Sediment	Pecos River	Semiannually	Gamma spectra
		INGESTION	
Fruits and vegetables	Any locally produced	At harvest	Gamma spectra on edible portion; tritium for green leafy vegetables only
Meat and poultry	Animals feeding on land within 10 miles of site in prevailing downwind direction (one domestic fowl; one beef animal, if available; one mourning dove; one sample of eggs)	Annually	Gamma spectra and actinide analysis on edible portion

[a]Presently operating. Other stations will begin operations 2 years before WIPP operation.

[b]Gamma spectra if gross beta concentration is greater than 0.06 pCi/m^3.

[c]Including isotopic analyses for Pu isotopes, Cm-244, Am-241.

[d]Normally very little flow, samples taken preferably after rainfall to obtain runoff.

There are no communities within 10 miles of the site. The Kerr-McGee, IMCC, and Mississippi Chemical potash mines are expected to have the largest population concentrations within 12 miles of the site. All anticipated sampling locations are shown in Figure J-10.

Radioiodine

The only radioiodine isotope that might be detected in the long term is iodine-129. Other radioiodine isotopes will have decayed to undetectable levels because of their short half-lives. However, even the iodine-129 levels (in spent fuel) are expected to be very low. The contact-handled and remotely handled transuranic wastes will not contain significant amounts of iodine isotopes. Consequently, no sampling for iodine isotopes is planned.

Soil samples

Soil samples will be collected from the same locations as the air-particulate samples. Several sets of soil samples will be taken from each location at 6-month intervals. The samples will be analyzed for alpha emitters--including plutonium isotopes, curium-244, and americium-241--as well as for gamma-emitting radioisotopes.

Direct gamma radiation

Levels of direct gamma radiation are being measured at the site and in Carlsbad. This program will be continued on a limited basis until 2 years before operation. The present program uses one Reuter-Stokes pressurized ionization chamber at the meteorological station. The radiation level is measured continuously and averaged on a weekly basis. Gamma-radiation measurements are also made at seven different locations by thermoluminescent dosimeters (TLDs). Six locations are in the vicinity of the site, as shown in Figure J-11, and the seventh is in Carlsbad. At each location, five TLD-100 chips are placed approximately 1 meter above the ground; these are exchanged and evaluated quarterly.

As recommended by the EPA, the monitoring program will be increased in scope 2 years prior to the WIPP operation to include TLD stations at all of the air-particulate-sampling locations (Figure J-10). Five TLD chips will be placed at each station and exchanged quarterly.

Water sampling

One of the most important aspects of the radiological monitoring program will be to monitor groundwater at all available sampling locations (Figure J-12). Considerable attention will be given to groundwater monitoring since groundwater constitutes a possible primary pathway from the repository. Sampling locations at the site will be established and sampling begun 2 years before operation. All sites will be monitored quarterly for gross alpha, gross beta, and tritium concentrations. Isotopes present in the water will be identified by analysis of gamma-ray spectra.

Beginning 2 years before the repository begins operating, surface-water samples from the Pecos River will be taken quarterly, preferably after periods of rainfall. Surface-water samples will be analyzed for tritium, and gamma-spectrum isotope analyses will be performed.

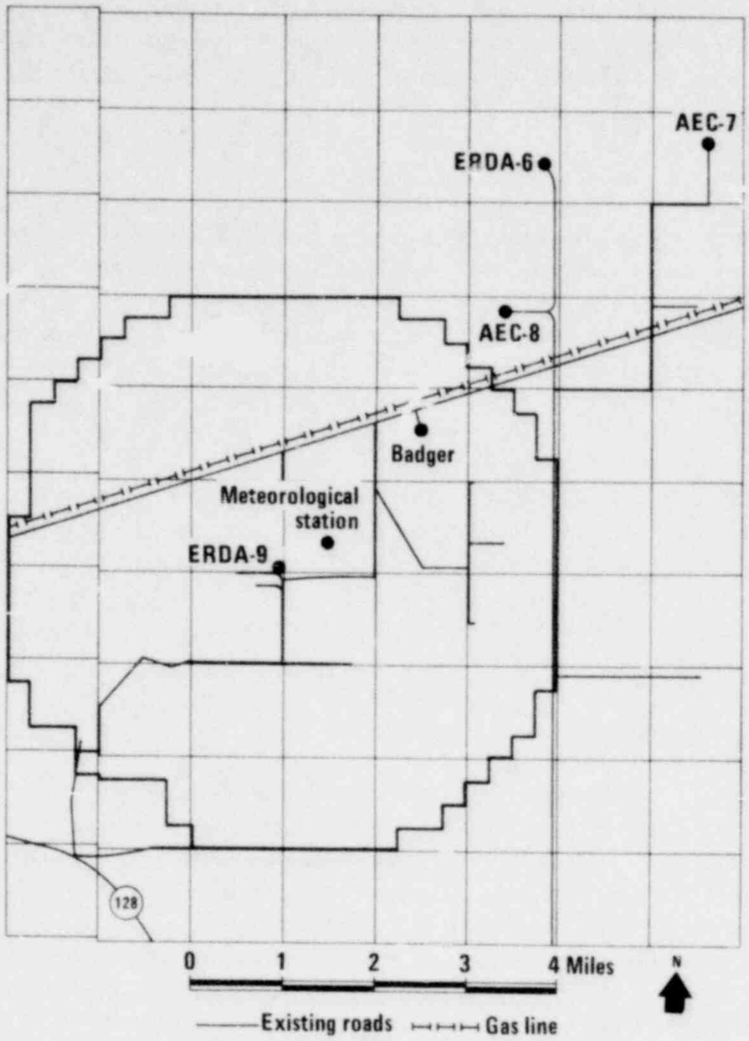


Figure J-11. Locations of thermoluminescent dosimeters in the site area. An additional thermoluminescent dosimeter will be located in Carlsbad.

Only one well whose water is used for human consumption exists within 5 miles of the site. It is located at the James Ranch (Figure J-10). Samples will be taken of this well quarterly, gamma-spectrum isotope and tritium analyses will be performed, with additional analysis of alpha-emitting actinides and strontium-90. Public drinking water supplies in Carlsbad, Loving, and Malaga are presently being monitored annually by the EPA as a result of the Gnome project in 1961. That monitoring program is discussed elsewhere in this appendix.

<u>Sediment, benthic organisms, aquatic plants, fish, and shellfish</u>

No samples of benthic organisms, aquatic plants, fish, or shellfish will be taken since the nearest surface water, excluding water tanks, an impoundment, and salt lakes, is 14 miles away from the site at its closest point. However, to account for the extremely remote possibility of radionuclide buildup on sediments over long periods of time, baseline radiation levels in sediments of the Pecos River will be determined; these will be compared with data obtained after operation commences. Such samples will be taken along with surface-water sampling and will be subjected to gamma-spectrum isotope analyses.

Milk

No milk sampling is planned since the nearest dairy farm is more than 40 miles away. No commercial feed crops are grown within 10 miles of the site.

Fruits and vegetables

No food crops for public consumption are grown within 10 miles of the site. Therefore, no samples will be taken except for green leafy vegetables and representative fruits from any private garden plot that may come to exist within 5 miles of the site. Sampling will be performed at each harvest. The edible portions of these fruits and vegetables will be subjected to a gamma-spectrum isotope analysis. The green leafy vegetables will also be analyzed for tritium. The sampling of private garden plots will commence 2 years before anticipated operation if such gardens exist or whenever they come into existence.

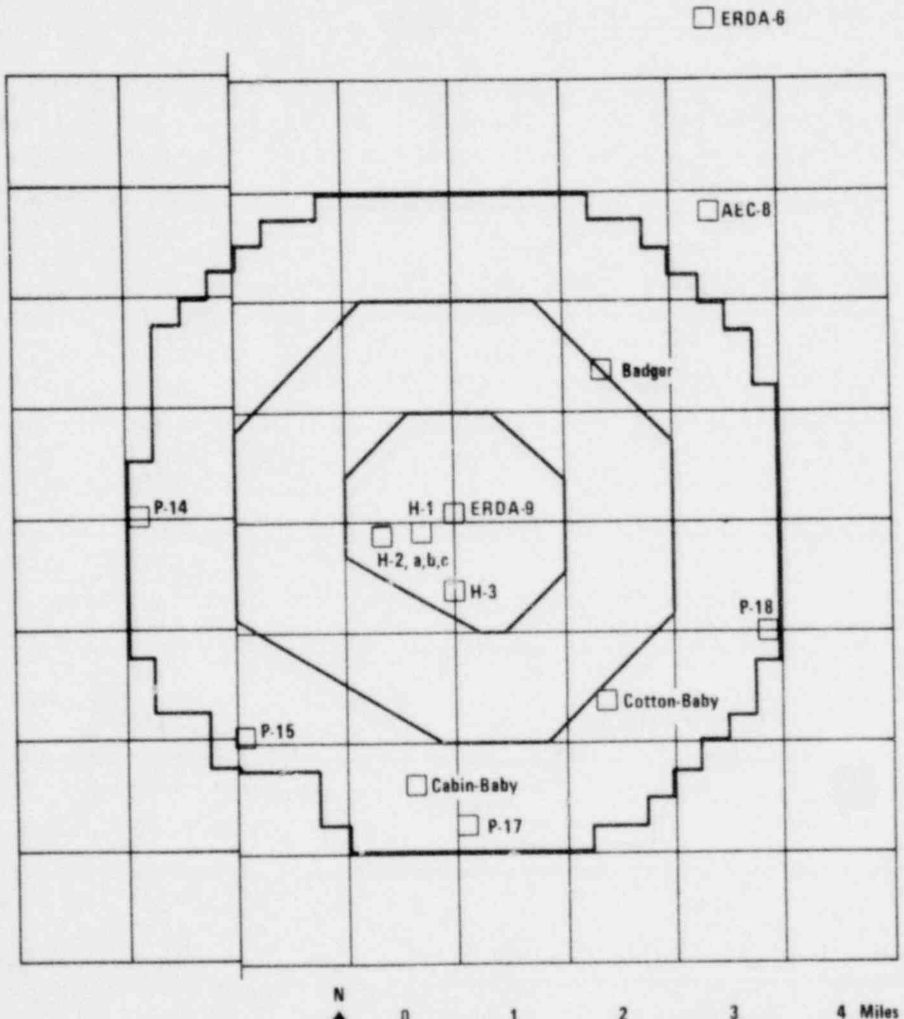


Figure J-12. Groundwater-sampling locations.

1790 013

Meat and poultry

At least one sample each of meat, poultry, and eggs from fowl, if any, feeding on land within 10 miles of the site in the prevailing downwind direction will be collected annually. One of the major game species, the mourning dove, will be collected in season. One sample of beef from cattle grazing within 10 miles of the site in the prevailing downwind direction will be taken annually, if available. This sampling will commence 2 years before the repository begins operating. Edible portions will be analyzed for gamma-emitting radioisotopes and the predominant actinides anticipated in the repository inventory.

Instruments and detection sensitivities

A limited radiation-monitoring program already exists, but the bulk of sample analysis will commence 2 years before the repository begins operating. The specific radioassay techniques and minimum detectable levels will depend on the instrumentation used. In general, state-of-the-art techniques and instruments will be used. As presently planned the instrumentation will include GeLi, SiLi, and NaI detectors and associated multichannel analyzers, for gamma and X-ray analysis; alpha spectrometers and proportional counters, for alpha analysis; and liquid scintillation and proportional counters, for beta analysis.

A strict quality-assurance program will be followed. Procedures will be written and standardized for each type of analysis. Accuracy and standardization will be maintained by routinely submitting samples to the EPA's Analytical Quality Control Service of the Surveillance and Inspection Division or by some other interlaboratory comparison. The quality-assurance program will also insure samples of sufficient size to provide accurate measurements.

Table J-5 summarizes typical analytical methods, sample sizes, and detection sensitivities. Table J-6 summarizes the detection levels currently

Table J-5. Typical Detection Methods[a]

Sample	Method	Sample size	Form	MDA[b]
Air particulates				
Gross alpha	Gas proportional counter	V[c] (ml)	Filter	0.18/V pCi/ml[d]
Gross beta	Gas proportional counter	V[c] (ml)	Filter	0.30/V pCi/ml[d]
Water				
Gross alpha	Gas proportional counter	50 ml evaporated	Planchet	0.02 pCi/ml
Gross beta	Gas proportional counter	100 ml evaporated	Planchet	0.02 pCi/ml
Gross gamma	NaI(Tl) Cs-137 gamma	1 liter evaporated to 300 ml	Water	0.09 pCi/ml
Tritium	Liquid scintillation	1 liter	Water	0.2 pCi/ml[d]
Solid vegetation, gross gamma	3 x 3-inch NaI(Tl) well detector	User specified; normally 2 g	Dried and ashed	2 pCi/g

[a]At Sandia Laboratories, Albuquerque, New

[b]Minimum detectable activity ±100% at 95% [illegible]ence.

[c]Volume of sample, V, specified by user, determines the minimum detectable activity as shown.

[d]Based on a standard 100-minute counting time.

Table J-6. Environmental Protection Agency ERAMS Reporting Increments and Minimum Detectable Levels for Radionuclide Analyses

Radionuclide	Medium	Reporting units[a]	Reporting increment[a]	Minimum detectable level
Gross alpha	Water	pCi/l	1 pCi/l	2 pCi/l
Gross beta	Air	pCi/m^3	0.01 pCi/m^3	0.01 pCi/m^3
	Water	pCi/l	1 pCi/l	1 pCi/l
	Precipitation	nCi/m^2	0.01 nCi/m^2	[b]0.01 nCi/m^2
Tritium	Water	nCi/l	0.1 nCi/l	0.2 nCi/l
	Milk	nCi/l	0.1 nCi/l	0.2 nCi/l
Carbon-14	Milk	pCi/l	1 pCi/l	15 pCi/l
Krypton-85	Ambient air	pCi/m^3	0.1 pCi/m^3	2 pCi/m^3
Plutonium-238, 239	Air	aCi/m^3	0.1 aCi/m^3	[c]0.015 pCi per sample
	Milk	pCi/l	0.001 pCi/l	0.015 pCi per sample
	Water	pCi/l	0.001 pCi/l	0.015 pCi per sample
Uranium-234, 235, 238	Air	aCi/m^3	0.1 aCi/m^3	[c]0.015 pCi per sample
	Milk	pCi/l	0.001 pCi/l	0.015 pCi per sample
	Water	pCi/l	0.001 pCi/l	0.015 pCi per sample
Radium-226	Water	pCi/l	0.1 pCi/l	0.1 pCi/l
Strontium-90	Milk	pCi/l	0.1 pCi/l	1 pCi/l
	Water	pCi/l	0.1 pCi/l	1 pCi/l
Strontium-89	Milk	pCi/l	1 pCi/l	[d]5 pCi/l
Iodine-131	Milk	pCi/l	1 pCi/l	[d]10 pCi/l
	Water	pCi/l	1 pCi/l	[d]10 pCi/l
	Water (specific radiochemical analysis)	pCi/l	0.1 pCi/l	0.4 pCi/l
Iodine-129	Milk	fCi/l	0.1 fCi/l	0.4 fCi/l
Iodine-127	Milk	g/l	10 g/l	10 g/l
Cesium-137	Milk	pCi/l	1 pCi/l	10 pCi/l
	Water	pCi/l	1 pCi/l	10 pCi/l
Barium-140	Milk	pCi/l	1 pCi/l	[d]10 pCi/l
	Water	pCi/l	1 pCi/l	[d]10 pCi/l
Potassium	Milk	g/l	0.1 g/l	0.12 g/l
	Water	g/l	0.1 g/l	0.12 g/l
Potassium-40	Water	pCi/l	1 pCi/l	100 pCi/l

Source: Environmental Radiation Data, quarterly reports distributed by the Eastern Environmental Radiation Facility, Environmental Radiation Data, P.O. Box 3009, Montgomery, Alabama 36109.

[a]Abbreviations: nCi = 10^{-9} curie; pCi = 10^{-12} curie; fCi = 10^{-15} curie; aCi = 10^{-18} curie.

[b]The value in terms of nCi/m^3 would depend on precipitation.

[c]This value in terms of pCi/m^3 would depend on the air volume.

[d]Activity as of the day of counting.

1790 015

achievable with state-of-the-art methods and instrumentat[illegible]sted by the EPA in its Environmental Radiation Ambient Monitoring Sys[illegible]) quarterly reports, "Environmental Radiation Data." For nuclides of s[illegible] concern not included in Table J-6, detection sensitivities will be evaluated as the analytical procedures are refined during the preoperational phase.

J.2 PROPOSED OPERATIONAL MONITORING PROGRAM

The preoperational monitoring programs described in this appendix will form the basis of the operational monitoring programs. The operational programs, however, will profit from the experience and the techniques developed during the preoperational phase.

J.2.1 Geology

During the construction and routine operation of the WIPP reference repository, several monitoring programs will be conducted to insure that no unacceptable geologic conditions are encountered or caused by repository development.

Underground monitoring

As shafts are sunk and drifts are mined into the salt, geologic mapping of stratigraphic units and structural features will be conducted regularly. Before mining drifts, horizontal pilot holes will be cored along the drift paths and the rock examined to provide information on physical properties. When suitable, radar sounding will be used to probe in advance of mining for pockets of brine or gas.

Deformation gauges will be installed at important locations in the shaft pillar region and in major haulage-and-access drifts. These gauges will be monitored regularly and compared with anticipated deformations calculated by rock-mechanics computer codes. The shafts will be regularly inspected to detect any unusual movement of the shaft walls.

Bulk salt samples obtained from the waste storage and experiment rooms will be analyzed to determine the chemical makeup, brine content, mechanical properties, and thermal properties. This sampling will establish whether the medium has been adequately described from earlier, more limited, samples. If the deviations in properties are significant, new calculations will be performed to describe the repository behavior.

Surface measurements of geologic parameters

Continuous monitoring of seismic activity will be conducted by seismometers located near the surface buildings but remote enough to avoid microseisms produced by human activities. This station will monitor regional and local natural seismicity and microseisms that may develop from repository subsidence; it will document the ground motions imposed on surface facilities.

Surface level-line stations that have been and will be installed over the site will be resurveyed on a regular basis, perhaps every 1 to 5 years, to detail the movement of the surface in response to thermal loading and room collapse. These measurements will be compared with calculated results to monitor the progress of room collapse after closure of individual rooms or sections of the repository.

J.2.2 Hydrology

The hydrologic program described in this appendix is expected to extend well beyond the operational lifetime of the repository. Long-term proposals include the installation of water-level recorders in all monitored wells. The continuous output from the recorders will be correlated with barometric data from the local weather station to eliminate atmospheric influences in water-level fluctuations.

The surface hydrology of the region will be defined in terms of the major components that contribute to surface flows and water quality. Water balances in critical areas of interest or local watersheds will be investigated to establish the scope of aquifer recharge and to predict hydrologic changes. Measurement programs for spring flows, potash effluent, and other surface run-off will be carried out.

It is expected that groundwater sampling for long-term monitoring will be performed on an annual basis. However, after mining for the repository has started, sampling will be quarterly until conditions stabilize. The increased frequency of measurement will permit early detection of changes in groundwater systems from mining and construction activities.

J.2.3 Meteorology

The operational monitoring program will follow the preoperational program very closely. The measurements taken during the preoperational phase will continue to be taken at a permanently established monitoring station. The increased amounts of data will be used to better characterize the meteorological conditions at the site.

J.2.4 Air Quality

The operational air-quality monitoring program is expected to be identical with the preoperational program. The program will remain flexible, however, and will include the requirements of updated sampling regulations and guidelines, either State or Federal. The program, in all cases, will be adequate to establish whether or not the State and Federal air-quality standards are being violated as a result of repository operation.

J.2.5 Ecology

The operational ecological monitoring program, building on the foundation established through preoperational ecological monitoring, will document the ecological effects of repository construction and operation. The proposed monitoring plan will be flexible to permit modifications. Initial experience may suggest such modifications as changes in instrumentation, addition or deletion of parameters, adjustments in the number and location of sampling stations, or alterations in the frequency of observations and the number of replications.

Sampling methods and strategy will follow those presented in the preoperational biological monitoring program, unless there is substantial reason to modify them. However, operational monitoring will focus primarily on indicator organisms and selected abiotic parameters. Biological data will be collected near meteorological and radiation-monitoring stations (when possible) to facilitate correlation with data collected at these stations. Samples will be collected during each season at biologically significant times (as determined through preoperational monitoring). When unusual trends are observed, sampling will be intensified to elucidate the cause. Unusual trends will not necessarily be attributable to the repository because biota respond dramatically to fluctuations in rainfall and resource availability.

Information generated by the operational (and preoperational) monitoring program will be published by the principal investigators in recognized professional journals, and presented at appropriate meetings and symposia. In addition, all work will be reviewed by an independent committee of scientists from appropriate fields. These practices will insure that data are being collected and interpreted according to the most up-to-date professional standards.

J.2.6 Radiation Monitoring

Effluent monitoring

The gaseous-exhaust systems provide potential pathways for the release of airborne radionuclides. To minimize the release of radionuclides, the repository will use a high-efficiency filtration system to treat particulate effluents. The discharge will be monitored in accordance with ANSI standards N13.1-1969 and N13.10-1974. The monitoring systems, including alarms and probes, will be redundant.

Samples will be taken by two off-line monitoring samplers placed in different locations, which will insure isokinetic sampling and complete mixing of all gaseous radionuclides. Each monitoring system will have a probe designed to continuously extract about 6 cfm of effluent gas. Part of this 6-cfm flow will then be diverted to the alpha monitor and the other part to the beta-gamma monitor. The sampled air streams will then be returned to the effluent stream.

The flow rate through each of the two monitors will be measured to determine the concentration of airborne radioactive material in the exhaust gases and to insure that the collector is operating at its design rate. The total volume of air exhausted will be recorded to assist in determining the total discharge of radioactive material to the environment.

Alpha-particle monitoring

In the monitoring system for the waste-handling building an air stream will be directed through a large-pore membrane filter monitored by an

1790 018

alpha-radiation detector. A large-pore membrane is used so that alpha emissions of particles retained on the filter will not be lost by attenuation within the filter material. The specific detector to be selected will probably be a solid-state device that continuously monitors the filter paper. The radon-220/radon-222 background, determined by detecting radon-220 separately, can be subtracted from the observed count rate.

It is expected that alpha activity will be so low that the particles may be allowed to accumulate on the filter for as long as a week. Once a filter is removed, it will be counted for gross alpha activity, and an alpha-spectroscopy analysis will be performed if gross alpha activity is detected. The sensitivity currently available in a laboratory-controlled count of alpha activity is 0.18 pCi for a count duration of 100 minutes. The filters will be retained as a record of effluent monitoring.

The alpha detector will have a lower detection limit of 2×10^{-12} μCi/ml for plutonium-238 at the 95% confidence level after continuous monitoring for a 4-hour period. Alarms will signal instrument failures and high alpha activity in the air stream; visible and audible signals will be produced near the detector and at a control station where monitor readings will be displayed.

Beta and gamma monitoring

A part of the monitoring system in the waste-handling building will direct air through high-efficiency filters of cellulose-asbestos or glass fiber that are monitored by beta and gamma radiation detectors. The system to be selected will probably be a lead-shielded pancake-type geiger tube that continuously monitors the filter.

It is expected that the beta and gamma activity will be so low that particles may be allowed to accumulate on the filter for as long as a week. Once a filter is removed, it will be counted for gross beta activity and for gross gamma activity, and a gamma-spectroscopy analysis will be performed. The filters will be retained as a record of effluent monitoring.

The beta and gamma monitoring system will have a low-detection limit of 4×10^{-12} μCi/ml for a gaseous effluent stream consisting solely of strontium-90 and 5×10^{-12} μCi/ml for a gaseous effluent stream consisting solely of cesium-137, both at the 95% confidence level after continuous monitoring for a 4-hour period. The instrument response time will be less than 60 seconds. Alarms will signal instrument failures and high beta activity.

Environmental radiation monitoring

After the repository begins operating, a program for monitoring environmental radiation levels will be operated continuously in order to verify projected or anticipated radioactivity concentrations and related public exposures in accordance with NRC Regulatory Guide 4.8. At the onset of operation, the operational monitoring program is expected to be essentially identical with the preoperational monitoring program. Initially, at least, the same media will be sampled, the same sampling locations will be monitored, and the same types of analyses will be made. However, the operational program will be flexible; it will be continually reevaluated and modified if needed. A strict quality-control program will be followed to insure the accuracy of samples and measurements. If any additional radioactivity is detected beyond

1790 019

the levels expected from preoperational monitoring results, an immediate program of evaluation will be undertaken to discover and eliminate the cause.

Equipment sensitivities

The equipment used for measurement during operation will meet or exceed the sensitivities described in Table J-5. State-of-the-art equipment and instruments will continually be evaluated for incorporation into the monitoring program.

Data reporting

Annual reports will summarize the environmental-sample monitoring. These reports will provide applicable data in a format similar to that in NRC Regulatory Guide 4.8. They will include results of environmental activities and assessments of observed environmental impacts.

J.3 POSTOPERATIONAL MONITORING PROGRAMS

The basic purpose of geologic disposal is to isolate wastes from the biosphere so that surveillance will not be needed after the repository is closed. Indeed, the repository will not be closed up at all if there is any serious concern regarding the post-decommissioning risk.

For a limited time after the WIPP is decommissioned, monitoring will continue. This monitoring will, for the most part, be a continuation of the operational monitoring program. The rationale for the postoperational monitoring program is presented in this section.

The objective of postoperational monitoring is to give timely warning of radionuclide releases or of events or processes that may precede the release of radionuclides to the environment. This goal will require measures to assure people in the future that no gross underestimate of risks has been made. It is expected that this purpose can be accomplished by periodic, rather than continuous, observations and that the monitoring program would not be complex.

Three kinds of post-decommissioning monitoring appear to be appropriate: geologic, hydrologic, and radiologic. Probable measurements are outlined in Table J-7. Much of the operational monitoring program is designed to detect impacts associated with operation of the repository. Portions of the operational monitoring program, like measurements of effluents and meteorological measurements, will no longer be appropriate.

Geologic monitoring is primarily concerned with detecting variations in geologic parameters that may reveal a possibility for the release of radioactivity, whether the variations are caused by natural geologic events or by the presence of the repository. The fundamental measurement will be periodic resurveys of the surface to observe the depth and areal extent of subsidence associated with closure of the subsurface cavities. In addition, a periodic surface geologic reconnaissance will be conducted for fractures and other phenomena indicative of subsurface movement. Borehole monitoring would not be undertaken because holes located close enough to the waste to measure geologic

Table J-7. Outline of the Post-decommissioning Monitoring Program

Measurement	Location	Frequency	Objective
	HYDROLOGIC		
Borehole measurement and sampling			
Gross alpha activity Gross beta activity Chemistry	Holes downgradient at a distance of 2 miles or more	5-10 years	To detect migration of radionuclides out of disposal area
Head measurements			To confirm no change in hydrology
	GEOLOGIC		
Resurvey surface topography	Level lines across surface of site	5-10 years	To detect and measure subsidence and/or uplift
	RADIOLOGICAL		
Sample indicator species	At and near site	5-10 years	To detect releases directly
Sample water, indicator species	At groundwater discharge points	5-10 years	To detect releases directly

movement and subsurface temperatures would at the same time breach the natural integrity of the strata over or near the waste.

The postoperational radiation-monitoring program will include measurements of activity levels in biological indicator species. The sampling program will give direct assurance that some unanticipated event has not bypassed the natural and man-made barriers against release of radioactivity and that radionuclides have not been missed in the radiobiological monitoring of downgradient groundwater. Useful indicator species will be designated before decommissioning. At the surface above the disposal area, such sampling might be of grasses and game birds. At the groundwater discharge points in lower Nash Draw and along the Pecos River, such sampling might be of water and periphyton.

Hydrologic monitoring will continue almost undiminished from the operational phase inasmuch as the more serious long-term concerns for the repository would require transport of radionuclides by groundwater. The basic hydrologic monitoring will consist of periodic sampling and radiobiological analysis of water from open boreholes downgradient from the disposal area.

1790 021

There are at present five hydrologic holes in control zone IV that could be used for this purpose (holes P-14, P-15, P-17, P-18, and H-4), and it may be necessary to drill more holes to eliminate the possibility that a plume of released radionuclides might pass between monitoring holes without being observed. The hydrologic test holes in control zone II and all upgradient test holes will be plugged. The latter will not be needed, and to leave the former open would be to leave a potential connection between aquifers and Salado salt.

J.4 RELATED ENVIRONMENTAL PROGRAMS BY OTHERS

J.4.1 Bureau of Land Management

In 1974, the BLM began preparation of a preliminary regional Environmental Assessment Record (EAR) (BLM, 1976a) in order to fulfill responsibilities outlined in the National Environmental Policy Act of 1969. The compilation of an EAR was the major step toward the resumption of potash leasing and prospecting in the Carlsbad area. The preliminary document was published in October 1975, and the Executive Summary and Supplement (BLM, 1976a and b) was completed in 1976. Public-reference copies of this document are available in the city libraries of Carlsbad, Hobbs, and Albuquerque, as well as at the BLM offices in Santa Fe and Albuquerque.

J.4.2 New Mexico Environmental Improvement Division

The New Mexico Environmental Improvement Agency (now Division) performed an air-quality assessment of the potash-mining activities in the general area of the reference site. The assessment was undertaken after apparent violations of the State and Federal air-quality standards were mentioned in the Environmental Assessment Record of the Bureau of Land Management. The assessment analyzes the impact of the potash industry on the air; the analysis used computer-modeling techniques to predict average air-particulate levels in the vicinity of the local potash mines.

The Air Quality Division of the NMEID monitors air quality throughout the State and provides data on the concentrations of total suspended particulates, sulfur dioxide, carbon monoxide, and ozone. The information recently gathered in the vicinity of the site is in the Municipal Building in Carlsbad. Only total suspended particulates are measured at the site. Other sites of interest are at Artesia, Hobbs, and Lovington; data are available on microfiche on a semiannual basis.

J.4.3 U.S. Geological Survey

The USGS has had major involvement in characterizing the hydrology and geology of the area surrounding the site. The involvement was further intensified when the DOE (and its predecessors, ERDA and AEC) and BLM requested detailed studies in the area. The AEC needed site characterization for

Project Gnome in 1961; the USGS performed a detailed hydrologic and geologic study of the Gnome site during the period between 1958 and 1961. The BLM needed assistance in preparing the preliminary Environmental Analysis Record and requested input from the USGS. Also, the State of New Mexico has received assistance in preparation of hydrologic reports throughout the State--including the site. On a routine monitoring basis, the USGS issues an annual generic water-data report. The report describes water resources in the State of New Mexico (USGS, 1977). The detailed data include discharge rates of streams and water levels of selected wells in the site area. Some chemical analysis of selected water samples is also documented in the same report.

J.4.4 Environmental Protection Agency, Las Vegas, Nevada

The EPA has performed environmental monitoring surveys in the vicinity of the site as a result of Project Gnome. Except at the Nevada Test Site, the EPA monitors wells, springs, and spring-fed surface water sources at sites where underground nuclear detonations have taken place; the monitoring looks for migration of radionuclides resulting from the movement of groundwater. Consequently, a number of wells in the vicinity of the Gnome site are monitored annually by the EPA. In addition to the water monitoring, the EPA has monitored radionuclide concentrations in plant and animal tissues collected at the Gnome site.

J.4.5 Potash Industry

Some detailed environmental monitoring of the potash industry before 1976 resulted from the preliminary Environmental Assessment Record. Although the monitoring included soil and well-water sampling, the potash mines in the Carlsbad area do not generally have extensive environmental monitoring programs. Present levels of monitoring are beginning to increase as a result of interaction with the NMEID. The most extensive monitoring programs include collection of meteorological data and high-volume air sampling for total suspended particulates; such programs are conducted at two of the seven potash mines in the vicinity of the reference site. As State guidelines for high-volume sampling are formulated, similar programs can be expected at other mines.

J.4.6 National Oceanic and Atmospheric Administration

The NOAA provides a Climatological Data Publication, which is published by the National Climatic Center (NCC). It is a compendium of reports from selected weather stations throughout the United States, and it includes such meteorological data as temperature, daily precipitation, wind speed, humidity, and sky cover. More detailed meteorological data are available through the NCC for selected sites. This information is available to the general public through a monthly subscription service. However, meteorological data specific to the reference site are not available from the NCC.

J.4.7 New Mexico Department of Game and Fish

Two studies being conducted by the New Mexico Department of Game and Fish will provide information related to the WIPP biological monitoring program. One study monitors conditions and trends of range lands grazed by livestock and wildlife in four southern New Mexico counties (including Eddy County). The other deals with the Harris hawk; it monitors population size and age composition, determines range in southeastern New Mexico, and gathers data on reproductive biology.

J.4.8 Ongoing Regional Ecological Studies

In addition to the comprehensive ecological studies being carried out by the WIPP project, several ecological investigations are being carried out in the region of the reference site by governmental agencies and university researchers.

The Roswell District of the Bureau of Land Management (BLM) is completing an extensive preliminary draft environmental statement (PDES) on proposed livestock-grazing practices on public lands in southeastern New Mexico, east of the Pecos River. In addition, the BLM is sponsoring a groundwater study related to potash mining in the Region (A. Gebel, personal communication, August 25, 1978). The primary questions to be answered by the BLM study are the following:

1. Is fresh water in the Carlsbad potash area in danger of contamination from current or expanded potash-mining activity?

2. Is the brackishness of the Pecos River below Malaga Bend in whole or in part attibutable to mining activities?

3. Is the amount of leakage from brine-disposal ponds significant when compared to the tremendous volumes of naturally occurring brines?

The hydrology investigation also includes an evaluation of phreatophytes and wetland vegetation as water-quality indicators and a botanical evaluation of Nash Draw (Geohydrology Associates, 1978).

The Bureau of Reclamation at Amarillo, Texas, is continuing to update the project history of the Malaga Bend Division-McMillan Delta Project. The Malaga Bend Division was an experimental salinity-alleviation project intended to improve the water quality in the Pecos River by lowering the head of the brine aquifer at Malaga Bend and thus diverting the brine. In 1976 active monitoring on the project was discontinued.

The Bureau of Reclamation at Amarillo is also currently preparing a supplement to its Final Environmental Impact Statement on the Brantley Dam project, which is located on the Pecos River approximately 12 miles northwest of Carlsbad. Fishery studies have been conducted by the State of New Mexico to determine the fish species present in the area and to develop possible mitigation measures to protect the rare fish located in Major Johnson Springs.

Reynolds Electrical & Engineering Co., Inc., has been conducting a radiological survey for the DOE Nevada Operations Office at the Gnome site. Project Gnome was the first scientific experiment in the Plowshare Program in December 1961. Portions of the 1-square-mile site were contaminated during mine-back operations and postshot activities. The survey involves monitoring radiation levels and executing an operational plan for the decontamination and decommissioning of the site (D. D. Jackson, DOE, personal communication, September 26, 1978).

Various projects are being carried out in the site area by university researchers. For example, graduate students at Eastern New Mexico University have been studying the fish fauna in the Black River; an endemic subspecies of white-tailed deer at the Mescalero Sands in northern Eddy County; and pocket mice in eastern Eddy County (A. L. Gennaro and J. E. Sublette, Eastern New Mexico University, personal communication, September 21, 1978).

The two studies being conducted by the New Mexico Department of Game and Fish, which will provide information to the WIPP biological monitoring program, were discussed earlier.

1790 025

REFERENCES

Best, T., 1978. Draft Biological Program for the Waste Isolation Pilot Project, prepared for Sandia Laboratories, Albuquerque, N.M.

Blankenagel, R. K., 1968. "Geophysical Logging and Hydraulic Testing, Pahute Mesa, Nevada Test Site," Ground Water, 6(4).

BLM (U.S. Bureau of Land Management), 1976a. Environmental Assessment Record, U.S. Department of the Interior, New Mexico State Office.

BLM (U.S. Bureau of Land Management), 1976b. Executive Summary and Supplement to Preliminary Potash EAR, U.S. Department of the Interior, New Mexico State Office.

Brewer, L. W., and J. H. Metcalf, 1977. Environmental Monitoring at the WIPP Site, CY 1976, SAND77-1201, Sandia Laboratories, Albuquerque, N.M.

Brown, E., M. W. Skougstad, and M. J. Fishman, 1970. "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," in Techniques of Water Resources Investigations of USGS, Book 5, Chapter Al.

Geohydrology Associates, 1978. Ground-Water Study Related to Proposed Expansion of Potash Mining near Carlsbad, New Mexico, prepared for U.S. Bureau of Land Management, Denver, Colo.

Keys, W. S., and L. M. McCary, 1971. "Application of Borehole Geophysics to Water Resources Investigations," in Techniques of Water Resources Investigations of the USGS, Book 2, Chapter El.

Lambert, S. J., and J. W. Mercer, 1977. Hydrologic Investigations of the Los Medanos Area, Southeastern New Mexico, 1977, SAND77-1401, Sandia Laboratories, Albuquerque, N.M.

Mercer, J. W., and B. R. Orr, 1977. Review and Analysis of Hydrogeologic Conditions Near the Site of a Potential Nuclear-Waste Repository, Eddy and Lea Counties, New Mexico, Open-File Report 77-123, U.S. Geological Survey.

Powers, D. W., S. J. Lambert, S.-E. Shaffer, L. R. Hill, and W. D. Weart (eds.), 1978. Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, 2 vols., SAND78-1596, Sandia Laboratories, Albuquerque, N.M.

Sanford, A. R., and T. R. Toppozada, 1974. Seismicity of Proposed Radioactive Waste Disposal Site in Southeastern New Mexico, Circular 143, New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, N.M.

USGS (U.S. Geological Survey), 1977. Water Resources Data for New Mexico--Water Year 1976, NM-76-1, Albuquerque, N.M.

Wolfe, H. G., et al. (eds.), 1977a. An Environmental Baseline Study of the Los Medanos Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report, prepared for Sandia Laboratories by the New Mexico Environmental Institute.

Wolfe, H. G., et al. (eds.), 1977b. An Environmental Baseline Study of the Los Medanos Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report--An Addendum, prepared for Sandia Laboratories by the New Mexico Environmental Institute.

Appendix K

METHODS USED IN LONG-TERM SAFETY ANALYSES

1790 028

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1790 029

LIST OF FIGURES (continued)

Appendix K

METHODS USED IN LONG-TERM SAFETY ANALYSES

K.1 HYDROLOGIC TRANSPORT

K.1.1 Introduction

The numerical model used for geosphere-transport calculations was developed by Intera Environmental Consultants, Inc., for the U.S. Nuclear Regulatory Commission. It is a modified version of a deep-well disposal model developed by Intera for the U.S. Geological Survey. This three-dimensional, finite-difference model solves a set of partial differential equations describing total flow, energy, salinity, and radionuclide transport in a porous medium. The equations are coupled by two properties of the fluid: density and viscosity.

The three basic coupled equations describe the conservation of the total liquid mass, the conservation of energy, and the conservation of the mass of a specific contaminant dissolved in the fluid. In addition, the model solves, for each of the radioactive constituents, an equation describing the conservation of mass for the species dissolved in the fluid phase and adsorbed onto the rock medium; this equation includes radioactive decay and generation from other constituents. Although the equations describing constituents are coupled by daughter-parent relationships between isotopes, they can be effectively decoupled by solving them in a systematic parent-to-daughter sequence.

The first equation describes the three-dimensional Darcy flow of a single-phase liquid in a porous aquifer; the density of the liquid phase can be a function of temperature, pressure, and concentration. The second equation describes the convection and dispersion of energy after the injection of a fluid of different temperature and pressure into the resident aquifer fluid. The third equation describes the convection and hydrodynamic dispersion of an inert component whose salinity or chemical composition differs from that of the resident aquifer water. The fourth equation describes the convective dispersion and adsorption of a radioactive constituent present in trace amounts.

This set of equations predicts the concentrations of these decaying constituents and of the specified inert components. It also predicts the temperature and pressure patterns that result from the flow of liquid waste and the discharge of solid or liquid waste. The aquifer fluid properties are permitted to be functions of the concentration and temperature of liquid chemical waste.

For solving these equations, the computer code provides, in addition to a three-dimensional rectangular Cartesian grid, a two-dimensional (r, z) grid system. The cylindrical-coordinate system is well suited to single-source interpretive or predictive calculations.

The basic assumptions contained in the model are as follows:

a. Flow is three-dimensional, transient, and laminar (Darcy).

1790 031

b. Fluid density can be a function of pressure, temperature, and concentration of the inert component. Fluid viscosity can be a function of temperature and concentration.

c. Injected wastes can mix with the in-place fluids.

d. Aquifer properties vary with position; i.e., porosity, permeability, thickness, and elevation can be specified for each numerical grid block in the model.

e. Hydrodynamic dispersion is a function of fluid velocity.

f. Radioactive constituents are present in trace quantities only; i.e., fluid properties are independent of the concentrations of these contaminants.

g. The energy equation can be described as "enthalpy in - enthalpy out = change in the internal energy of the system." This is rigorous except for kinetic energy and potential energy, which have been neglected.

h. Boundary conditions allow natural water movement in the aquifer, heat losses to adjacent formations, and the location of injection, production, and observation points anywhere within the system.

Within the code, a wellbore model provides the boundary conditions for a reservoir model, which calculates pressure, temperature, and contaminant concentrations at the numerical-grid-block centers. However, the grid-block centers may not correspond to the points at which boundary conditions are specified. The wellbore model calculates energy losses or gains and fluid pressure difference between these points and the corresponding grid-block centers. Depending on the option selected, the model may calculate total fluid-mass fluxes across horizontal grid-block boundaries and allocate the total flow rate between each vertical layer. The wellbore may be a physical well drilled from the surface to the aquifer formation. If it is, the user model will then calculate the bottom-hole conditions that correspond to the boundary conditions for the reservoir model.

K.1.2 Reservoir Model Equations

Suppose x, y, z to be a Cartesian coordinate system and let Z(x,y,z) be the height of a point above a horizontal reference plane. The basic equation describing single-phase flow in a porous medium combines the continuity equation

$$\nabla \cdot \rho \underline{u} + q' = -\frac{\partial}{\partial t}(\phi\rho) \qquad \text{(K-1)}$$

and Darcy's law in three dimensions,

$$\underline{u} = -\frac{k}{\mu}(\nabla p - \rho g \nabla Z) \qquad \text{(K-2)}$$

(Symbols are defined in Table K-1.) The basic flow equation is then

$$\nabla \cdot \frac{\rho k}{\mu}(\nabla p - \rho g \nabla Z) - q' = \frac{\partial}{\partial t}(\phi \rho) \qquad \text{(K-3)}$$

The energy balance defined as [enthalpy in - enthalpy out = change in internal energy] is described by the energy equation,

$$\nabla \cdot \left[\frac{\rho H k}{\mu}(\nabla p - \rho g \nabla Z)\right] + \nabla \cdot \underline{\underline{E}}_H \cdot \nabla T - q'_L - q'H - q'_H$$

$$= \frac{\partial}{\partial t}[\phi \rho U + (1 - \phi)(\rho C_p)_R T] \qquad \text{(K-4)}$$

The five terms on the left-hand side of Equation K-4 describe net energy convection, conduction, heat loss to surrounding strata, enthalpy accompanying a fluid source, and energy not accompanying a fluid source. A material balance for the solute produces the solute-concentration equation.

$$\nabla \cdot \left[\rho \hat{C} \frac{k}{\mu} (\nabla p - \rho g \nabla Z)\right] + \nabla \cdot \rho \underline{\underline{E}}_c \cdot \nabla \hat{C} - q' \hat{C} = \frac{\partial}{\partial t}(\rho \phi \hat{C}) \qquad \text{(K-5)}$$

The three terms on the left-hand side of Equation K-5 represent net convection, dispersion, and production of the solute. A similar material for N radioactive components results in N component equations. For component i,

$$\nabla \cdot \left[\rho C_i \frac{k}{\mu} (\nabla p - \rho g \nabla Z)\right] + \nabla \cdot \rho \underline{\underline{E}}_c \cdot \nabla C_i - q'_i$$

$$+ \sum_{j=1}^{N} k_{ij} K_j \rho \phi C_j - \sum_{k=1}^{N} k_{ki} K_i \rho \phi C_i = \frac{\partial}{\partial t}(\phi \rho K_i C_i) \qquad \text{(K-6)}$$

where

$$k_{ki} K_i \rho \phi C_i = k_{ki} \rho \phi C_i + k_{ki} \rho_s (1 - \phi) C_{si} \qquad \text{(K-7)}$$

The two summation terms describe the generation of component i from the decay of other radionuclides and the decay of component i to other radionuclides. Implicit in Equation K-6 is the approximation

$$\frac{\partial}{\partial t}(\phi \rho K_i C_i) \approx \frac{\partial}{\partial t}(\phi \rho C_i) + \frac{\partial}{\partial t}[(1 - \phi)\rho_s C_s] \qquad \text{(K-8)}$$

1790 033

The equilibrium adsorption constant is defined as follows:

$$K_i = 1 + \frac{\rho_B K_{d_i}}{\phi} \quad \text{(K-9)}$$

The system of equations K-3, K-4, K-5, and K-6--along with the fluid-property dependence on pressure, temperature, and concentration--describes the reservoir flow due to the discharge of wastes into an aquifer. This nonlinear system of partial differential equations must be solved numerically by high-speed digital computers. Equations K-3, K-4, and K-5 are coupled through fluid-property dependence. Since we have assumed that the radioactive components are present in trace quantities only and the fluid properties are independent of these concentrations, Equation K-6 is uncoupled from the other equations.

These equations are solved by dividing the region of interest into three-dimensional grid blocks and developing finite-difference approximations for this grid. Then finite-difference equations are developed whose solution closely approximates the solution of Equations K-3, K-4, K-5, and K-6. These finite-difference equations are as follows:

Basic flow equation

$$\Delta[T_w(\Delta p - \rho g \Delta Z)] - q = \frac{V}{\Delta t}\delta(\phi\rho) \quad \text{(K-10)}$$

Energy equation

$$\Delta[T_w H(\Delta p - \rho g \Delta Z)] + \Delta(T_H \Delta T) - q_L - qH - q_H$$

$$= \frac{V}{\Delta t}\delta[\phi\rho U + (1 - \phi)(\rho C_p)_R T] \quad \text{(K-11)}$$

Solute equation

$$\Delta[T_w \hat{C}(\Delta p - \rho g \Delta Z)] + \Delta(T_c \Delta \hat{C}) - \hat{C}q = \frac{V}{\Delta t}\delta(\rho\phi\hat{C}) \quad \text{(K-12)}$$

Trace-component equation

$$\Delta[T_w C_i(\Delta p - \rho g \Delta Z)] + \Delta(T_c \Delta C_i) - q_i + V\rho \sum k_{ij} K_j C_j$$

$$- V\rho K_i C_i \sum k_{ik} = \frac{V K_i \rho}{\Delta t}\delta C_i \quad \text{(K-13)}$$

The difference operators in space are defined by

$$\Delta(T_w \Delta p) = \Delta_x(T_w \Delta_x p) + \Delta_y(T_w \Delta_y p) + \Delta_z(T_w \Delta_z p) \quad \text{(K-14)}$$

with

1790 034

$$\Delta_x(T_w \Delta_x p) = T_{w,i+1/2,j,k}\left(p^{n+1}_{i+1,j,k} - p^{n+1}_{i,j,k}\right)$$

$$- T_{w,i-1/2,j,k}\left(p^{n+1}_{i,j,k} - p^{n+1}_{i-1,j,k}\right) \qquad \text{(K-15)}$$

The symbol δ denotes variation over a single time step; for any quantity χ,

$$\delta\chi = \chi^{n+1} - \chi^{n} \qquad \text{(K-16)}$$

The terms

$$T_w = \frac{kA\rho}{\mu \ell} \qquad \text{(K-17)}$$

$$T_H = \frac{E_H A}{\ell} \qquad \text{(K-18)}$$

$$T_c = \rho\frac{E_c A}{\ell} \qquad \text{(K-19)}$$

have been introduced for notational convenience; since all of them are position-dependent, a further expansion is illustrated as

$$T_{w,i+1/2,j,k} = \frac{2\Delta y_j \Delta z_k}{\left(\frac{\Delta x}{k_x}\right)_i + \left(\frac{\Delta x}{k_x}\right)_{i+1}} \left(\frac{\rho}{\mu}\right)_{i+1/2,j,k} \qquad \text{(K-20)}$$

For radial geometry, the term

$$\frac{2\Delta y_j \Delta z_k}{\Delta x_i + \Delta x_{i+1}}$$

becomes $2\pi\Delta z_k/\ln(r_{i+1}/r_i)$. The volume term is written as $\pi\Delta r_i^2 \Delta z_k$.

Two terms, the constituent-dispersion tensor E_C and the effective heat-conductivity tensor E_H need additional description. In the present model both depend on hydrodynamic dispersivity, which is a function of local fluid velocity. For an isotropic porous medium there can be no more than two independent dispersivity factors; this requirement insures that the dispersion tensor is invariant under coordinate transformations. These two dispersivities are longitudinal, in the direction of flow, and transverse, perpendicular to flow. Generally, both are functions of the magnitude of the flow velocity:

$$D_l = \alpha_l |\underline{u}|$$

and

$$D_t = \alpha_t |\underline{u}|$$

1790 035

When the velocity vector is divided into components along three coordinate axes, nine components of both the dispersivity and conductivity tensors occur.

More general expressions for the dispersivity and conductivity tensors can be written in terms of molecular properties and hydrodynamic dispersivity:

$$\underline{\underline{E}}_C \equiv \phi \, \underline{\alpha}\underline{u}/\phi + D_m$$

and (K-21)

$$\underline{\underline{E}}_H \equiv \phi \, \underline{\alpha}\underline{u}/\phi(\rho C_p)_w + K_m$$

where the dispersivity coefficient α is a vector quantity. The apparent conductivity due to hydrodynamic dispersion in the porous medium has been taken as the product of the dispersivity and velocity multiplied by fluid volumetric heat capacity. The ordinary molecular heat conductivity of fluid plus rock, K_m, has been treated as an additive constant. The concept expressed in Equations K-21 is that the microscopic heterogeneity in convective flow creates the same dispersive effect in temperature that it creates in constituent concentration.

1790 015

1790 036

Table K-1. Nomenclature

A	Area to flow--either $\Delta x\Delta y$, $\Delta x\Delta z$, or $\Delta y\Delta z$
C	Concentration, mass fraction
$\hat{C}$	Concentration of solute, salinity
C_p	Specific heat
C_s	Concentration of radioactive component on rock
D	Diffusion coefficient
E	Dispersion coefficient
E_C	Constituent-dispersion tensor
E_H	Effective heat-conductivity tensor (including hydrodynamic dispersion)
g	Acceleration due to gravity
H	Enthalpy
k	Permeability
k_{ij}	Rate of decay of component j to component i
K	Thermal conductivity
K_d	Adsorption-distribution constant
K_i	Equilibrium adsorption constant defined in Equation K-9
ℓ	Distance between grid-block centers
p	Pressure
q	Mass source per grid block
q'	Mass source per unit of porous-medium volume
q_H'	Energy stored without fluid input per grid block
q_H'	Energy stored without fluid input per unit of porous-medium volume
q_L	Rate of heat loss per grid block
q_L'	Rate of heat loss per unit of porous-medium volume
r	Radial space coordinate
t	Time

1790 037

Table K-1. Nomenclature (continued)

T	Temperature
T_H, T_W, T_C	Transmissibility of energy, flow, and contaminant; defined by Equations K-17, K-18, K-1
u	Superficial (Darcy) fluid velocity in the porous rock
U	Internal energy
V	Grid-block volume
x	Cartesian space coordinate
Z	Elevation above reference plane

<u>Subscripts</u>

av	Average over depth increment
R	Rock
S	Solid material (always rock)
i,j,k	Indices labeling radioactive components or, in Equations K-15 and K-20, indices labeling grid blocks
w	Liquid
l,t	Longitudinal and transverse, respectively
m	Molecular properties in porous media

<u>Superscripts</u>

n	Time level n

<u>Greek</u>

α	Dispersivity coefficient
ϕ	Porosity
ρ_B	Bulk density $= (1 - \phi)\rho_S$
ρ_S	Density of rock
ρ	Density of fluid
μ	Viscosity
Δt	Time increment
$\Delta x, \Delta y, \Delta z$	Grid-block dimensions

1790 038

K.2 APPLICATION TO THE REFERENCE SITE

This section describes in detail the application of the hydrologic transport code in modeling the reference site.

As mentioned in Section 9.5 1.2, a systematic three-step approach was used for geosphere-transport calculations: regional hydrologic modeling or data interpretation, scenario or waste-release modeling, and nuclide-transport modeling. These three parts of the modeling effort are discussed in this section under separate headings.

K.2.1 Data Interpretation

The objectives of the regional modeling are as follows:

a. To check consistency or lack of it between various sets of hydrologic data.

b. To calculate the extent of communication (vertical permeabilities) between various hydrologic units.

c. To delineate heterogeneities existing within each geologic formation. Heterogeneity here refers to spatial variation of permeability values.

d. To calculate potentials and/or hydraulic conductivities in areas where data are lacking.

e. To calculate boundary conditions for local scenario and nuclide-transport modeling.

The calculational procedure is straightforward. Permeability values determined by laboratory or well tests are used as initial values in the calculations. Permeability distributions are adjusted until the calculated potentials are in satisfactory agreement with a consistent set of measured potential values.

Hydrologic data used in this work were obtained primarily from Mercer and Orr (1977), who reviewed and summarized all data existing through February 1977 (see also Section 7.3). After issuing this report, the USGS conducted well tests in the Los Medanos area; some data from a draft USGS report to Sandia were used to check consistency and obtain permeabilities immediately above the reference site. Other sources of data were Griswold (1977), Rai and Mason (1977), Lambert (1978), and Lambert and Mercer (1977), and laboratory-measured adsorption-distribution coefficients in unpublished form.

A map of the modeled region is shown in Figure K-1, and a geologic cross section of the Los Medanos area looking toward the northwest is presented in Figure K-2. The Santa Rosa Sandstone is a moderately permeable formation containing relatively fresh water. However, the low permeability of the Dewey Lake Red Beds prevents significant seepage of water from the Santa Rosa Sandstone to the Rustler Formation. Two thin aquifers, the Magenta and the Culebra, are contained in the Rustler Formation, which is predominantly com-

1790 039

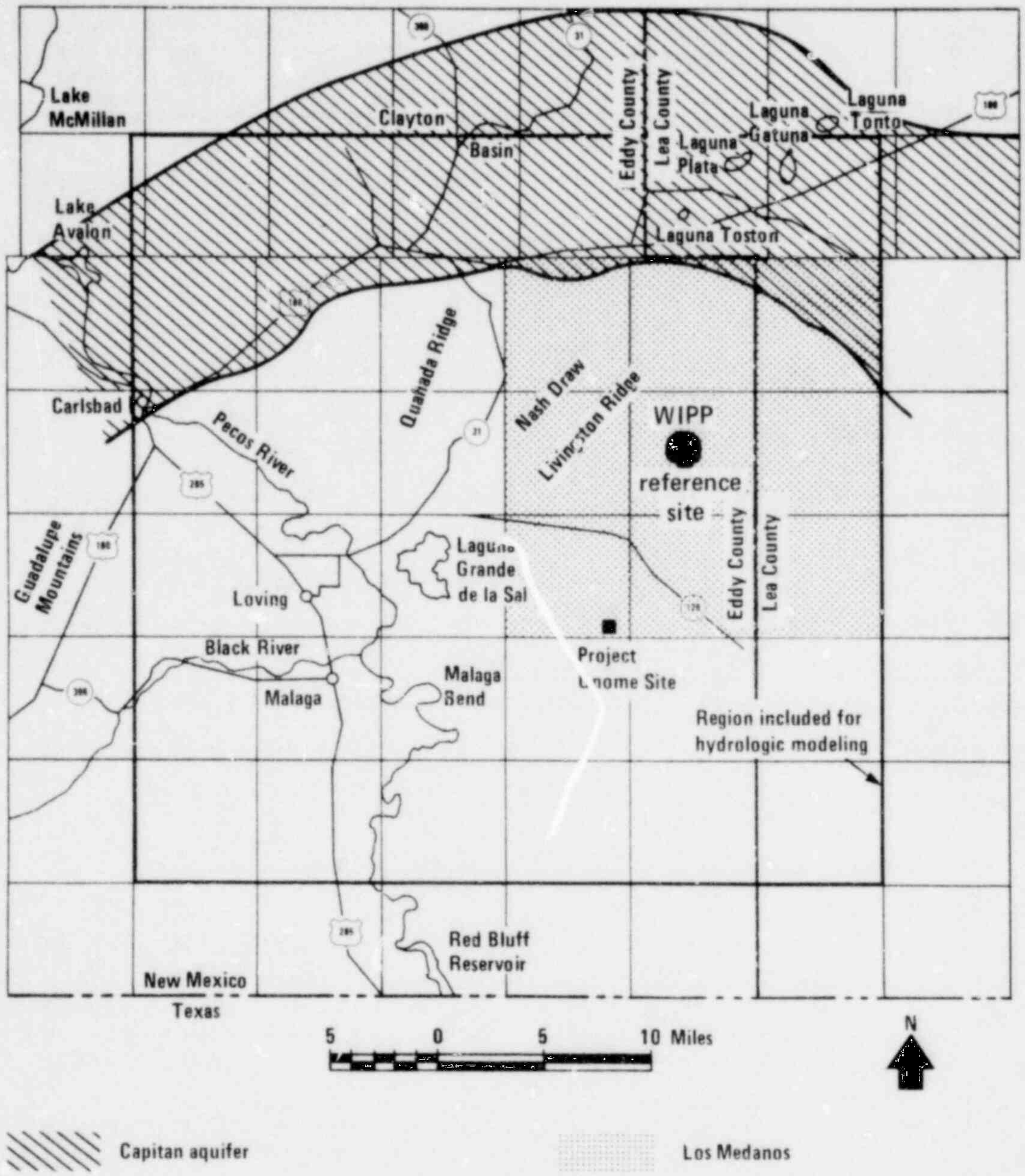


Figure K-1. Hydrologic modeling region.

posed of impervious anhydrites, polyhalites, and gypsum. The WIPP reference repository will be in the Salado Formation. The Castile Formation, composed of very pure halite and anhydrite, contains no water-bearing strata. Beneath it lies the Delaware Mountain Group, approximately 3000 feet thick, which contains aquifers.

The Castile Formation is in a basin bounded by the Capitan aquifer (Figure K-1). These two geological formations are at about the same vertical level. The Capitan aquifer is quite permeable, and its degree of communication with the Delaware Mountain aquifers varies considerably at different locations. A shallow-dissolution zone lying along the Rustler-Salado interface in Nash Draw is roughly 50 feet thick, 30 miles long, and 2 to 10 miles wide. The nearest edge of this dissolution zone is several miles west of the repository.

Within the hydrologic region modeled in this study, the Rustler Formation aquifers (Culebra and Magenta) apparently do not communicate hydrologically with any of the aquifers below the Salado Formation or with the shallow-dissolution zone. The Magenta and Culebra are modeled as one aquifer, the Rustler aquifer, with a total thickness equal to the combined thicknesses of the two actual aquifers. Regional Rustler flow in the site area is generally to the southwest.

The Santa Rosa Sandstone does not extend beyond the reference repository to the west, and the intermediate Dewey Lake Red Beds are essentially confining beds. Therefore, the upper surface of the Rustler was assumed impermeable, and the Santa Rosa Sandstone was not included in the model calculations. In the regional modeling, the Capitan aquifer was combined with the Bell Canyon aquifer of the Delaware Mountain Group.

Existing hydrologic data in the region were compiled by the U.S. Geological Survey, Albuquerque, New Mexico (Mercer and Orr, 1977). Hydraulic potentials observed in the Rustler Formation, the Delaware Mountain Group, and the Capitan aquifer by Mercer and Orr are shown in Figures K-3 and K-4. As can be seen from Figure K-3, discharge from the Rustler is into the Pecos River at Malaga Bend, about 15 miles from the reference site, although it is likely that some discharge occurs south of Malaga Bend. More recent data obtained by the U.S. Geological Survey and presented by Mercer and Orr (1978) suggest that flow immediately above the repository in the Culebra is toward the southeast. However, combining the map in Figure K-3 with the recent data shows that the flow toward the southeast is only local; on a larger scale the flow in the Rustler Formation is toward the Pecos River. Potentials in the Delaware Mountain Group show that flow there is essentially toward the northeast.

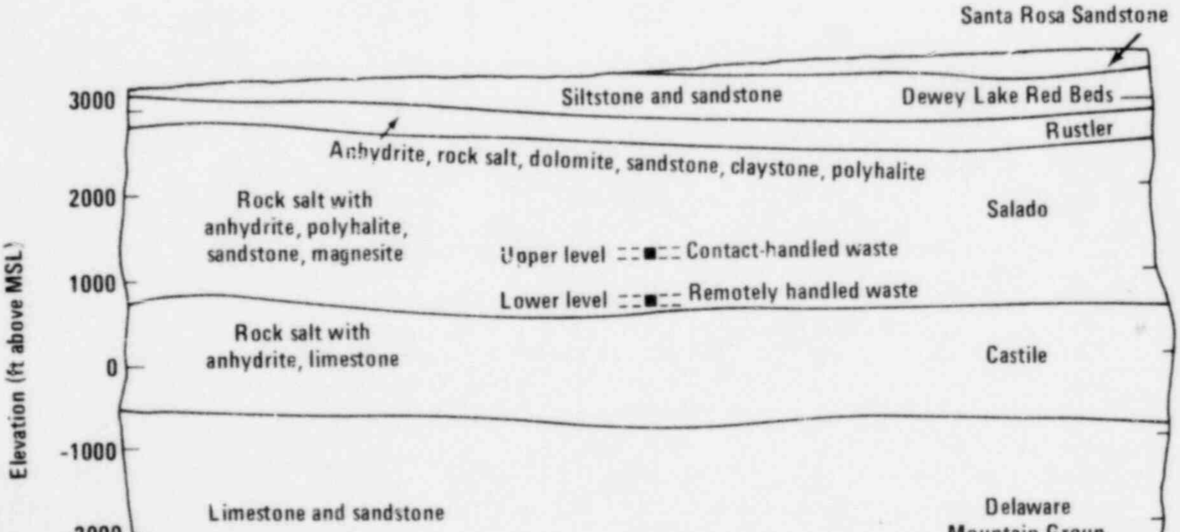
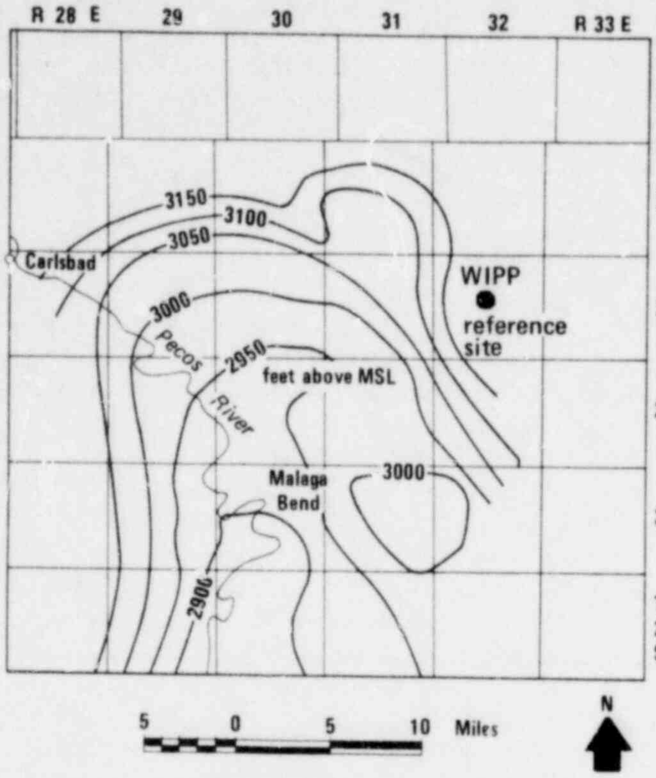


Figure K-2. Geologic section of the Los Medanos area.

1790 041



Fiⁿure K-3. Hydraulic potentials (feet above MSL) measured in the Rustler Formation.

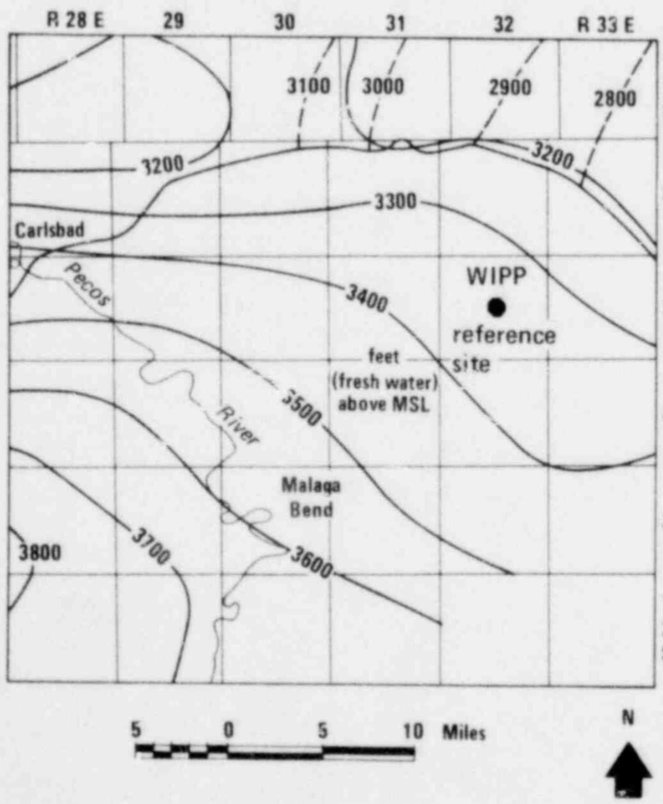


Figure K-4. Hydraulic potentials (feet above MSL) measured in the Capitan aquifer (broken lines) and in the Delaware Mountain Group (solid lines).

1790 042

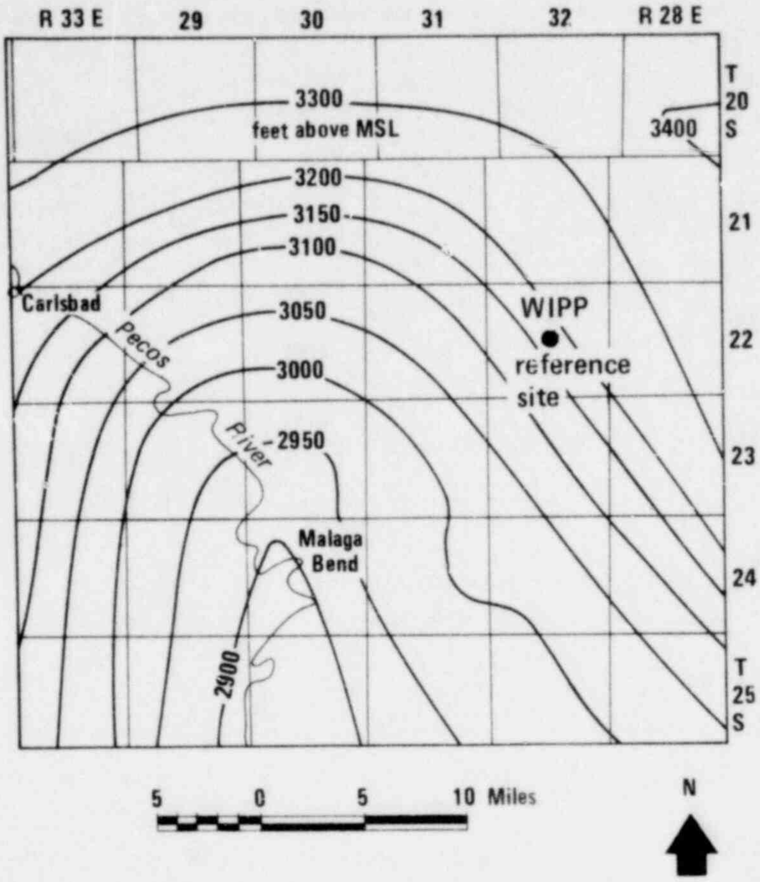


Figure K-5. Calculated hydraulic potentials (feet above MSL) for the Rustler Formation.

The Rustler Formation, the shallow-dissolution zone, the Delaware Mountain Group, and the Capitan reef were modeled to obtain a match with the observed potentials. Modeling of intervening anhydrite and salt layers showed that the anhydrite and salt had to be essentially impermeable; an upper limit to the vertical hydraulic conductivity in these formations was calculated to be 10^{-6} ft/day. It was difficult to simultaneously match potentials in different layers with a higher value. Calculated potentials in the Rustler and the Delaware Mountain Group are shown in Figures K-5 and K-6. The match of measured and calculated potentials in the Rustler (Figures K-3 and K-5, respectively) is especially reasonable for this analysis, in which only the potentials between the site and Malaga Bend determine the flow path. The match of the potentials in the Delaware Mountain Group (Figures K-4 and K-6) is adequate; these, however, are of little importance to the transport of radionuclides from the reference repository.

A set of calculated hydraulic conductivities in various layers is shown in Figures K-7 to K-10. It is important to note that these conductivity values are not unique. Any set of conductivity values scaled up or down by a constant factor will produce exactly the same results; the velocities and flow rates will differ by the same factor. Therefore, it is necessary to use one or more conductivity values obtained from well tests. Based on the available data, two values of the conductivity in the Rustler aquifers were used to

1790 043

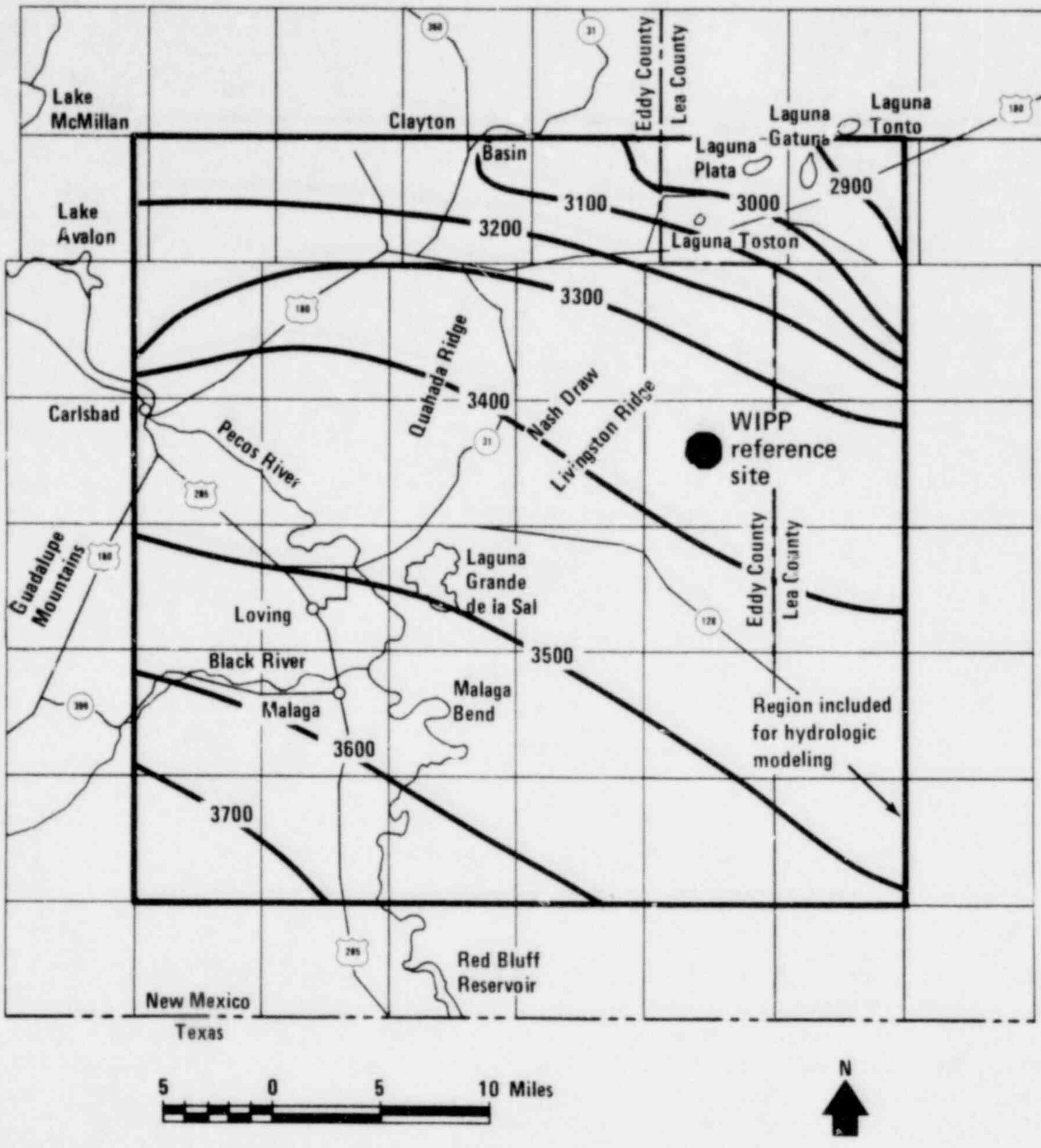


Figure K-6. Calculated hydraulic potentials (feet above MSL) in the Delaware Mountain Group.

describe upper and lower bounds. The lower-bound conductivities are lower by a factor of 20 than the values shown in Figure K-7.

Calculated natural water velocities in the Rustler aquifers ranged from 0.075 to 15 ft/yr, and in the Delaware Mountain Group aquifer the velocities are less than 0.1 ft/yr. A direct travel path to the shallow-dissolution zone for any waste released from the repository would have to be either through salt or along the Salado-Rustler interface; water velocities along these paths are essentially zero at the site. A path to the Capitan aquifer would have to be through the Delaware Mountain Group aquifer. Consequently, the time needed for the waste to travel from the repository to either the shallow-dissolution zone or the Capitan aquifer would be very long and of little concern.

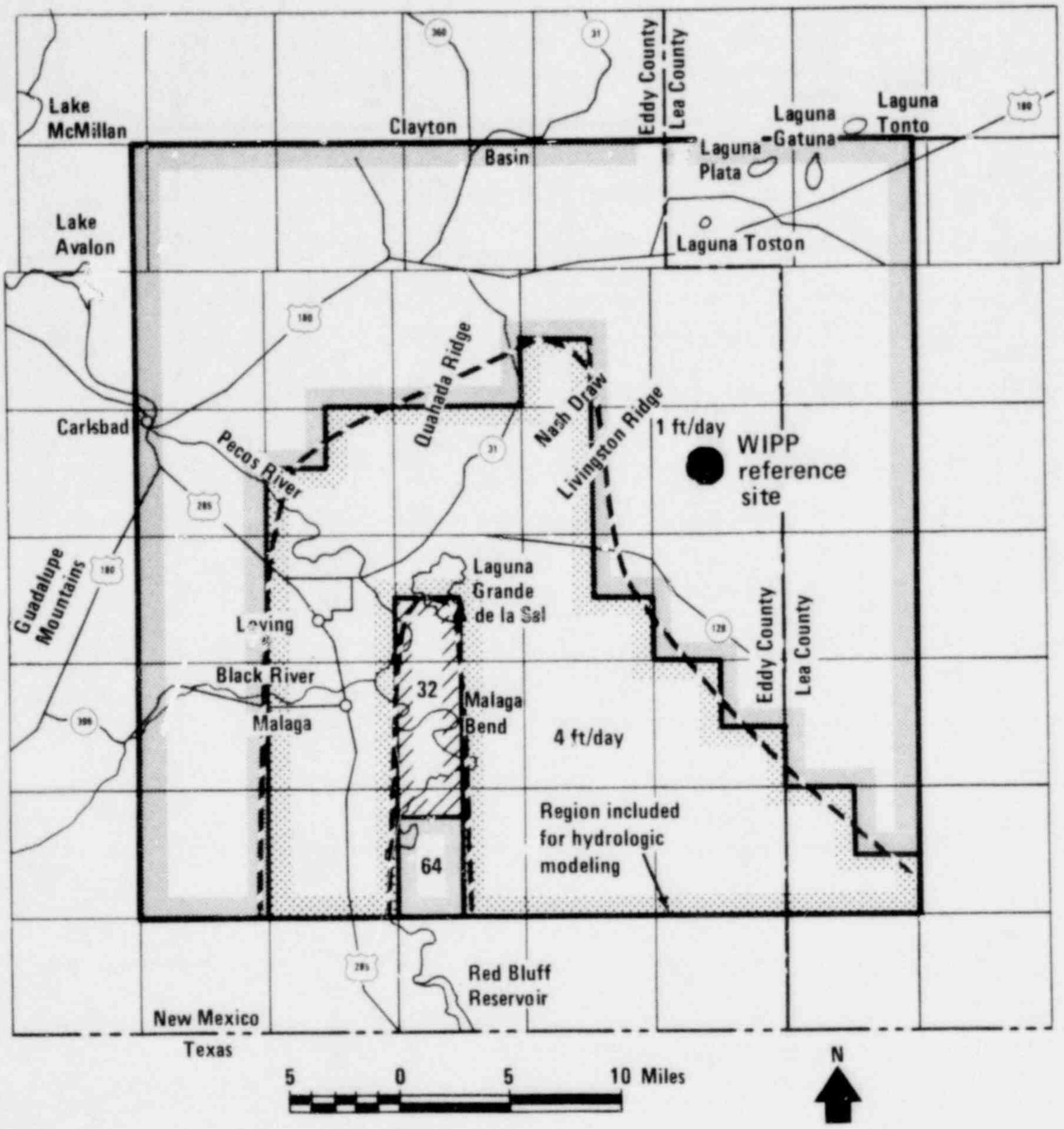


Figure K-7. Hydraulic conductivities in the Rustler aquifers.

Development of a vertical communication would most likely form the shortest geosphere-transport path to the biosphere. Therefore, the hydrologic model to be evaluated depicts the repository in bedded salt bounded by the Rustler aquifers above and the Delaware Mountain Group aquifers below.

The Rustler aquifers are of primary importance in the reference-case safety analysis for two reasons: the travel times to the biosphere are shorter there than in the Delaware Mountain Group, and the greater hydraulic potentials in the Delaware Mountain Group provide a driving force for upward water flow into the Rustler. As mentioned above, a degree of uncertainty is

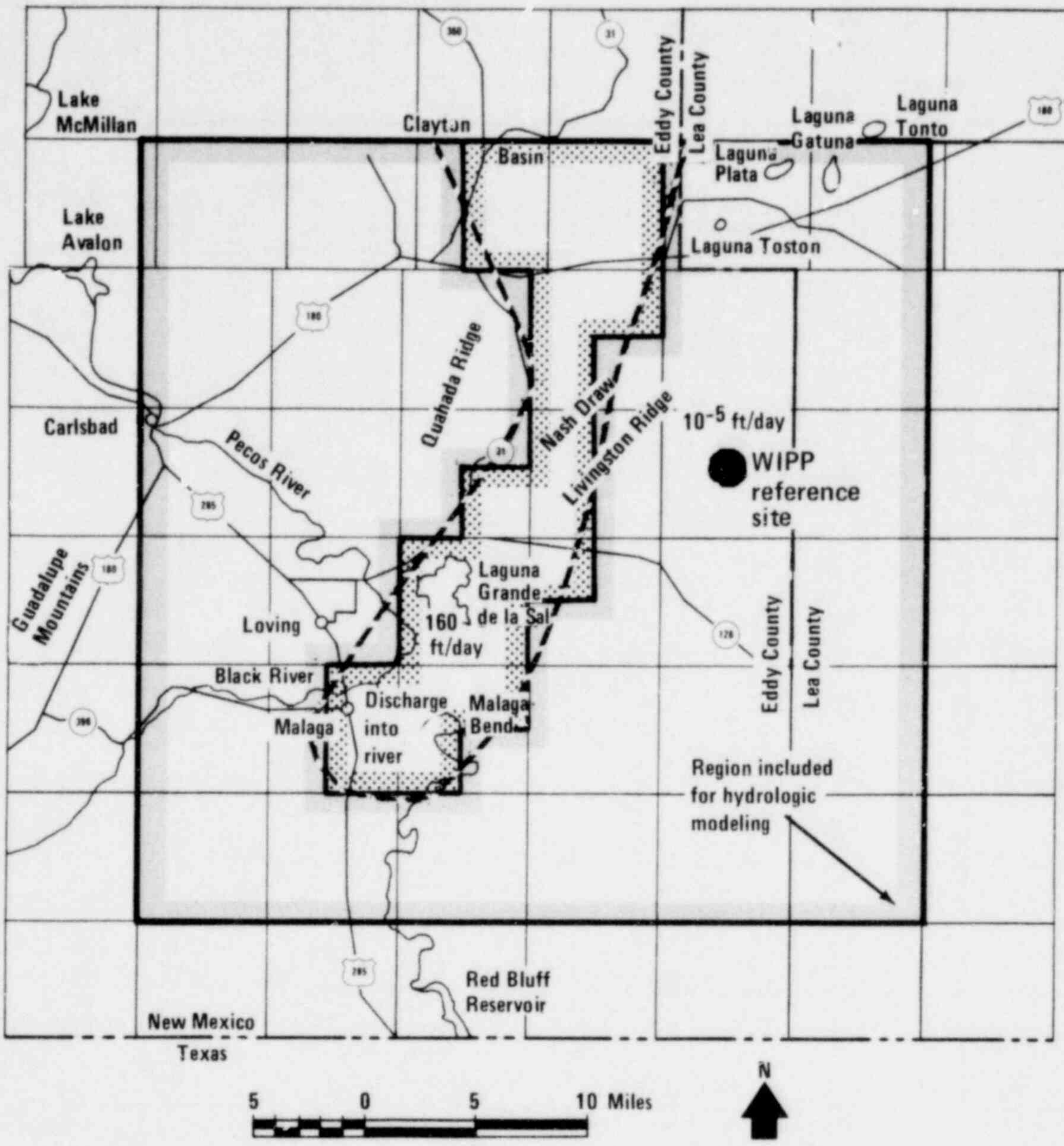


Figure K-8. Hydraulic conductivities in the shallow-dissolution zone.

associated with the hydrologic data for the Rustler. The analysis accounts for this uncertainty in the following ways:

a. Reasonably conservative values were used throughout the analysis.

b. Upper and lower bounds were placed on the combined Culebra-Magenta hydraulic conductivities. Two sets of calculations were performed using the two bounding values.

c. A stochastic analysis was carried out (Tang and Pinder, 1976) to evaluate the possible uncertainty in results due to the uncertainty in input data mentioned above.

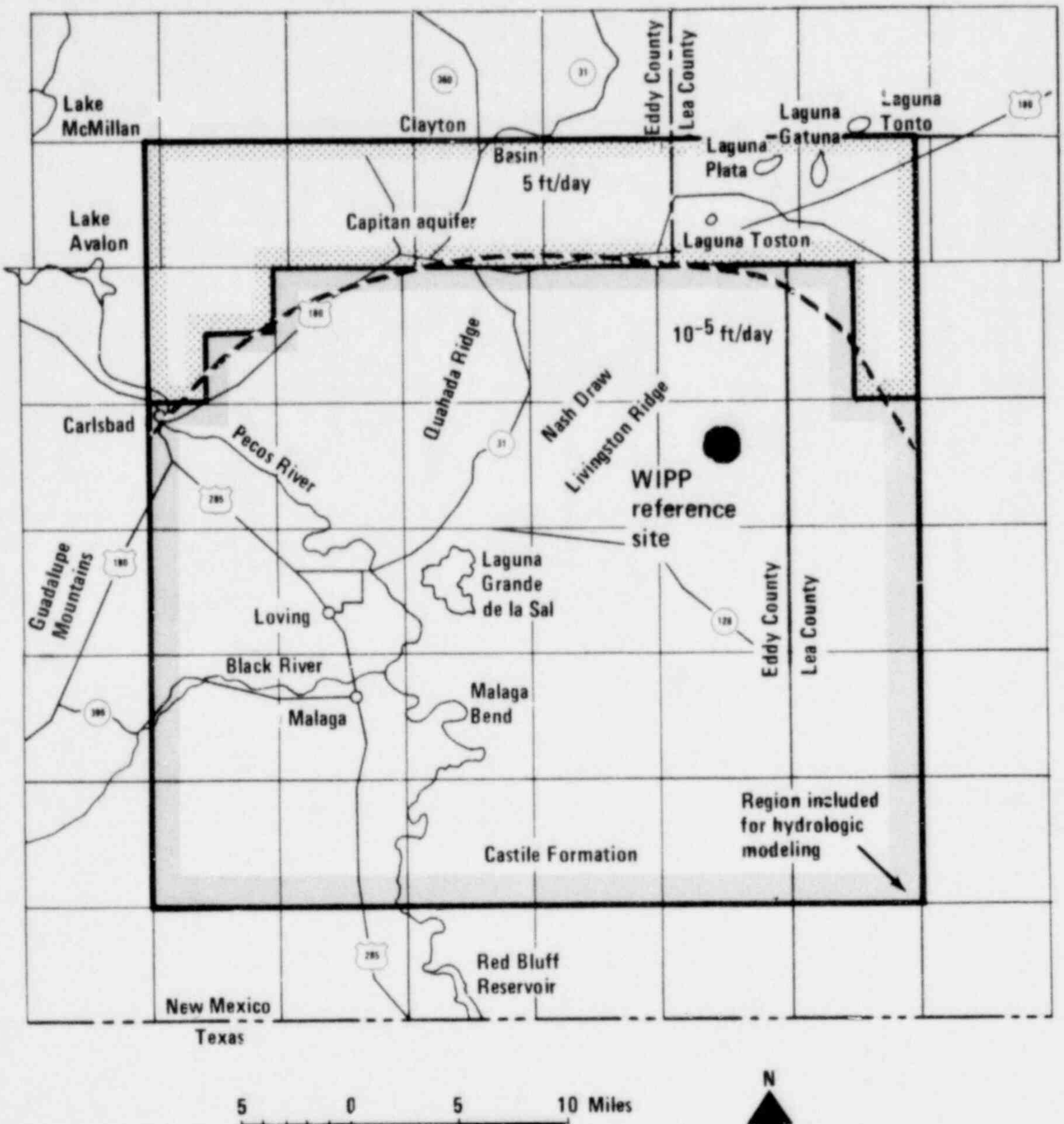


Figure K-9. Hydraulic conductivities in the Capitan aquifer and the Castile Formation.

The total thickness of the upper aquifer was taken to be 40 feet, although the effective hydraulic thickness may actually be much smaller. The larger value of 40 feet was used because the calculated communication flow through the repository is then conservatively calculated on the high side.

A summary of available hydrologic data and the values used in this work are given in Table K-2. As can be seen from the table, the values used are reasonably conservative; that is, they are upper bounds on conductivity and permeability. They are, however, consistent with the measured data.

4790 047

Table K-2. Summary of Hydrologic Data

Property	Formation	Reported value	Reference	Value used in this work
Thickness, ft	Rustler	210	Griswold, 1977	210
	Rustler--Culebra	20	Griswold, 1977	
	Rustler--Magenta	20		40 (total)
	Shallow-dissolution zone	50	Mercer and Orr, 1977	50
	Salado	1600	Griswold, 1977	2000
	Capitan aquifer	1600	Mercer and Orr, 1977	
	Salado	1000-1500	Griswold, 1977	1000
	Delaware Mountain Group	3000	Mercer and Orr, 1977	3000
Hydraulic transmissivity, ft^2/day	Rustler	0 to 500	Griswold, 1977	Not used
	Rustler--Culebra	10^{-4} to 140	Mercer and Orr, 1978	2 to 1280 (total)
	Rustler--Magenta	1 to 40	Mercer and Orr, 1978	
	Shallow-dissolution zone	8000	Mercer and Orr, 1977	8000
	Delaware Mountain Group	50	Mercer and Orr, 1977	1 to 200
Hydraulic conductivity, ft/day	Capitan aquifer	1 to 25, average 5	Mercer and Orr, 1977	
	Salado, Castile, and Rustler anhydrite	4×10^{-6} to 2×10^{-5}	Lambert and Mercer, 1977	10^{-5}
Porosity	Rustler	0.1	Mercer and Orr, 1977	0.1
	Shallow-dissolution zone			0.2
	Capitan aquifer			0.15
	Delaware Mountain Group	0.1565	Mercer and Orr, 1977	0.16
	Salado, Castile, and Rustler anhydrite			0.005

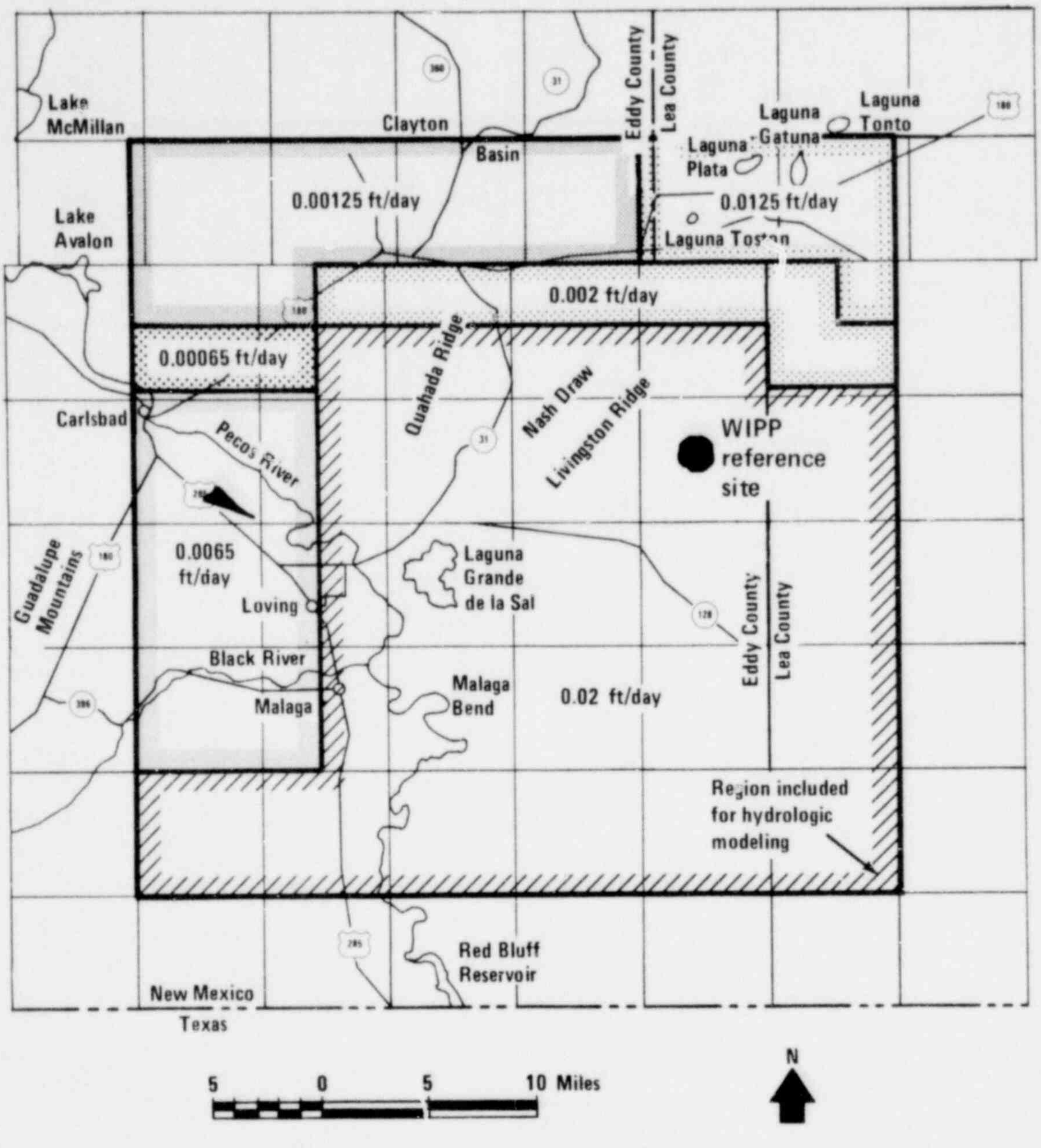


Figure K-10. Hydraulic conductivities in the Delaware Mountain Group.

Geochemical data required for complete modeling would consist of water quality, the adsorption-distribution coefficient for each radionuclide, nuclide solubilities in the Rustler water, and waste leach rates. For a real repository the rates at which radionuclides could enter the water would be limited by the solubility of the waste and by the rate at which the nuclides could be leached from the waste. This analysis took no advantage of these reductions; the waste-dissolution rate was assumed to be the same as the rate of dissolution of the salt formation. A number of adsorption-distribution coefficients have been measured at Sandia Laboratories (Dosch and Lynch, 1978) for the reference-site rock material. Site-specific adsorption data were, however, not available for some radionuclides included in the modeling here. The adsorption-distribution coefficients for these nuclides were estimated

Table K-3. Summary of Geochemical Data

Formation	Water quality		
	Reported value (mg/l)	Reference	Value used in this work
Rustler	3,350-35,600 TDS[a]	Lambert, 1978	Not used
Rustler--Culebra	23,720-118,290 TDS 17,900-89,200 NaCl	Mercer and Orr, 1978	8,000 TDS
Rustler--Magenta	10,350-20,680 TDS 6,800-24,300 NaCl	Mercer and Orr, 1978	
Delaware Mountain Group	296,400 TDS	Lambert, 1978	230,000 TDS

Adsorption-Distribution Coefficients in the Rustler Aquifer[b]

Element	Distribution coefficient (ml/g)
Neptunium	700
Uranium	1
Thorium	2200
Plutonium	2100
Cesium	15
Iodine	0
Technetium	0
Radium	25
Strontium	0

[a]TDS = total dissolved solids.
[b]See text for the sources of the distribution coefficients.

from the ratios of distribution coefficients for similar elements, measured at Sandia Laboratories in reference-site rock and at Battelle (Rai and Mason, 1977) in desert soil. A summary of the adsorption-distribution coefficients and the water-quality data used is given in Table K-3.

K.2.2 Scenario Modeling

Scenario modeling includes hydrologic modeling of the movement of water, salt, and waste through a connection developed between the repository and one or more aquifers. A separate modeling process is necessary for each of the scenarios for liquid breach and transport selected for analysis in this study (Section 9.5.1.2).

There are three basic mechanisms that can release waste into an aquifer:

a. Forced convection-fluid flow due to pressure or potential gradient.

b. Natural convection-fluid flow due to density gradient.
c. Molecular diffusion-transport due to concentration gradient.

Each of the four scenarios selected for analysis postulates a hydraulic connection and one of these three driving mechanisms. Because the driving mechanism largely determines the properties of the connection, detailed modeling of this small group of scenarios predicts the consequences of many scenarios. Of the four scenarios, three specify forced convection and one specifies molecular diffusion. None specifies natural convection, which is expected to produce much weaker effects than forced convection.

The transport calculations performed in this study generally assume that the events in the scenarios begin 1000 years after the repository is sealed. The calculations are carried out for all actinides present in the waste and for the fission-product nuclides I-129, Tc-99, and Cs-135; shorter-lived fission products are present only in negligible amounts 1000 years after waste emplacement. Since nearly all the nuclides remaining after 1000 years are long-lived isotopes, the nuclide inventory changes slowly during the events described by the scenarios.

Although there would be a diminished radionuclide inventory in scenarios that begin later than 1000 years after burial, the consequences would be much the same as those predicted for scenarios beginning at 1000 years; the consequences would simply be displaced to a later time. Hence, in this consequence analysis the 1000-year-event calculations are conservative predictions of events occurring after many thousands of years.

Calculations for a 100-year bounding-condition event were carried out for the fission-product nuclides Sr-90 and Cs-137. The results, which are presented in Section 9.5.1.4, reveal why it is not important to model events at early times: the travel times to the biosphere are so long that only the long-lived nuclides are still active when the contaminated aquifer water is discharged. The consequences of a scenario are not affected significantly if it begins 900 years later.

In the scenario modeling, all fluid coming out of the repository into an aquifer is assumed to be saturated brine with 410,000 ppm by weight of total dissolved solids. Fluid enters the repository at the total-dissolved-solids concentration listed in Table K-3. The salt formation and the canisters are assumed to dissolve uniformly, bringing the total-dissolved-solids concentration to the saturated-brine concentration. The combined specific gravity of the formation, including waste, is assumed to be 2.

Potentials, waste-dissolution rates, and fluid-flow rates were based on hydrologic steady states. This assumption is reasonable because the time required to reach steady state is small relative to total waste-dissolution times.

The repository depths were assumed to be 2100 and 2700 feet. The spent-fuel canisters were assumed to be 11.25 feet apart in one horizontal direction and 75 feet apart in the other direction. The total thickness of the lower repository level was taken to be 42 feet; a total of 1000 spent-fuel assemblies were assumed to be emplaced in this 20-acre (930 by 930 feet) repository. For a canister with a 14-inch diameter and a length of 16 feet, the ratio of canister volume to repository volume is 4.7×10^{-4}.

For modeling convenience, the contact-handled TRU waste was assumed to be distributed uniformly over the entire upper repository level, a volume with dimensions of 9000 by 12,000 by 16.5 feet. Since the WIPP reference repository will devote about 100 acres to CH TRU waste initially and about 2000 acres at full development, the 2500 acres assumed for the model repository overestimates the amount of waste present. Thirty percent of the volume of the contact-handled TRU-waste repository was assumed to be waste, the remaining portion being salt; this fraction is the extraction ratio planned for mining at the WIPP reference repository.

K.3 DIRECT-ACCESS SCENARIO

The direct-acess scenario for the WIPP reference repository arises from the assumption that at some distant future time people are motivated to drill in the unguarded and unmarked site. It is assumed that the drill hole penetrates a waste storage canister. The radionuclides from the canister are assumed to be mixed uniformly with the drilling mud. The contaminated mud is brought to the surface and directed to a mud pit, where it is left to dry uncovered and undisturbed. Thereafter wind erodes the surface, transporting contaminants downwind.

Drilling mud is pure clay (usually bentonite) with additives to adjust its density and pH. The surface of the mud pit is likely to dry to a crusted bricklike consistency, which would not present much opportunity for wind erosion. However, it is assumed that sand particles from the surrounding plain will cause resuspension of the material from the mud pit surface to the same degree as from the rest of the plain.

K.3.1 Radionuclide Concentration and Transport in Air

Provided the area of the mud pit is small (<100 square meters), the suspended material transported to distances greater than, say, 100 meters from the pit may be assumed to come from a point source. The Reactor Safety Study uses a squared Gaussian plume model for air concentration downwind (NRC, 1975, Appendix VI, p. 4-1, and Appendix A). Its expression is

$$\chi = \frac{2Q}{3\sigma_y \sqrt{2\pi}\ \sigma_z u}$$

where

χ = the ground-level air concentration (Ci/m^3)

Q = the source strength (Ci/sec)

$3\sigma_y$ = the lateral width of the assumed uniform distribution (m)

σ_z = the vertical standard deviation (m)

u = the average wind speed (m/sec)

The quantity Q may be expressed as the upward flux of suspended particles multiplied by the area of the source (Healy, 1977). The resuspension rate, in reciprocal units of sec^{-1}, multiplied by the surface concentration gives the value of the upward flux. The resuspension rate measured from desert soil at the Nevada Test Site is 10^{-13} sec^{-1} and varies as the cube of the wind speed (Healy, 1977). Thus the transport of suspended material is described by the equation

$$\chi_1 = \frac{2\rho\, d_0\, AK\, \Omega_i \times 10^4}{\sqrt{2\pi}\, 3\sigma_y\, \sigma_z u}$$

where

Ω_i = concentration of isotope i in the drilling mud (Ci/g)

ρ = density of the drilling mud (assumed to be 2 g/cm^3)

d_0 = depth from which material is available for resuspension (assumed to be 1 cm)

K = the resuspension rate = 10^{-13} $(u/u_0)^3$; sec^{-1} (u_0 is assumed to be 1 m/sec)

A = area of the mud pit (m^2)

10^4 = conversion factor from square meters to square centimeters

The expressions for σ_y and σ_z for slightly unstable to neutral conditions typical of the desert southwest (Pasquill stability category C) are

$$\sigma_y = 0.11d\ (1 + 10^{-4}d)^{-1/2}$$

$$\sigma_z = 0.08d\ (1 + 2 \times 10^{-4}d)^{-1/2}$$

The mud-pit areas assumed are 720 square feet (66.9 square meters) for the 10-inch drill hole and 144 square feet (13.4 square miles) for the 3-inch drill hole. To allow for the finite size of these pits, a virtual point source is created upwind of the pond such that $3\sigma_y = A^{1/2}$ at the leeward site. Thus for the 10- and 3-inch drill holes the virtual point source is taken to be 24.8 and 11.1 meters, respectively, upwind of the leeward side. All downwind transport distances given below are measured from the middle of the pond.

	χ_i (Ci/m^3)	
d' (m)	10-inch drill hole	3-inch drill hole
100	$3.58 \times 10^{-9}\ \Omega_i$	$8.73 \times 10^{-10}\ \Omega_i$
500	$2.04 \times 10^{-10}\ \Omega_i$	$4.25 \times 10^{-11}\ \Omega_i$
1000	$5.67 \times 10^{-11}\ \Omega_i$	$1.16 \times 10^{-11}\ \Omega_i$

1790 053

The particle-size distribution of the suspended material can be related to the particle-size distribution of the surface source. Healy (1977) indicates that for days the aerodynamic mean activity diameter (AMAD) of these particles is 1 μm or less. Thus 1 μm is taken to be the nominal value for the suspended and transported material.

K.3.2 Dry Deposition

It is assumed that the dry-deposition flux is product of the deposition velocity and the air concentration near the ground (Ci/m^2-sec = $V_d \times \chi$). The deposition velocity V_d is taken to be 0.01 m/sec.

K.3.3 Uncertainties in the Calculation

Air concentrations and surface depositions previously described as applying to the direct-access scenario have been obtained using generally conservative assumptions and parameters. However, it is worthwhile to understand how uncertainties in these assumptions and parameters may affect the results.

Radioisotope distribution in the drilling mud. Assuming uniform distribution of radioisotopes in the drilling mud, their concentration and hence the resulting dose will vary inversely with total mass of the mud. However, to the extent that the heavy elements settle to the bottom of the pond, they will not be resuspended in significant quantities even if the mass of mud is greatly reduced.

Resuspension factor. The dried drilling mud (clay) is most likely to have a bricklike consistency that, if left in an undisturbed state, is not liable to produce as much suspendable material as the surface at the Nevada Test Site, where small and large particles are more intimately but more loosely mixed. This tendency is likely to persist even if the surface is mechanically disturbed after drying, provided the mud thickness is on the order of feet.

Atmospheric stability. Values cited above are for slightly unstable atmospheric conditions. Under very stable conditions, air concentrations downwind of the source would increase by more than a factor of 10. In the case of very unstable conditions they would decrease by about a factor of 5. However, the exposures being estimated are long-term exposures, and for this purpose median stability conditions are in order.

Wind direction. In directions other than the usual downwind direction, concentrations and hence exposures will be smaller than those estimated.

Particle deposition. The assumption used in the transport and deposition calculation above holds that the dust cloud is not depleted by surface deposition as it travels downwind. In fact, material is continuously lost from the cloud; thus all downwind concentrations are overestimated, roughly by a factor of 2.

REFERENCES

Griswold, G. B., 1977. Site Selection and Evaluation Studies of the Waste Isolation Pilot Plant (WIPP), Los Medanos, Eddy County, New Mexico, SAND77-0946, Sandia Laboratories, Albuquerque, N.M.

Healy, J. W., 1977. An Examination of the Pathways from Soil to Man for Plutonium, LA-6741-MS, Los Alamos Scientific Laboratory, Los Alamos, N.M.

Lambert, S. J., 1978. "The Geochemistry of Delaware Basin Groundwaters," in Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas, New Mexico Bureau of Mines and Mineral Resources, Circular 159, pp. 33-38.

Lambert, S. J., and J. W. Mercer, 1977. Hydrologic Investigations of the Los Medanos Area, Southeastern New Mexico, SAND77-1401, Sandia Laboratories, Albuquerque, N.M.

Mercer, J. W., and B. R. Orr, 1977. Review and Analysis of Hydrogeologic Conditions Near the Site of a Potential Nuclear-Waste Repository, Eddy and Lea Counties, New Mexico, U.S. Geological Survey Open File Report 77-123.

Mercer, J. W., and B. R. Orr, 1978. Geohydrology of the Proposed Waste Isolation Pilot Plant, Southeast New Mexico, U.S. Geological Survey, under contract to Sandia Laboratories, Albuquerque, N.M.

NRC (U.S. Nuclear Regulatory Commission), 1975. Reactor Safety Study--An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400, Washington, D.C.

Rai, D., and M. J. Mason, 1977. K_d Measurements of Nuclides to Estimate Migration Potential at the Proposed Waste Isolation Pilot Plant in New Mexico, PNL-2448, Battelle Pacific Northwest Laboratories, Richland, Wash.

Tang, D. H., and G. F. Pinder, 1976. Simulation of Groundwater Flow and Mass Transport Under Uncertainty, Water Resources Program, Department of Civil Engineering, Princeton University, Princeton, N.J.

1790 055

Appendix L

AN OUTLINE OF THE INPUT-OUTPUT MODEL AND THE IMPACT PROJECTIONS METHODOLOGY

1790 056

CONTENTS

1790 057

LIST OF TABLES

1790 059

Appendix L

AN OUTLINE OF THE INPUT-OUTPUT MODEL AND THE IMPACT PROJECTIONS METHODOLOGY

L.1 INPUT-OUTPUT MODEL

A static model in the form of a regional input-output model was constructed for Eddy and Lea Counties, New Mexico. The original derivation of the input-output model is described in the Proceedings of the 1975 Conference of the Association of University Business and Economic Research. That paper is attached to this appendix as an annex. The procedure described in that document was followed in general detail.

Since the publication of that document, information on the agricultural sector in New Mexico has been improved, and the credibility of the agricultural information is believed to be such that the variation experienced in the original model has been decreased. Regardless of the extent of the accuracy of the agricultural information, the effect of the construction and operation of the WIPP on the agricultural sector is believed to be less than 1% in terms of employment and income. Therefore, the accuracy of the agricultural sector in terms of indirect consequences is negligible in the overall modeling process.

This model has been used to assess the economic impacts of the following activities for the following agencies: San Juan generating units 1, 3, and 4 for the Public Service Company of New Mexico; Social and Economic Assessment Study, Gallup-Navajo Indian Water Supply Project for the Bureau of Reclamation; analysis of multipliers for a proposed nuclear power plant at Cementon, New York, for Harbridge House, Inc., an agency of the Power Authority of the State of New York; analysis of two sites for nuclear or fossil fuel electric generating units for Harbridge House, Inc., an agent of the New York State Electric & Gas Corporation; analysis of four coal development scenarios in northwest New Mexico for Harbridge House, Inc., an agent of the Bureau of Land Management; socioeconomic analysis of the proposed New Mexico generating station for the Public Service Company of New Mexico; and general economic impacts (an ongoing process) for the Bureau of Business and Economic Research, University of New Mexico.

During or about the same time this study was being conducted, the model was used for analysis of the economic impacts of a proposed coal-fired generating unit for Burns and McDonnell, an agent of Plains Electric Cooperative and an analysis of industrial linkages in Cecil County, Maryland, for Harbridge House, Inc., an agent of the Cecil County Development Agency. Thus, the model has been used extensively and is accepted as a tool to determine the economic impact of proposed new facilities and developments.

L.1.1 Base Model

The regional model adjusts a national model by means of location quotients and aggregating techniques. The national model, or base model, used in this process contains 407 economic categories or subsectors of the economy, 389 of which represent the private economy and 18 of which represent activities dealing primarily with the public sector. The 389 private subsectors were used in the model; the government impact was computed after the private sector analysis was completed.

The national base model is an updated version of the 1967 National Input-Output Model constructed by the Department of Commerce, Bureau of Economic Analysis. Two important changes in the 1967 version have been made. First, the mining sectors have been expanded to 44 subsectors in the latest version. Second, the Lawrence Berkeley Laboratory has mathematically updated the 1967 version to a 1972 version using a process called RAS. In simple terms, the RAS process updates the technical coefficients using 1972 data collected through the Bureau of the Census in the 1972 Census of Business.

As previously noted, discussion of the detailed modeling process and technical procedures can be found in the annex to this appendix. However, several important aspects of this particular model for Eddy and Lea Counties should be noted. First, detailed information on employment, by category, was determined from information supplied by the Employment Security Commission of New Mexico (now renamed the Employment Security Division). Using this information, detailed location quotients for manufacturing were determined at the four-digit "SIC" Code level, and this added credibility and accuracy to the modeling process.

Second, because of the makeup of retail and wholesale subsectors within Eddy and Lea Counties, a detailed analysis of the types of outlets located within the area was conducted. Basic information from the 1972 Census of Business was used with updated information from the employment files for this analysis.

Finally, once the location quotients had been determined, 1972 Census data and various other State and local data sources were used to identify output per employee for those subsectors with location quotients computed through employment statistics. A total output figure was derived for these subsectors. In turn, the total ouput figures were used to aggregate the 389 subsectors in the base model into 37 private business subsectors for the regional model.

Subsectors for WIPP aboveground construction (1981, 1982, 1983, and 1984), WIPP nonconstruction employment, WIPP belowground construction (1981, 1982, 1983, and 1984), WIPP operation--above ground, WIPP operation--storage, and WIPP operation--below ground were derived from data supplied by Sandia Laboratories; Bechtel, Incorporated; and Westinghouse Electric Corporation. Thus, there are a total of 49 private subsectors in the model for Eddy and Lea Counties and two additional subsectors to account for labor compensation.

L.1.2 Household Compensation for Labor and Personal Consumption in the Area

The figures for labor percentages, or coefficients, were determined through material produced in the 1967 National Input-Output Model. These figures represent the average percentage of cost going to labor from the technical production process (direct coefficients). Personal consumption figures were adjusted by weighting the location quotients of each of the 37 identified private business subsectors in the regional model. An additional personal consumption column adjusted for reduced local purchases was incorporated in the model to allow for lower local consumption by construction workers that commute on a weekly basis. The labor coefficients for the 12 WIPP subsectors were derived from data supplied by Sandia, Bechtel, and Westinghouse. The allocation of the labor coefficients of the four WIPP aboveground construction subsectors and the four WIPP belowground construction subsectors between construction workers that commute and those that reside in the two-county area was made using the comparable factors from the Construction Worker Profile.

The final results of the determination of the location quotients and the aggregation process can be found on Table L-1, which lists the direct coefficients. The results of the matrix inversion, or the aggregated direct, indirect, and induced effects of the modeling effort follow in Table L-2.

L.2 OUTPUT MULTIPLIER

The volume of activity generated in the private sector due to a $1 exogenous increase in a subsector can be determined through the input-output process. For example, considering WIPP aboveground construction (1983), subsector 40, we find the column sum of 1.92026 in Table L-2. By subtracting from 1.92026 the amount of money flowing both directly and indirectly through weekly commuter and local households (0.52312), the residual is 1.39714, or approximately $1.40 in total activity due to $1 exogenous increase in WIPP aboveground construction (1983) activity. Thus, an additional $0.40 of indirect activity will be generated in Eddy and Lea Counties.

It should be noted at this point that the output multiplier is not of primary concern in determining overall impact of new developments within the area. The employment and income multipliers are believed to be of greater importance. And these multipliers may vary significantly from the 1.40 multiplicative multiplier noted for dollar output change due to an increase in activity in the aboveground construction (1983) subsector of the two-county economy.

L.3 EMPLOYMENT MULTIPLIERS

In order to determine the employment multipliers for the WIPP related development, three basic steps (procedures) must be undertaken. First, wage information for the area or region under consideration must be determined in constant dollars--in this case 1977 dollars. Second, the change in total output on an annual basis for an exemplary year using constant 1977 dollars must be determined. Finally, computations to determine the actual number of dollars from the technical process going for labor costs must be derived.

Once having determined by subsector the number of dollars for labor costs flowing on an annual basis, the average labor unit cost is divided into each gross amount to determine the actual number of jobs supported in that specific subsector due to an exogenous increase in the specific activity being investigated, e.g., WIPP aboveground construction, belowground construction, aboveground operation.

Table L-1

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING 1	2	3	4	5	6	7	8	
	LIVESTK & LIVESTK PROD	1	0.30891	0.02889	0.09777	0.01457	0.14889	0.00151	0.00000	0.00000	1
	COTTON	2	0.00000	0.01636	0.00000	0.00000	0.00000	0.00095	0.00000	0.00000	2
	GRAINS AND SEEDS	3	0.26662	0.00000	0.02988	0.00000	0.00000	0.00772	0.00000	0.00000	3
	FRUITS AND VEGETABLES	4	0.00049	0.00000	0.00000	0.00378	0.00000	0.00090	0.00000	0.00000	4
	FORESTRY&FISHERY PRODS	5	0.00000	0.00000	0.00000	0.00000	0.07198	0.00000	0.00000	0.00000	5
	AGRICULTURAL SERVICES	6	0.00263	0.10165	0.01289	0.05881	0.02604	0.00000	0.00000	0.00000	6
	MISC MET & NON-MET MIN	7	0.00000	0.00009	0.00020	0.00008	0.00000	0.00000	0.00836	0.00000	7
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00250	8
	NATURAL GAS & LIQ. PET	9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
	STONE, GRAVEL AND SAND	10	0.00001	0.00137	0.00184	0.00094	0.00000	0.00000	0.00000	0.00000	10
	POTASH MINING	11	0.00000	0.00071	0.00120	0.00056	0.00000	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00387	0.01065	0.00935	0.00702	0.00000	0.00000	0.00222	0.02719	15
I	FOOD PRODUCTS	16	0.02322	0.00000	0.00000	0.00000	0.01580	0.00003	0.00000	0.00000	16
N	FABRICS AND APPAREL	17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	17
D	PAPER PRODUCTS	18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
U	PRINTING	19	0.00001	0.00003	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000	19
S	CHEMICAL PRODUCTS	20	0.00079	0.00507	0.00659	0.00247	0.00056	0.00000	0.02144	0.00319	20
T	PLASTIC & PETROLEUM	21	0.00328	0.03672	0.03285	0.01250	0.03032	0.00012	0.00205	0.00426	21
R	GLASS AND STONE PRODS.	22	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00008	24
	MACHINERY	25	0.00008	0.00024	0.00011	0.00010	0.00000	0.00000	0.01063	0.00008	25
	ELECTRICAL PRODS.	26	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	26
S	TRNSPRTTN & WRHSING	27	0.01356	0.01047	0.01312	0.00869	0.00522	0.00065	0.00984	0.00139	27
E	COMMUNICATIONS	28	0.00146	0.00296	0.00184	0.00133	0.00000	0.00000	0.00282	0.00078	28
L	ELECTRICAL UTILITY	29	0.00186	0.00738	0.00161	0.00281	0.00021	0.00003	0.01118	0.01071	29
L	GAS UTILITY	30	0.00002	0.00000	0.00000	0.00000	0.00028	0.00003	0.00239	0.00159	30
I	WATER AND SEWER	31	0.00018	0.00832	0.00720	0.00770	0.00000	0.00000	0.00000	0.00050	31
N	WHOLESALE TRADE	32	0.01542	0.03706	0.02949	0.02561	0.02824	0.00047	0.00958	0.00409	32
G	RETAIL TRADE	33	0.01004	0.02745	0.02302	0.01103	0.00893	0.00023	0.00119	0.00382	33
	F. I. & R.E	34	0.00868	0.07375	0.04181	0.02078	0.01685	0.00107	0.00815	0.09158	34
	PERSONAL & REPAIR SER.	35	0.00330	0.00862	0.00442	0.00377	0.00575	0.00002	0.00051	0.00216	35
	BUSINESS & MISC. SERV.	36	0.00139	0.02915	0.02602	0.01550	0.00005	0.00000	0.00816	0.01375	36
	MEDICAL & NON-PROFIT	37	0.00051	0.00056	0.00035	0.00040	0.00000	0.00000	0.00121	0.00028	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.03952	0.07601	0.07601	0.07601	0.05769	0.26895	0.18067	0.05865	51
	*** COLUMN SUMS ***		0.70585	0.48350	0.41757	0.27448	0.41684	0.28268	0.28040	0.22660	

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING								
			9	10	11	12	13	14	15	16	
	LIVESTK & LIVESTK PROD	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07349	1
	COTTON	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.10494	2
	GRAINS AND SEEDS	3	0.00000	0.00000	0.00000	0.00031	0.00013	0.00018	0.00000	0.02323	3
	FRUITS AND VEGETABLES	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00155	4
	FORESTRY&FISHERY PRODS	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5
	AGRICULTURAL SERVICES	6	0.00000	0.00000	0.00000	0.00139	0.00077	0.00285	0.00047	0.00000	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005	7
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	8
	NATURAL GAS & LIQ. PET	9	0.14584	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
	STONE, GRAVEL AND SAND	10	0.00000	0.00446	0.00000	0.00201	0.00271	0.02103	0.00657	0.00012	10
	POTASH MINING	11	0.00000	0.00048	0.01395	0.00000	0.00000	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.03218	0.00796	0.00205	0.00025	0.00036	0.00034	0.00015	0.00244	15
I	FOOD PRODUCTS	16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02480	16
N	FABRICS AND APPAREL	17	0.00000	0.00000	0.00000	0.00098	0.00003	0.00061	0.00010	0.00019	17
D	PAPER PRODUCTS	18	0.00000	0.00000	0.00000	0.03789	0.01187	0.00210	0.00382	0.00000	18
U	PRINTING	19	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00111	19
S	CHEMICAL PRODUCTS	20	0.00803	0.00646	0.01969	0.00049	0.00191	0.00263	0.00332	0.00106	20
T	PLASTIC & PETROLEUM	21	0.00441	0.01289	0.00574	0.00601	0.00944	0.02759	0.00749	0.00317	21
R	GLASS AND STONE PRODS.	22	0.00000	0.05511	0.00000	0.02664	0.03524	0.02147	0.00287	0.00000	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00003	0.00000	0.00000	0.00196	0.00309	0.00187	0.00047	0.00000	24
	MACHINERY	25	0.00011	0.00509	0.01535	0.00038	0.00058	0.00051	0.00024	0.00000	25
	ELECTRICAL PRODS.	26	0.00000	0.00000	0.00000	0.00020	0.00029	0.00023	0.00307	0.00000	26
S	TRNSPRTTN & WRHSING	27	0.00167	0.01329	0.00977	0.02637	0.02787	0.04716	0.02166	0.02313	27
E	COMMUNICATIONS	28	0.00093	0.00020	0.00259	0.00316	0.00471	0.00431	0.00211	0.00465	28
L	ELECTRICAL UTILITY	29	0.00574	0.02649	0.02001	0.00055	0.00084	0.00077	0.00037	0.00500	29
L	GAS UTILITY	30	0.01419	0.00291	0.02469	0.00012	0.00017	0.00015	0.00007	0.00197	30
I	WATER AND SEWER	31	0.00105	0.00281	0.00000	0.00029	0.00044	0.00036	0.00017	0.00040	31
N	WHOLESALE TRADE	32	0.00923	0.03455	0.00250	0.05106	0.04953	0.04327	0.03911	0.02976	32
G	RETAIL TRADE	33	0.00448	0.01193	0.00138	0.08578	0.04874	0.03914	0.06360	0.00185	33
	F. I. & R.E	34	0.10845	0.03037	0.00694	0.00697	0.01026	0.00946	0.00484	0.00709	34
	PERSONAL & REPAIR SER.	35	0.00255	0.01085	0.00064	0.00488	0.00730	0.00801	0.00354	0.00341	35
	BUSINESS & MISC. SERV.	36	0.01627	0.03144	0.00860	0.05413	0.07157	0.04270	0.01963	0.00810	36
	MEDICAL & NON-PROFIT	37	0.00033	0.00009	0.00119	0.00078	0.00115	0.00106	0.00352	0.00060	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.05865	0.31124	0.18067	0.31413	0.31413	0.31413	0.50288	0.14922	51
	*** COLUMN SUMS ***		0.41413	0.56863	0.31575	0.62673	0.60312	0.59192	0.68109	0.47239	

1790 064

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978

DIRECT COEFFICIENTS

			INDUSTRY PURCHASING							
			17	18	19	20	21	22	23	24
	LIVESTK & LIVESTK PROD	1	0.00568	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
	COTTON	2	0.03292	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
	GRAINS AND SEEDS	3	0.00000	0.00000	0.00000	0.00006	0.00000	0.00000	0.00000	0.00000	3
	FRUITS AND VEGETABLES	4	0.00000	0.00000	0.00000	0.00114	0.00000	0.00000	0.00000	0.00000	4
	FORESTRY&FISHERY PRODS	5	0.01529	0.00000	0.00000	0.00374	0.00000	0.00000	0.00000	0.00000	5
	AGRICULTURAL SERVICES	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	0.00124	0.00004	0.00000	0.00000	0.00000	7
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00000	0.00000	0.45740	0.00000	0.00000	0.00000	8
	NATURAL GAS & LIQ. PET	9	0.00000	0.00000	0.00000	0.00231	0.02337	0.00000	0.00000	0.00000	9
	STONE, GRAVEL AND SAND	10	0.00000	0.00000	0.00000	0.00038	0.00000	0.06606	0.00000	0.00008	10
	POTASH MINING	11	0.00000	0.00000	0.00000	0.00755	0.00000	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00131	0.00294	0.00311	0.00431	0.01019	0.00289	0.00000	0.00224	15
I	FOOD PRODUCTS	16	0.00001	0.00000	0.00000	0.00088	0.00000	0.00000	0.00000	0.00000	16
N	FABRICS AND APPAREL	17	0.10091	0.00080	0.00143	0.00021	0.00007	0.00047	0.00000	0.00075	17
D	PAPER PRODUCTS	18	0.00000	0.00791	0.00000	0.00000	0.00000	0.00000	0.00000	0.00065	18
U	PRINTING	19	0.00001	0.00004	0.01586	0.00004	0.00000	0.00008	0.00000	0.00000	19
S	CHEMICAL PRODUCTS	20	0.00080	0.00274	0.01263	0.05002	0.00578	0.00123	0.00000	0.00071	20
T	PLASTIC & PETROLEUM	21	0.00093	0.00272	0.00236	0.05459	0.05487	0.00919	0.00000	0.00410	21
R	GLASS AND STONE PRODS.	22	0.00000	0.00034	0.00000	0.00000	0.00001	0.02440	0.00000	0.00018	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00000	0.00000	0.00000	0.00005	0.00001	0.00000	0.00000	0.00141	24
	MACHINERY	25	0.00000	0.00191	0.00030	0.00002	0.00001	0.00308	0.00000	0.02363	25
	ELECTRICAL PRODS.	26	0.00000	0.00001	0.00002	0.00002	0.00000	0.00000	0.00000	0.00001	26
S	TRNSPRTTN & WRHSING	27	0.00945	0.02748	0.01179	0.02047	0.02876	0.12118	0.00000	0.01518	27
E	COMMUNICATIONS	28	0.00319	0.00406	0.01098	0.00326	0.00067	0.00573	0.00000	0.00490	28
L	ELECTRICAL UTILITY	29	0.00687	0.00674	0.00499	0.01371	0.00569	0.00645	0.00000	0.00639	29
L	GAS UTILITY	30	0.00048	0.00134	0.00096	0.01014	0.01029	0.00399	0.00000	0.00339	30
I	WATER AND SEWER	31	0.00049	0.00000	0.00062	0.00235	0.00188	0.00008	0.00000	0.00008	31
N	WHOLESALE TRADE	32	0.02700	0.04642	0.01965	0.01909	0.00657	0.02680	0.00000	0.02364	32
G	RETAIL TRADE	33	0.00261	0.00177	0.00510	0.00247	0.00045	0.00175	0.00000	0.00844	33
	F. I. & R.E	34	0.01053	0.01530	0.01723	0.01438	0.01657	0.01788	0.00000	0.01264	34
	PERSONAL & REPAIR SER.	35	0.00102	0.00163	0.00339	0.00129	0.00048	0.00418	0.00000	0.00103	35
	BUSINESS & MISC. SERV.	36	0.00681	0.00877	0.02700	0.01384	0.00968	0.01648	0.00000	0.00885	36
	MEDICAL & NON-PROFIT	37	0.00043	0.00049	0.00156	0.00056	0.00015	0.00078	0.00000	0.00055	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.27174	0.24220	0.37181	0.18377	0.08521	0.30792	0.00000	0.27761	51
	*** COLUMN SUMS ***		0.49846	0.37561	0.51050	0.41189	0.71815	0.62064	0.00000	0.39648	

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING							
			25	26	27	28	29	30	31	32	
	LIVESTK & LIVESTK PROD	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
	COTTON	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
	GRAINS AND SEEDS	3	0.00000	0.00000	0.00133	0.00000	0.00000	0.00000	0.00000	0.00000	3
	FRUITS AND VEGETABLES	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	4
	FORESTRY&FISHERY PRODS	5	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	5
	AGRICULTURAL SERVICES	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00117	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	7
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00065	0.00000	0.00059	0.02381	0.00000	0.00001	8
	NATURAL GAS & LIQ. PET	9	0.00000	0.00000	0.00405	0.00000	0.00361	0.14625	0.00000	0.00004	9
	STONE, GRAVEL AND SAND	10	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00002	10
	POTASH MINING	11	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00168	0.00245	0.02048	0.01411	0.02801	0.01443	0.06484	0.00094	15
I	FOOD PRODUCTS	16	0.00000	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00327	16
N	FABRICS AND APPAREL	17	0.00070	0.00086	0.00036	0.00012	0.00022	0.00009	0.00031	0.00093	17
D	PAPER PRODUCTS	18	0.03302	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00035	18
U	PRINTING	19	0.00000	0.00235	0.00037	0.00016	0.00001	0.00000	0.00001	0.00064	19
S	CHEMICAL PRODUCTS	20	0.00029	0.00000	0.00015	0.00001	0.00086	0.00000	0.00154	0.00072	20
T	PLASTIC & PETROLEUM	21	0.00562	0.00735	0.02989	0.00193	0.01204	0.00076	0.00334	0.00877	21
R	GLASS AND STONE PRODS.	22	0.00000	0.00002	0.00001	0.00000	0.00000	0.00000	0.00000	0.00048	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	24
	MACHINERY	25	0.01938	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000	0.00044	25
	ELECTRICAL PRODS.	26	0.00081	0.01076	0.00000	0.00000	0.00000	0.00000	0.00000	0.00006	26
S	TRNSPRTTN & WRHSING	27	0.01890	0.01110	0.08829	0.00146	0.02086	0.00020	0.00232	0.01572	27
E	COMMUNICATIONS	28	0.00339	0.00726	0.00861	0.01282	0.00250	0.00210	0.00443	0.01173	28
L	ELECTRICAL UTILITY	29	0.00541	0.00596	0.01622	0.00553	0.07355	0.00260	0.02800	0.00382	29
L	GAS UTILITY	30	0.00134	0.00193	0.00338	0.00110	0.03353	0.36157	0.01550	0.00046	30
I	WATER AND SEWER	31	0.00047	0.00013	0.00114	0.00125	0.00097	0.00065	0.00091	0.00168	31
N	WHOLESALE TRADE	32	0.04501	0.02005	0.02379	0.00304	0.00623	0.00063	0.00463	0.01558	32
G	RETAIL TRADE	33	0.00664	0.00762	0.01069	0.00492	0.00168	0.00156	0.00329	0.01564	33
	F. I. & R.E	34	0.01276	0.01924	0.01853	0.01229	0.00464	0.00549	0.01416	0.02239	34
	PERSONAL & REPAIR SER.	35	0.00082	0.00193	0.02424	0.06180	0.00203	0.00034	0.00783	0.01772	35
	BUSINESS & MISC. SERV.	36	0.00679	0.01306	0.00894	0.00983	0.00417	0.00455	0.00751	0.02311	36
	MEDICAL & NON-PROFIT	37	0.00045	0.00127	0.00052	0.00059	0.00027	0.00025	0.00051	0.00099	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.35653	0.29904	0.39619	0.33549	0.13141	0.13141	0.13141	0.42734	51
	*** COLUMN SUMS ***		0.52005	0.41238	0.65814	0.46644	0.32718	0.69669	0.29153	0.57405	

1790 066

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING								
			33	34	35	36	37	38	39	40	
	LIVESTK & LIVESTK PROD	1	0.00000	0.00034	0.00109	0.00000	0.00003	0.00000	0.00000	0.00000	1
	COTTON	2	0.00000	0.00006	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	2
	GRAINS AND SEEDS	3	0.00000	0.00067	0.00337	0.00000	0.00000	0.00006	0.00006	0.00006	3
	FRUITS AND VEGETABLES	4	0.00000	0.00003	0.00001	0.00000	0.00002	0.00000	0.00000	0.00000	4
	FORESTRY&FISHERY PRODS	5	0.00000	0.00001	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	5
	AGRICULTURAL SERVICES	6	0.00000	0.00028	0.00020	0.00000	0.00000	0.00032	0.00032	0.00032	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	7
	CRUDE PETROLEUM	8	0.00000	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	8
	NATURAL GAS & LIQ. PET	9	0.00000	0.00037	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
	STONE, GRAVEL AND SAND	10	0.00000	0.00004	0.00001	0.00000	0.00000	0.00744	0.00744	0.00744	10
	POTASH MINING	11	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00280	0.01757	0.00743	0.00494	0.00900	0.00000	0.00000	0.00000	15
I	FOOD PRODUCTS	16	0.00017	0.00012	0.00000	0.00000	0.00032	0.00000	0.00000	0.00000	16
N	FABRICS AND APPAREL	17	0.00005	0.00010	0.00148	0.00000	0.00018	0.00000	0.00000	0.00000	17
D	PAPER PRODUCTS	18	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
U	PRINTING	19	0.00049	0.00299	0.00009	0.00051	0.00300	0.00000	0.00000	0.00000	19
S	CHEMICAL PRODUCTS	20	0.00005	0.00013	0.00030	0.00090	0.00017	0.00000	0.00000	0.00000	20
T	PLASTIC & PETROLEUM	21	0.00540	0.00357	0.00838	0.00430	0.00884	0.00047	0.00047	0.00047	21
R	GLASS AND STONE PRODS.	22	0.00001	0.00002	0.00004	0.00001	0.00000	0.00000	0.00000	0.00000	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00000	0.00000	0.00000	0.00001	0.00000	0.00136	0.00136	0.00136	24
	MACHINERY	25	0.00005	0.00011	0.00387	0.00238	0.00000	0.00011	0.00011	0.00011	25
	ELECTRICAL PRODS.	26	0.00000	0.00000	0.00009	0.00009	0.00084	0.00000	0.00000	0.00000	26
S	TRNSPRTTN & WRHSING	27	0.00172	0.00350	0.00487	0.00803	0.00349	0.00431	0.00431	0.00431	27
E	COMMUNICATIONS	28	0.00559	0.01517	0.00644	0.01478	0.01308	0.00439	0.00439	0.00439	28
L	ELECTRICAL UTILITY	29	0.01428	0.00966	0.01214	0.00214	0.01781	0.00094	0.00094	0.00094	29
L	GAS UTILITY	30	0.00314	0.00194	0.00265	0.00262	0.00352	0.00000	0.00000	0.00000	30
I	WATER AND SEWER	31	0.00225	0.00393	0.00340	0.00118	0.00646	0.00000	0.00000	0.00000	31
N	WHOLESALE TRADE	32	0.00573	0.00635	0.02391	0.01323	0.02089	0.06613	0.06613	0.06613	32
G	RETAIL TRADE	33	0.00383	0.00913	0.01504	0.01652	0.01888	0.00000	0.00000	0.00000	33
	F. I. & R.E	34	0.03464	0.08665	0.03929	0.03435	0.06246	0.00830	0.00830	0.00830	34
	PERSONAL & REPAIR SER.	35	0.00793	0.00453	0.03926	0.01584	0.02056	0.00211	0.00211	0.00211	35
	BUSINESS & MISC. SERV.	36	0.00795	0.05356	0.01151	0.05497	0.02381	0.00000	0.00000	0.00000	36
	MEDICAL & NON-PROFIT	37	0.00082	0.00689	0.00191	0.00221	0.00340	0.00008	0.00008	0.00008	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.02334	0.05661	0.05503	50
	HOUSEHOLDS/PC LOCAL	51	0.42734	0.36220	0.32393	0.28410	0.48521	0.14014	0.33985	0.33032	51
	*** COLUMN SUMS ***		0.52422	0.58998	0.51070	0.46314	0.70199	0.25950	0.49248	0.48137	

1790 067

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING								
			41	42	43	44	45	46	47	49	
	LIVESTK & LIVESTK PROD	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
	COTTON	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
	GRAINS AND SEEDS	3	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00133	3
	FRUITS AND VEGETABLES	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	4
	FORESTRY&FISHERY PRODS	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	5
	AGRICULTURAL SERVICES	6	0.00032	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00034	7
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00065	8
	NATURAL GAS & LIQ. PET	9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00405	9
	STONE, GRAVEL AND SAND	10	0.00744	0.00000	0.00268	0.00268	0.00268	0.00268	0.00000	0.00000	10
	POTASH MINING	11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00000	0.00494	0.00000	0.00000	0.00000	0.00000	0.00494	0.02048	15
I	FOOD PRODUCTS	16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005	16
N	FABRICS AND APPAREL	17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00036	17
D	PAPER PRODUCTS	18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
U	PRINTING	19	0.00000	0.00051	0.00000	0.00000	0.00000	0.00000	0.00051	0.00037	19
S	CHEMICAL PRODUCTS	20	0.00000	0.00090	0.00000	0.00000	0.00000	0.00000	0.00090	0.00015	20
T	PLASTIC & PETROLEUM	21	0.00047	0.00430	0.00000	0.00000	0.00000	0.00000	0.00430	0.02989	21
R	GLASS AND STONE PRODS.	22	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00136	0.00001	0.00051	0.00051	0.00051	0.00051	0.00001	0.00000	24
	MACHINERY	25	0.00011	0.00238	0.00141	0.00141	0.00141	0.00141	0.00238	0.00017	25
	ELECTRICAL PRODS.	26	0.00000	0.00009	0.00000	0.00000	0.00000	0.00000	0.00009	0.00000	26
S	TRNSPRTTN & WRHSING	27	0.00431	0.00803	0.00401	0.00401	0.00401	0.00401	0.00803	0.08829	27
E	COMMUNICATIONS	28	0.00439	0.01478	0.00067	0.00067	0.00067	0.00067	0.01478	0.00861	28
L	ELECTRICAL UTILITY	29	0.00094	0.00214	0.00882	0.00882	0.00882	0.00882	0.00214	0.01522	29
L	GAS UTILITY	30	0.00000	0.00262	0.00000	0.00000	0.00000	0.00000	0.00262	0.00338	30
I	WATER AND SEWER	31	0.00000	0.00118	0.00000	0.00000	0.00000	0.00000	0.00118	0.00114	31
N	WHOLESALE TRADE	32	0.06613	0.01323	0.07448	0.07448	0.07448	0.07448	0.01323	0.02379	32
G	RETAIL TRADE	33	0.00000	0.01652	0.00000	0.00000	0.00000	0.00000	0.01652	0.01069	33
	F. I. & R.E	34	0.00830	0.03435	0.00347	0.00347	0.00347	0.00347	0.03435	0.01853	34
	PERSONAL & REPAIR SER.	35	0.00211	0.01584	0.00236	0.00236	0.00236	0.00236	0.01584	0.02424	35
	BUSINESS & MISC. SERV.	36	0.00000	0.05497	0.00000	0.00000	0.00000	0.00000	0.05497	0.00894	36
	MEDICAL & NON-PROFIT	37	0.00008	0.00221	0.00011	0.00011	0.00011	0.00011	0.00221	0.00052	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.05728	0.00000	0.01244	0.04173	0.05091	0.05290	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.34383	0.28410	0.06504	0.21809	0.26607	0.27647	0.28410	0.39619	51
	*** COLUMN SUMS ***		0.49713	0.46311	0.17600	0.35834	0.41550	0.42789	0.46311	0.65811	

1790 068

Table L-1 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT COEFFICIENTS

			INDUSTRY PURCHASING 49	50	51		*** ROW SUMS ***
	LIVESTK & LIVESTK PROD	1	0.00000	0.00027	0.00108	1	0.68251
	COTTON	2	0.00000	0.00000	0.00000	2	0.15525
	GRAINS AND SEEDS	3	0.00000	0.00012	0.00047	3	0.33566
	FRUITS AND VEGETABLES	4	0.00000	0.00022	0.00088	4	0.00991
	FORESTRY&FISHERY PRODS	5	0.00000	0.00024	0.00094	5	0.09224
	AGRICULTURAL SERVICES	6	0.00000	0.00007	0.00029	6	0.21080
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	7	0.01016
	CRUDE PETROLEUM	8	0.00000	0.00000	0.00000	8	0.48567
	NATURAL GAS & LIQ. PET	9	0.00000	0.00000	0.00000	9	0.32990
	STONE, GRAVEL AND SAND	10	0.00000	0.00000	0.00001	10	0.14816
	POTASH MINING	11	0.00000	0.00000	0.00000	11	0.02447
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	12	0.00000
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	13	0.00000
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	14	0.00000
	CONST. MAINTENANCE	15	0.00205	0.00000	0.00000	15	0.35409
I	FOOD PRODUCTS	16	0.00000	0.00473	0.01893	16	0.09239
N	FABRICS AND APPAREL	17	0.00000	0.00001	0.00003	17	0.11236
D	PAPER PRODUCTS	18	0.00000	0.00000	0.00000	18	0.09763
U	PRINTING	19	0.00000	0.00082	0.00326	19	0.03351
S	CHEMICAL PRODUCTS	20	0.00000	0.00015	0.00060	20	0.16239
T	PLASTIC & PETROLEUM	21	0.00000	0.00540	0.02158	21	0.49510
R	GLASS AND STONE PRODS.	22	0.00000	0.00000	0.00001	22	0.16689
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	23	0.00000
	FABRICATED METAL PRODS	24	0.00000	0.00000	0.00000	24	0.01653
	MACHINERY	25	0.01535	0.00014	0.00055	25	0.11563
	ELECTRICAL PRODS.	26	0.00000	0.00000	0.00000	26	0.01369
S	TRNSPRTTN & WRHSING	27	0.00977	0.00448	0.01791	27	0.81840
E	COMMUNICATIONS	28	0.00259	0.00318	0.01270	28	0.25142
L	ELECTRICAL UTILITY	29	0.04470	0.00402	0.01607	29	0.46885
L	GAS UTILITY	30	0.00000	0.00235	0.00940	30	0.53310
I	WATER AND SEWER	31	0.00000	0.00096	0.00386	31	0.06769
N	WHOLESALE TRADE	32	0.00250	0.01250	0.05000	32	1.44487
G	RETAIL TRADE	33	0.00138	0.04351	0.17404	33	0.74327
	F. I. & R.E	34	0.00694	0.01294	0.05176	34	1.12442
	PERSONAL & REPAIR SER.	35	0.00064	0.01465	0.05859	35	0.43524
	BUSINESS & MISC. SERV.	36	0.00000	0.00202	0.00810	36	0.79666
	MEDICAL & NON-PROFIT	37	0.00119	0.00270	0.01081	37	0.05405
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	38	0.00000
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	39	0.00000
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	40	0.00000
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	41	0.00000
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	42	0.00000
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	43	0.00000
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	44	0.00000
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	45	0.00000
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	46	0.00000
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	47	0.00000
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	48	0.00000
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	49	0.00000
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	50	0.35024
	HOUSEHOLDS/PC LOCAL	51	0.25000	0.00000	0.00000	51	12.00460
	*** COLUMN SUMS ***		0.33711	0.11548	0.46187		

1790 069

Table L-2

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

INDUSTRY SELLING		INDUSTRY PURCHASING 1	2	3	4	5	6	7	8	
LIVESTK & LIVESTK PROD	1	1.51092	0.04603	0.15330	0.02314	0.24527	0.00505	0.00125	0.00082	1
COTTON	2	0.00434	1.01744	0.00090	0.00051	0.00291	0.00170	0.00058	0.00036	2
GRAINS AND SEEDS	3	0.41658	0.01398	1.07351	0.00713	0.06850	0.00978	0.00072	0.00052	3
FRUITS AND VEGETABLES	4	0.00102	0.00037	0.00031	1.00402	0.00035	0.00121	0.00027	0.00016	4
FORESTRY&FISHERY PRODS	5	0.00025	0.00030	0.00027	0.00020	1.07775	0.00035	0.00037	0.00018	5
AGRICULTURAL SERVICES	6	0.01001	0.10394	0.01452	0.05937	0.03004	1.00052	0.00022	0.00018	6
MISC MET & NON-MET MIN	7	0.00009	0.00011	0.00023	0.00009	0.00002	0.00000	1.00846	0.00[illegible]1	7
CRUDE PETROLEUM	8	0.01319	0.02312	0.02146	0.00920	0.02038	0.00461	0.00562	1.00743	8
NATURAL GAS & LIQ. PET	9	0.00203	0.00291	0.00257	0.00145	0.00222	0.00144	0.00230	0.00163	9
STONE, GRAVEL AND SAND	10	0.00091	0.00156	0.00211	0.00104	0.00018	0.00004	0.00005	0.00022	10
POTASH MINING	11	0.00055	0.00080	0.00137	0.00061	0.00010	0.00002	0.00018	0.00003	11
RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
CONST. MAINTENANCE	15	0.01382	0.01709	0.01549	0.01020	0.00478	0.00203	0.00501	0.03092	15
FOOD PRODUCTS	16	0.04048	0.00654	0.00823	0.00418	0.02691	0.00679	0.00535	0.00327	16
FABRICS AND APPAREL	17	0.00015	0.000[illegible]7	0.00014	0.00010	0.00012	0.00009	0.00011	0.00008	17
PAPER PRODUCTS	18	0.00009	0.00011	0.00010	0.00007	0.00005	0.00003	0.00040	0.00014	18
PRINTING	19	0.00109	0.001[illegible]	0.00112	0.00082	0.00084	0.00127	0.00106	0.00095	19
CHEMICAL PRODUCTS	20	0.00473	0.00636	0.00830	0.00303	0.00191	0.00046	0.02315	0.00368	20
PLASTIC & PETROLEUM	21	0.02838	0.04996	0.04642	0.01980	0.04414	0.00969	0.01168	0.01034	21
GLASS AND STONE PRODS.	22	0.00012	0.00018	0.00020	0.00011	0.00005	0.00002	0.00004	0.00012	22
PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
FABRICATED METAL PRODS	24	0.00001	0.00001	0.00001	0.00001	0.00002	0.00000	0.00000	0.00010	24
MACHINERY	25	0.00051	0.00071	0.00053	0.00038	0.00027	0.00032	0.01123	0.00033	25
ELECTRICAL PRODS.	26	0.00001	0.00002	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	26
TRNSPRTTN & WRHSING	27	0.03722	0.02295	0.02660	0.01614	0.01811	0.00912	0.01900	0.00755	27
COMMUNICATIONS	28	0.00897	0.01086	0.00856	0.00584	0.00501	0.00585	0.00825	0.00582	28
ELECTRICAL UTILITY	29	0.01153	0.01774	0.01029	0.00880	0.00683	0.00806	0.01947	0.01704	29
GAS UTILITY	30	0.00577	0.00751	0.00624	0.00446	0.00506	0.00632	0.01009	0.00690	30
WATER AND SEWER	31	0.00494	0.01072	0.00953	0.00902	0.00186	0.00184	0.00159	0.00188	31
WHOLESALE TRADE	32	0.05260	0.05811	0.05051	0.03853	0.04916	0.02007	0.02686	0.01610	32
RETAIL TRADE	33	0.06742	0.08059	0.06989	0.04547	0.04706	0.06092	0.05013	0.03659	33
F. I. & R.E	34	0.05609	0.11120	0.07472	0.04041	0.04400	0.02654	0.03090	0.11493	34
PERSONAL & REPAIR SER.	35	0.02477	0.03043	0.02335	0.01768	0.02111	0.02257	0.01945	0.01461	35
BUSINESS & MISC. SERV.	36	0.02304	0.04507	0.04015	0.02323	0.00980	0.00669	0.01549	0.02471	36
MEDICAL & NON-PROFIT	37	0.00400	0.00462	0.00372	0.00284	0.00257	0.00400	0.00453	0.00302	37
WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
HOUSEHOLDS/PC LOCAL	51	0.22154	0.26821	0.22538	0.17891	0.17641	0.33730	0.26745	0.16331	51
*** COLUMN SUMS ***		2.56714	1.96110	1.90003	1.53683	1.91378	1.55468	1.55125	1.47393	

1790 070

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING							
			9	10	11	12	13	14	15	16	
	LIVESTK & LIVESTK PROD	1	0.00110	0.00239	0.00128	0.00262	0.00253	0.00252	0.00329	0.12361	1
	COTTON	2	0.00048	0.00111	0.00059	0.00124	0.00118	0.00118	0.00156	0.11037	2
	GRAINS AND SEEDS	3	0.00071	0.00143	0.00074	0.00186	0.00165	0.00173	0.00190	0.05916	3
	FRUITS AND VEGETABLES	4	0.00022	0.00048	0.00028	0.00051	0.00050	0.00050	0.00067	0.00195	4
	FORESTRY&FISHERY PRODS	5	0.00027	0.00056	0.00037	0.00059	0.00057	0.00057	0.00074	0.00032	5
	AGRICULTURAL SERVICES	6	0.00024	0.00045	0.00022	0.00189	0.00125	0.00332	0.00106	0.01261	6
	MISC MET & NON-MET MIN	7	0.00002	0.00001	0.00003	0.00001	0.00001	0.00001	0.00001	0.00008	7
	CRUDE PETROLEUM	8	0.00701	0.01466	0.00848	0.01161	0.01316	0.02215	0.01392	0.00955	8
	NATURAL GAS & LIQ. PET	9	1.17675	0.00422	0.00868	0.00309	0.00318	0.00383	0.00362	0.00250	9
	STONE, GRAVEL AND SAND	10	0.00031	1.00837	0.00006	0.00390	0.00521	0.02273	0.00688	0.00046	10
	POTASH MINING	11	0.00038	0.00055	1.01431	0.00002	0.00003	0.00005	0.00002	0.00017	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.04300	0.01436	0.00603	0.00578	0.00602	0.00673	1.00571	0.00853	15
I	FOOD PRODUCTS	16	0.00439	0.01030	0.00551	0.01114	0.01088	0.01072	0.01441	1.03428	16
N	FABRICS AND APPAREL	17	0.00011	0.00026	0.00012	0.00139	0.00031	0.00094	0.00038	0.00037	17
D	PAPER PRODUCTS	18	0.00019	0.00028	0.00057	0.03829	0.01208	0.00223	0.00394	0.00007	18
U	PRINTING	19	0.00129	0.00212	0.00109	0.00227	0.00222	0.00217	0.00283	0.00261	19
S	CHEMICAL PRODUCTS	20	0.01034	0.00779	0.02151	0.00153	0.00299	0.00394	0.00136	0.00278	20
T	PLASTIC & PETROLEUM	21	0.01359	0.03095	0.01600	0.02459	0.02797	0.04755	0.02951	0.02023	21
R	GLASS AND STONE PRODS.	22	0.00016	0.05705	0.00004	0.02761	0.03649	0.02336	0.00341	0.00009	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00006	0.00001	0.00001	0.00197	0.00310	0.00188	0.00043	0.00001	24
	MACHINERY	25	0.00047	0.00608	0.01618	0.00135	0.00161	0.00146	0.00109	0.00043	25
	ELECTRICAL PRODS.	26	0.00001	0.00003	0.00002	0.00023	0.00032	0.00025	0.00009	0.00001	26
S	TRNSPRTTN & WRHSING	27	0.01029	0.03783	0.01957	0.04957	0.05157	0.07106	0.04345	0.03905	27
E	COMMUNICATIONS	28	0.00805	0.01161	0.00825	0.01582	0.01726	0.01623	0.01621	0.01211	28
L	ELECTRICAL UTILITY	29	0.01482	0.04338	0.02961	0.01714	0.01673	0.01715	0.01971	0.01644	29
L	GAS UTILITY	30	0.03170	0.01724	0.04643	0.01214	0.01202	0.01217	0.01450	0.00972	30
I	WATER AND SEWER	31	0.00313	0.00599	0.00167	0.00374	0.00379	0.00373	0.00431	0.00364	31
N	WHOLESALE TRADE	32	0.02714	0.06921	0.02060	0.08896	0.08600	0.07926	0.08299	0.05764	32
G	RETAIL TRADE	33	0.04927	0.10709	0.05211	0.18808	0.14904	0.13800	0.19463	0.06226	33
	F. I. & R.E	34	0.15917	0.07836	0.03159	0.05872	0.06091	0.05979	0.06454	0.04660	34
	PERSONAL & REPAIR SER.	35	0.01379	0.04846	0.02016	0.04633	0.04818	0.04835	0.05440	0.02747	35
	BUSINESS & MISC. SERV.	36	0.03441	0.04884	0.01647	0.07255	0.09071	0.06058	0.03731	0.02300	36
	MEDICAL & NON-PROFIT	37	0.00410	0.00669	0.00465	0.00779	0.00805	0.00779	0.00930	0.00454	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.21768	0.51321	0.27679	0.55251	0.53990	0.53279	0.72079	0.29356	51
	*** COLUMN SUMS ***		1.84034	2.15139	1.63000	2.25681	2.21718	2.20670	2.35899	1.98621	

1790 071

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING							
			17	18	19	20	21	22	23	24	
	LIVESTK & LIVESTK PROD	1	0.01732	0.00174	0.00246	0.00257	0.00121	0.00259	0.00000	0.00187	1
	COTTON	2	0.03823	0.00084	0.00119	0.00080	0.00055	0.00122	0.00000	0.00090	2
	GRAINS AND SEEDS	3	0.00541	0.00103	0.00141	0.00127	0.00077	0.00167	0.00000	0.00108	3
	FRUITS AND VEGETABLES	4	0.00041	0.00035	0.00050	0.00150	0.00024	0.00051	0.00000	0.00038	4
	FORESTRY&FISHERY PRODS	5	0.01877	0.00041	0.00063	0.00458	0.00029	0.00059	0.00000	0.00043	5
	AGRICULTURAL SERVICES	6	0.00473	0.00035	0.00044	0.00047	0.00024	0.00047	0.00000	0.00034	6
	MISC MET & NON-MET MIN	7	0.00001	0.00001	0.00002	0.00132	0.00006	0.00001	0.00000	0.00000	7
	CRUDE PETROLEUM	8	0.00769	0.00717	0.00898	0.03341	0.49124	0.01504	0.00000	0.00805	8
	NATURAL GAS & LIQ. PET	9	0.00233	0.00242	0.00292	0.00947	0.03395	0.00501	0.00000	0.00305	9
	STONE, GRAVEL AND SAND	10	0.00011	0.00008	0.00008	0.00049	0.00022	0.06837	0.00000	0.00315	10
	POTASH MINING	11	0.00005	0.00003	0.00011	0.00807	0.00007	0.00006	0.00000	0.00001	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00561	0.00670	0.00766	0.01019	0.02974	0.01133	0.00000	0.00592	15
I	FOOD PRODUCTS	16	0.00933	0.00754	0.01058	0.00736	0.00502	0.01110	0.00000	0.00813	16
N	FABRICS AND APPAREL	17	1.11240	0.00108	0.00180	0.00038	0.00020	0.00081	0.00000	0.00100	17
D	PAPER PRODUCTS	18	0.00006	1.00810	0.00007	0.00007	0.00014	0.00021	0.00000	0.00151	18
U	PRINTING	19	0.00173	0.00156	1.01821	0.00134	0.00121	0.00236	0.00000	0.00162	19
S	CHEMICAL PRODUCTS	20	0.00177	0.00344	0.01421	1.05383	0.00875	0.00268	0.00000	0.00132	20
T	PLASTIC & PETROLEUM	21	0.01621	0.01503	0.01887	0.07144	1.06987	0.03153	0.00000	0.01676	21
R	GLASS AND STONE PRODS.	22	0.00006	0.00042	0.00006	0.00009	0.00013	1.02895	0.00000	0.00024	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00000	0.00001	0.00001	0.00006	0.00007	0.00001	0.00000	1.00142	24
	MACHINERY	25	0.00047	0.00239	0.00061	0.00054	0.00039	0.00425	0.00000	0.02457	25
	ELECTRICAL PRODS.	26	0.00001	0.00003	0.00004	0.00004	0.00001	0.00002	0.00000	0.00004	26
S	TRNSPRTTN & WRHSING	27	0.02408	0.04111	0.02753	0.03488	0.04240	0.15336	0.00000	0.02824	27
E	COMMUNICATIONS	28	0.01222	0.01200	0.02178	0.01033	0.00767	0.01818	0.00000	0.01306	28
L	ELECTRICAL UTILITY	29	0.01965	0.01742	0.01922	0.02518	0.02027	0.02577	0.00000	0.01763	29
L	GAS UTILITY	30	0.00972	0.00998	0.01239	0.02551	0.02526	0.01912	0.00000	0.01375	30
I	WATER AND SEWER	31	0.00335	0.00221	0.00368	0.00452	0.00406	0.00365	0.00000	0.00242	31
N	WHOLESALE TRADE	32	0.05836	0.07041	0.05219	0.04092	0.02696	0.06700	0.00000	0.04949	32
G	RETAIL TRADE	33	0.08295	0.07039	0.10190	0.06111	0.05097	0.10550	0.00000	0.08269	33
	F. I. & R.E	34	0.05062	0.04755	0.06157	0.04754	0.09349	0.07026	0.00000	0.04675	34
	PERSONAL & REPAIR SER.	35	0.03205	0.02894	0.04122	0.02452	0.02072	0.04759	0.00000	0.02987	35
	BUSINESS & MISC. SERV.	36	0.01972	0.01940	0.04157	0.02536	0.02918	0.03534	0.00000	0.01936	36
	MEDICAL & NON-PROFIT	37	0.00582	0.00515	0.00814	0.00462	0.00392	0.00778	0.00000	0.00556	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.43154	0.37236	0.53034	0.31470	0.25031	0.55466	0.00000	0.40633	51
	*** COLUMN SUMS ***		1.99277	1.75763	2.01240	1.82844	2.21957	2.29698	1.00000	1.79396	

1790 072

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING								
			25	26	27	28	29	30	31	32	
	LIVESTK & LIVESTK PROD	1	0.00242	0.00197	0.00316	0.00233	0.00112	0.00158	0.00116	0.00321	1
	COTTON	2	0.00117	0.00095	0.00137	0.00104	0.00053	0.00074	0.00054	0.00169	2
	GRAINS AND SEEDS	3	0.00140	0.00114	0.00331	0.00150	0.00067	0.00092	0.00069	0.00196	3
	FRUITS AND VEGETABLES	4	0.00049	0.00040	0.00058	0.00045	0.00022	0.00032	0.00023	0.00056	4
	FORESTRY&FISHERY PRODS	5	0.00055	0.00046	0.00067	0.00050	0.00026	0.00036	0.00027	0.00064	5
	AGRICULTURAL SERVICES	6	0.00046	0.00036	0.00055	0.00039	0.00021	0.00029	0.00023	0.00170	6
	MISC MET & NON-MET MIN	7	0.00001	0.00000	0.00006	0.00000	0.00000	0.00001	0.00000	0.00001	7
	CRUDE PETROLEUM	8	0.01043	0.00974	0.02568	0.00778	0.01218	0.04365	0.00625	0.01282	8
	NATURAL GAS & LIQ. PET	9	0.00308	0.00281	0.01032	0.00261	0.01600	0.27096	0.00613	0.00330	9
	STONE, GRAVEL AND SAND	10	0.00007	0.00006	0.00022	0.00014	0.00025	0.00026	0.00048	0.00011	10
	POTASH MINING	11	0.00001	0.00001	0.00002	0.00001	0.00003	0.00002	0.00002	0.00002	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONST.	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00621	0.00634	0.02893	0.01835	0.03426	0.03575	0.06855	0.00631	15
I	FOOD PRODUCTS	16	0.01055	0.00854	0.01257	0.00957	0.00481	0.00678	0.00493	0.01537	16
N	FABRICS AND APPAREL	17	0.00103	0.00114	0.00070	0.00038	0.00037	0.00026	0.00046	0.00126	17
D	PAPER PRODUCTS	18	0.03402	0.00006	0.00017	0.00011	0.00015	0.03016	0.00028	0.00044	18
U	PRINTING	19	0.00209	0.00414	0.00290	0.00206	0.00097	0.00145	0.00101	0.00306	19
S	CHEMICAL PRODUCTS	20	0.00114	0.00064	0.00133	0.00065	0.00153	0.00287	0.00207	0.00161	20
T	PLASTIC & PETROLEUM	21	0.02199	0.02055	0.05332	0.01631	0.02187	0.01292	0.01187	0.02718	21
R	GLASS AND STONE PRODS.	22	0.00008	0.00007	0.00016	0.00009	0.00013	0.00014	0.00025	0.00056	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00002	0.00001	0.00002	0.00001	0.00002	0.00003	0.00003	0.00002	24
	MACHINERY	25	1.02038	0.00047	0.00096	0.00075	0.00028	0.00042	0.00032	0.00117	25
	ELECTRICAL PRODS.	26	0.00085	1.01089	0.00002	0.00002	0.00001	0.00001	0.00001	0.00008	25
S	TRNSPRTTN & WRHSING	27	0.03646	0.02395	1.11533	0.01462	0.03225	0.01079	0.01152	0.03346	27
E	COMMUNICATIONS	28	0.01399	0.01593	0.02183	1.02235	0.00778	0.01071	0.00975	0.02377	28
L	ELECTRICAL UTILITY	29	0.01976	0.01763	0.03579	0.01881	1.08639	0.01549	0.03699	0.02001	29
L	GAS UTILITY	30	0.01280	0.01186	0.01977	0.01161	0.06214	1.57957	0.03256	0.01297	30
I	WATER AND SEWER	31	0.00347	0.00260	0.00497	0.00414	0.00252	0.00338	1.00244	0.00518	31
N	WHOLESALE TRADE	32	0.07936	0.04620	0.06513	0.03332	0.02318	0.02530	0.02256	1.05231	32
G	RETAIL TRADE	33	0.10252	0.08576	0.12740	0.09393	0.04808	0.06799	0.05277	0.12555	33
	F. I. & R.E	34	0.05666	0.05566	0.07537	0.05334	0.02819	0.07208	0.03700	0.07342	34
	PERSONAL & REPAIR SER.	35	0.03804	0.03234	0.07148	0.09796	0.01985	0.02526	0.02597	0.06106	35
	BUSINESS & MISC. SERV.	36	0.02030	0.02457	0.02655	0.02203	0.01200	0.02293	0.01604	0.03889	36
	MEDICAL & NON-PROFIT	37	0.00691	0.00661	0.00835	0.00660	0.00331	0.00494	0.00368	0.00848	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.52502	0.42809	0.62731	0.48269	0.24145	0.34130	0.24754	0.60333	51
	*** COLUMN SUMS ***		2.03373	1.82192	2.34630	1.92646	1.66301	2.55961	1.60462	2.14141	

1790 073

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING							
			33	34	35	36	37	38	39	40	
	LIVESTK & LIVESTK PROD	1	0.00266	0.00328	0.00454	0.00207	0.00339	0.00112	0.00228	0.00222	1
	COTTON	2	0.00125	0.00130	0.00114	0.00095	0.00157	0.00053	0.00108	0.00105	2
	GRAINS AND SEEDS	3	0.00154	0.00243	0.00555	0.00125	0.00199	0.00071	0.00136	0.00133	3
	FRUITS AND VEGETABLES	4	0.00053	0.00055	0.00047	0.00041	0.00068	0.00022	0.00046	0.00045	4
	FORESTRY&FISHERY PRODS	5	0.00059	0.00060	0.00054	0.00046	0.00074	0.00024	0.00051	0.00050	5
	AGRICULTURAL SERVICES	6	0.00045	0.00077	0.00070	0.00037	0.00059	0.00058	0.00077	0.00076	6
	MISC MET & NON-MET MIN	7	0.00000	0.00001	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	7
	CRUDE PETROLEUM	8	0.01057	0.01000	0.01144	0.00863	0.01445	0.00380	0.00712	0.00696	8
	NATURAL GAS & LIQ. PET	9	0.00374	0.00388	0.00348	0.00299	0.00473	0.00113	0.00220	0.00215	9
	STONE, GRAVEL AND SAND	10	0.00007	0.00023	0.00013	0.00008	0.00014	0.00753	0.00754	0.00754	10
	POTASH MINING	11	0.00001	0.00002	0.00002	0.00002	0.00002	0.00001	0.00001	0.00001	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00786	0.02422	0.01288	0.00960	0.01648	0.00200	0.00340	0.00333	15
I	FOOD PRODUCTS	16	0.01158	0.01140	0.00994	0.00883	0.01447	0.00490	0.01000	0.00976	16
N	FABRICS AND APPAREL	17	0.00024	0.00031	0.00189	0.00018	0.00048	0.00015	0.00021	0.00021	17
D	PAPER PRODUCTS	18	0.00007	0.00015	0.00022	0.00016	0.00012	0.00005	0.00007	0.00007	18
U	PRINTING	19	0.00280	0.00555	0.00215	0.00238	0.00600	0.00097	0.00194	0.00190	19
S	CHEMICAL PRODUCTS	20	0.00082	0.00099	0.00108	0.00161	0.00123	0.00040	0.00068	0.00067	20
T	PLASTIC & PETROLEUM	21	0.02210	0.02079	0.02409	0.01805	0.03032	0.00801	0.01499	0.01465	21
R	GLASS AND STONE PRODS.	22	0.00007	0.00013	0.00013	0.00008	0.00010	0.00048	0.00049	0.00049	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00001	0.00002	0.00001	0.00002	0.00001	0.00136	0.00137	0.00137	24
	MACHINERY	25	0.00066	0.00085	0.00464	0.00308	0.00085	0.00046	0.00070	0.00069	25
	ELECTRICAL PRODS.	26	0.00002	0.00003	0.00012	0.00012	0.00088	0.00001	0.00002	0.00002	26
S	TRNSPRTTN & WRHSING	27	0.01697	0.01988	0.01958	0.02126	0.02344	0.01204	0.01827	0.01797	27
E	COMMUNICATIONS	28	0.01659	0.02812	0.01693	0.02477	0.02786	0.00964	0.01404	0.01383	28
L	ELECTRICAL UTILITY	29	0.02994	0.02596	0.02681	0.01448	0.03824	0.00747	0.01354	0.01325	29
L	GAS UTILITY	30	0.01689	0.01522	0.01500	0.01338	0.02084	0.00471	0.00947	0.00925	30
I	WATER AND SEWER	31	0.00552	0.00754	0.00653	0.00394	0.01076	0.00145	0.00278	0.00272	31
N	WHOLESALE TRADE	32	0.03969	0.04197	0.05541	0.04123	0.06435	0.08139	0.09602	0.09532	32
G	RETAIL TRADE	33	1.10809	0.11469	0.10652	0.09863	0.14907	0.04383	0.08996	0.08776	33
	F. I. & R.E	34	0.08229	1.14177	0.08495	0.07573	0.12601	0.02905	0.04792	0.04702	34
	PERSONAL & REPAIR SER.	35	0.04767	0.04591	1.07586	0.04912	0.07151	0.01989	0.03702	0.03620	35
	BUSINESS & MISC. SERV.	36	0.02216	0.07456	0.02638	1.07035	0.04471	0.00722	0.01198	0.01176	36
	MEDICAL & NON-PROFIT	37	0.00796	0.01451	0.00829	0.00798	1.01249	0.00304	0.00608	0.00594	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	40
	WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.02334	0.05661	0.05503	50
	HOUSEHOLDS/PC LOCAL	51	0.57555	0.56726	0.49495	0.44321	0.70987	0.23050	0.47999	0.46809	51
	*** COLUMN SUMS ***		2.03696	2.18489	2.02238	1.92543	2.39839	1.50825	1.94089	1.92026	

1790 074

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING							
			41	42	43	44	45	46	47	48	
	LIVESTK & LIVESTK PROD	1	0.00230	0.00207	0.00068	0.00157	0.00185	0.00191	0.00207	0.00316	1
	COTTON	2	0.00109	0.00095	0.00033	0.00075	0.00088	0.00091	0.00095	0.00137	2
	GRAINS AND SEEDS	3	0.00137	0.00125	0.00040	0.00090	0.00106	0.00109	0.00125	0.00331	3
	FRUITS AND VEGETABLES	4	0.00046	0.00041	0.00013	0.00031	0.00037	0.00038	0.00041	0.00058	4
	FORESTRY&FISHERY PRODS	5	0.00051	0.00046	0.00015	0.00035	0.00041	0.00043	0.00046	0.00068	5
	AGRICULTURAL SERVICES	6	0.00078	0.00037	0.00020	0.00035	0.00039	0.00040	0.00037	0.00055	6
	MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005	7
	CRUDE PETROLEUM	8	0.00719	0.00862	0.00238	0.00494	0.00575	0.00592	0.00862	0.02567	8
	NATURAL GAS & LIQ. PET	9	0.00222	0.00298	0.00082	0.00165	0.00190	0.00196	0.00298	0.01012	9
	STONE, GRAVEL AND SAND	10	0.00754	0.00008	0.00272	0.00273	0.00274	0.00274	0.00008	0.00022	10
	POTASH MINING	11	0.00001	0.00002	0.00000	0.00001	0.00001	0.00001	0.00002	0.00002	11
	RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
	NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
	ALL OTHER CONST.	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
	CONST. MAINTENANCE	15	0.00342	0.00960	0.00152	0.00260	0.00294	0.00301	0.00960	0.02893	15
I	FOOD PRODUCTS	16	0.01010	0.00883	0.00302	0.00695	0.00819	0.00845	0.00883	0.01257	16
N	FABRICS AND APPAREL	17	0.00021	0.00018	0.00013	0.00018	0.00020	0.00020	0.00018	0.00070	17
D	PAPER PRODUCTS	18	0.00007	0.00016	0.00009	0.00011	0.00011	0.00011	0.00016	0.00017	18
U	PRINTING	19	0.00196	0.00238	0.00060	0.00135	0.00158	0.00163	0.00238	0.00290	19
S	CHEMICAL PRODUCTS	20	0.00069	0.00161	0.00026	0.00049	0.00056	0.00057	0.00161	0.00133	20
T	PLASTIC & PETROLEUM	21	0.01513	0.01805	0.00498	0.01036	0.01205	0.01242	0.01805	0.05332	21
R	GLASS AND STONE PRODS.	22	0.00049	0.00007	0.00020	0.00022	0.00022	0.00022	0.00007	0.00015	22
Y	PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
	FABRICATED METAL PRODS	24	0.00137	0.00002	0.00051	0.00051	0.00051	0.00051	0.00002	0.00002	24
	MACHINERY	25	0.00070	0.00308	0.00165	0.00186	0.00189	0.00191	0.00308	0.00095	25
	ELECTRICAL PRODS.	26	0.00002	0.00011	0.00001	0.00001	0.00002	0.00002	0.00011	0.00002	26
S	TRNSPRTTN & WRHSING	27	0.01839	0.02126	0.00958	0.01438	0.01589	0.01621	0.02126	0.11532	27
E	COMMUNICATIONS	28	0.01413	0.02477	0.00425	0.00765	0.00871	0.00894	0.02477	0.02183	28
L	ELECTRICAL UTILITY	29	0.01366	0.01448	0.01353	0.01820	0.01967	0.01999	0.01448	0.03578	29
L	GAS UTILITY	30	0.00957	0.01337	0.00332	0.00699	0.00814	0.00839	0.01337	0.01977	30
I	WATER AND SEWER	31	0.00281	0.00394	0.00093	0.00196	0.00228	0.00235	0.00394	0.00497	31
N	WHOLESALE TRADE	32	0.09631	0.04123	0.08426	0.09554	0.09908	0.09985	0.04123	0.06513	32
G	RETAIL TRADE	33	0.09088	0.09863	0.02660	0.06216	0.07330	0.07572	0.09863	0.12740	33
	F. I. & R.E	34	0.04830	0.07572	0.01673	0.03127	0.03583	0.03682	0.07572	0.07537	34
	PERSONAL & REPAIR SER.	35	0.03736	0.04912	0.01359	0.02679	0.03093	0.03183	0.04912	0.07147	35
	BUSINESS & MISC. SERV.	36	0.01208	0.07035	0.00518	0.00885	0.01000	0.01025	0.07035	0.02654	36
	MEDICAL & NON-PROFIT	37	0.00615	0.00798	0.00191	0.00425	0.00499	0.00515	0.00798	0.00835	37
	WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
	WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
	WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
	WIPP A/G CONST 1984	41	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
	WIPP NON-CONST EMP	42	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
	WIPP B/G CONST 1981	43	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
	WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	44
	WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	45
	WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	46
	WIPP OPER A/G	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	47
	WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	48
	WIPP OPER B/G	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
	HOUSEHOLDS/PC WEEKLY	50	0.05728	0.00000	0.01244	0.04173	0.05091	0.05290	0.00300	0.00000	50
	HOUSEHOLDS/PC LOCAL	51	0.48497	0.44320	0.13679	0.32822	0.38823	0.40124	0.44320	0.62730	51
	*** COLUMN SUMS ***		1.94952	1.92537	1.34991	1.68618	1.79159	1.81444	1.92537	2.34623	

1790 075

Table L-2 (Continued)

INPUT-OUTPUT TABLES, LEA AND EDDY COUNTIES, NOVEMBER 1978
DIRECT, INDIRECT, AND COEFFICIENTS

			INDUSTRY PURCHASING			
		49	50	51		*** ROW SUMS ***
LIVESTK & LIVESTK PROD	1	0.00156	0.00139	0.00557	1	2.21749
COTTON	2	0.00074	0.00066	0.00263	2	1.21834
GRAINS AND SEEDS	3	0.00090	0.00078	0.00311	3	1.71561
FRUITS AND VEGETABLES	4	0.00032	0.00029	0.00114	4	1.02850
FORESTRY&FISHERY PRODS	5	0.00035	0.00032	0.00127	5	1.12258
AGRICULTURAL SERVICES	6	0.00026	0.00023	0.00091	6	1.26083
MISC MET & NON-MET MIN	7	0.00000	0.00000	0.00001	7	1.01082
CRUDE PETROLEUM	8	0.00514	0.00400	0.01597	8	2.07281
NATURAL GAS & LIQ. PET	9	0.00221	0.00129	0.00515	9	1.65455
STONE, GRAVEL AND SAND	10	0.00005	0.00002	0.00008	10	1.16741
POTASH MINING	11	0.00001	0.00000	0.00002	11	1.02765
RESIDENTIAL CONST.	12	0.00000	0.00000	0.00000	12	1.00000
NONRESIDENTIAL CONSTR	13	0.00000	0.00000	0.00000	13	1.00000
ALL OTHER CONST.	14	0.00000	0.00000	0.00000	14	1.00000
CONST. MAINTENANCE	15	0.00592	0.00168	0.00672	15	1.63306
I FOOD PRODUCTS	16	0.00684	0.00612	0.02450	16	1.52083
N FABRICS AND APPAREL	17	0.00013	0.00008	0.00032	17	1.13429
D PAPER PRODUCTS	18	0.00056	0.00002	0.00009	18	1.10670
U PRINTING	19	0.00134	0.00117	0.00465	19	1.11646
S CHEMICAL PRODUCTS	20	0.00047	0.00035	0.00139	20	1.21856
T PLASTIC & PETROLEUM	21	0.01062	0.00839	0.03355	21	2.20646
R GLASS AND STONE PRODS.	22	0.00004	0.00002	0.00008	22	1.18421
Y PRIMARY METAL PRODS.	23	0.00000	0.00000	0.00000	23	1.00000
FABRICATED METAL PRODS	24	0.00000	0.00000	0.00001	24	1.01703
MACHINERY	25	0.01599	0.00029	0.00114	25	1.14535
ELECTRICAL PRODS.	26	0.00002	0.00001	0.00003	26	1.01475
S TRNSPRTTN & WRHSING	27	0.02079	0.00748	0.02993	27	2.54891
E COMMUNICATIONS	28	0.00907	0.00530	0.02117	28	1.68843
L ELECTRICAL UTILITY	29	0.05693	0.00729	0.02916	29	2.08361
L GAS UTILITY	30	0.00914	0.00572	0.02287	30	2.29268
I WATER AND SEWER	3'	0.00193	0.00160	0.00642	31	1.19831
N WHOLESALE TRADE	32	0.02382	0.01759	0.07034	32	3.78618
G RETAIL TRADE	33	0.06393	0.05543	0.22172	33	5.45098
F. I. & R.E	34	0.03423	0.02267	0.09069	34	4.10604
PERSONAL & REPAIR SER.	35	0.02443	0.02059	0.08233	35	2.90470
BUSINESS & MISC. SERV.	36	0.00768	0.00572	0.02289	36	2.46422
MEDICAL & NON-PROFIT	37	0.00537	0.00365	0.01462	37	1.30875
WIPP A/G CONST 1981	38	0.00000	0.00000	0.00000	38	1.00000
WIPP A/G CONST 1982	39	0.00000	0.00000	0.00000	39	1.00000
WIPP A/G CONST 1983	40	0.00000	0.00000	0.00000	40	1.00000
WIPP A/G CONST 1984	41	0.00000	0.00000	0.00000	41	1.00000
WIPP NON-CONST EMP	42	0.00000	0.00000	0.00000	42	1.00000
WIPP B/G CONST 1981	43	0.00000	0.00000	0.00000	43	1.00000
WIPP B/G CONST 1982	44	0.00000	0.00000	0.00000	44	1.00000
WIPP B/G CONST 1983	45	0.00000	0.00000	0.00000	45	1.00000
WIPP B/G CONST 1984	46	0.00000	0.00000	0.00000	46	1.00000
WIPP OPER A/G	47	0.00000	0.00000	0.00000	47	1.00000
WIPP OPER STORAGE	48	0.00000	0.00000	0.00000	48	1.00000
WIPP OPER B/G	49	1.00000	0.00000	0.00000	49	1.00000
HOUSEHOLDS/PC WEEKLY	50	0.00000	1.00000	0.00000	50	1.35024
HOUSEHOLDS/PC LOCAL	51	0.34494	0.05983	1.23931	51	20.70929
*** COLUMN SUMS ***		1.65573	1.23997	1.95978		

1790 076

L.3.1 Wages

First, the level of wages must be determined. The average annual wages and labor cost figures for each of the 37 identified economic subsectors are listed in Table L-3.

Average employee costs for each of the 37 identified subsectors in the input-output model were computed from available Employment Security Commission of New Mexico information. Since complete 1977 data were not available, the 1976 average wage for the area was derived from Covered Employment and Wages, Quarterly Report. Estimates were made for the increase in wages from 1976 to 1977 for each subsector.

To these subsectors wages were added expected fringe benefits. The percentage of fringe benefits added to the wages was computed in several ways. First, several companies were contacted concerning additional costs for labor due to fringe benefits. These companies were principally in the construction, petroleum, and mining categories. For other areas where large companies are not predominant, averages were used which reflected minimum fringe benefits at various salary levels. Thus, the labor cost per employee is the estimated annual wage paid in 1977 plus the expected fringe benefit percentage. Table L-3 gives the annual wage, fringe benefit percent, and estimated annual labor cost for the 37 identified economic subsectors plus the government sector. The government sector annual wage was derived from Bureau of Economic Analysis data.

L.3.2 Calculating Indirect Job Impact

Detailed calculations for the derivation of all indirect jobs created by WIPP in Eddy and Lea Counties are too extensive to list here. However, listed below is a sample calculation that illustrates the procedure used to determine the estimated number of new indirect jobs created by WIPP in the two-county area.

The first step in the procedure is to determine the annual flow of dollars going through the economy due to the increase in activity in a specific economic subsector. The example used in this case is aboveground construction and the year is 1983. It is estimated that the new dollars brought to the area due to aboveground construction in 1983 will be \$63.346 million. This direct impact in construction is then multiplied by the coefficients listed in the input-output table, inverted version, i.e., the direct, indirect, and induced effects (Table L-2) for that specific column in which the activity is taking place (40: aboveground construction--1983).

The process for determining the impact on indirectly affected economic subsectors is illustrated in the following equations:

$$I_{ij} \times AIMP_{1983} = \$IMP_{ij}$$

$$[0.01383 \times \$63,346,000 = \$876,075]$$

Table L-3

ESTIMATED ANNUAL WAGES AND LABOR COSTS PER EMPLOYEE, 1977[1]
LEA AND EDDY COUNTIES

Subsector	Estimated 1977 Annual Wages	Estimated Fringe Benefits (%)	Estimated Annual Labor Costs per Employees, 1977
1. Livestock and livestock products	$ 5,470	10	$ 6,017
2. Cotton crops	5,470	10	6,017
3. Grains and seed crops	5,470	10	6,017
4. Fruits and vegetables	5,470	10	6,017
5. Forestry and fishery products	6,341	17	7,419
6. Agricultural services	6,341	17	7,419
7. Metalic and nonmetalic minerals, NEC	14,424	28	18,463
8. Crude petroleum	12,306	28	15,752
9. Natural gas and natural gas liquid	12,306	28	15,752
10. Stone, gravel and sand	14,424	28	18,463
11. Potash and salt mining	14,988	28	19,185
12. Residential construction	12,340	20	14,808
13. Nonresidential construction	18,033	25	22,541
14. All other construction	13,338	25	16,673
15. Construction maintenance	13,338	16	15,339
16. Food products	7,865	16	9,123
17. Fabrics and apparel	7,035	16	8,161
18. Paper products	7,610	16	8,828
19. Printing	7,332	16	8,505
20. Chemical products	16,968	15	19,513
21. Plastic and petroleum products	19,009	15	21,860
22. Glass and stone products	9,836	16	11,410
23. Primary metal products	*	*	*
24. Fabricated metal products	10,449	16	12,121
25. Machinery	12,374	16	14,354
26. Misc. and electrical products, NEC	7,517	16	8,720
27. Warehouse and transportation	13,090	16	15,184

Table L-3 (Continued)

ESTIMATED ANNUAL WAGES AND LABOR COSTS PER EMPLOYEE, 1977[1]
LEA AND EDDY COUNTIES

Subsector	Estimated 1977 Annual Wages	Estimated Fringe Benefits (%)	Estimated Annual Labor Costs per Employees, 1977
28. Communications	11,750	16	13,630
29. Electrical utilities	13,875	15	15,956
30. Gas utilities	13,875	15	15,956
31. Water and sewer utilities	13,875	16	16,095
32. Wholesale trade	11,761	16	13,643
33. Retail trade	6,344	17	7,422
34. Finance, insurance, and real estate	8,435	16	9,785
35. Persona and repair service	4,700	17	5,499
36. Business and miscellaneous services	7,555	16	8,764
37. Medical and nonprofit	6,148	17	7,193
Government	9,008	16	10,449

*No activity in this subsector in the two-county area.

[1]These wages and labor costs are for those jobs supported in indirectly affected subsectors. Jobs created by (directly associated with) the construction and operation of the WIPP project have annual wages which are not included in the listed figures.

SOURCES: 1977 average wage derived from "Covered Employment and Wages," Quarterly Report, Employment Security Commission of New Mexico, second quarters 1975 and 1976. Wages were estimated for 1977 using an adjustment factor of 6.25%.

Fringe benefits determined from interviews with private companies and unions. Minimum applicable percentages applies to most secondary and tertiary subsectors.

Per employee costs are representative of the annual wage and are not necessarily a 40-hour average week.

where

I_{ij} = coefficient from Table L-2 for row i and column entry j; i = 1,..., 49 and j = 1,..., 49. Example uses i = 28 and j = 40, i.e., $I_{28,\ 40}$ = 0.01383..

$AIMP_{1983}$ = aboveground-construction impact for 1983, i.e., $63,346,000.

$\$IMP_{ij}$ = dollar indirect impact in subsector i due to exogenous increase in subsector j; i.e., impact on communications subsector due to an increase in aboveground-construction activity.

From this calculation it is apparent that the model estimates that the increase in the communication subsector during 1983 will be about $876,000.

The next step is to determine the amount of money in the communications subsector that will be expended for labor, i.e., labor costs. The following equation illustrates this:

$$\$IMP_{ij} \times LC_{51j} = \$LC_{ij}$$

$$[\$876,075 \times 0.33549 = \$293,914]$$

where

LC_{51j} = coefficient for labor costs in subsector j, Table L-1; j = 1,..., 49 (i.e., $LC_{51,28}$ = 0.33549).

$\$LC_{ij}$ = dollars flowing to labor cost in subsector j due to an increase in activity in subsector i (i.e., total labor cost in communications j = 28 as an indirect result of an increase in aboveground-construction i = 40 of $63,346,000 in 1983).

After determining that almost $294,000 will flow into labor costs during 1983 through the communications subsector due to increase aboveground-construction activity, the remaining step is to determine how many jobs this $294,000 will support during 1983. This is accomplished by the following mathematical operation:

$$\$LC_{ij} \div \text{annual } ULC_j = \text{indirect job}_{ij}$$

$$[\$293,914 \div \$13,630 = 21.6]$$

where

Annual ULC_j = annual average per unit labor cost in subsector j (i.e., in subsector j = 28. Communications annual ULC_j = $13,630).

Indirect Job_{ij} = Number of new jobs in subsector j supported by new activity in subsector i (i.e., i = 40, aboveground construction $63,346,000 supports 18.9 jobs in j = 28 communications).

This example shows that the resulting impact on jobs in this subsector--communications--will be 21.6 jobs for 1983. Obviously the number of jobs supported indirectly by the WIPP project will vary from year to year. Tables L-4 through L-8 list the indirect effects of the WIPP for each year from 1981 through 1984, and for an average year thereafter. These tables list the estimated dollar volume flow into the indirect, private subsectors of the two-county economy, i.e., 37 subsectors, and the number of jobs indirectly created in each one of these subsectors. It should be noted that these jobs and the dollar flows are for the private sector only. The government sector is computed separately from the foregoing process.

Government jobs supported by the construction and operation impact of the WIPP are computed in a different manner. The Bureau of Economic Analysis, Department of Commerce, provides estimates of government employment as well as private major sector employment figures. The latest figures available from this source are for 1975. The period 1970-1975 was examined for increases in State and local government employment; Federal Government employment in the area was constant. The marginal increase in government jobs in relation to private sector jobs was then computed. For each 200 private sector jobs, 17 government jobs were created.

Tables L-9 through L-13 which list indirect employment impact by major sector (including government) and give the employment multiplier associated with each year. Table L-14 gives the total number of direct, private indirect, and government jobs supported (created) by the WIPP project for the years 1981 through 1986 for the two-county area covered by the study.

L.4 POPULATION

Three critical areas of economic analysis must be analyzed in order to determine overall impact generated by an exogenous increase in a specific activity within a region--employment increases, increases in the flow of dollars including personal income, and population changes. The order in which these specific categories are computed is important to the methodology demonstrated in this appendix.

Changes in employment and increases in dollar flows can be derived directly from the results of the input-output model. Population migration, however, is dependent upon the increase in employment derived from the input-output model. While derivation of employment depends on assumptions concerning certain coefficients and factors drawn from previous studies, increases in population may be significantly influenced by changes in activity in other areas of the economy which cannot be predicted with reasonable accuracy. Specific conditions of uncertainty involve mining, which supports much of the economic activity within the two-county area.

Recent examples of fluctuation in economic activity that make it difficult to determine exact population migration figures are evident. Between 1960 and 1970 both Eddy and Lea Counties lost population principally because of decreased levels of activity in the mining sector. The population of Eddy County during the 10-year period decreased 19% while the population loss in Lea County was just more than 7%. Before this decreasing trend was recognized, in the mid- and early 1960s, population projections produced by the

Table L-4

INDIRECT IMPACT IN 1981
DOLLAR VOLUME AND JOBS SUPPORTED (000S 1977 DOLLARS) BY SUB-SECTOR

SUB-SECTOR	ABOVEGROUND CONSTRUCTION		NON-CONSTRUCTION ACTIVITY		BELOWGROUND CONSTRUCTION	
	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED
1. LIVESTK & LIVESTK PROD	$ 22.6	0.1	$ 10.1	0.1	$ 9.2	0.1
2. COTTON	10.7	0.1	4.7	0.1	4.5	0.1
3. GRAINS AND SEEDS	14.4	0.2	6.1	0.1	5.4	0.1
4. FRUITS AND VEGETABLES	4.4	0.1	2.0	0.0	1.8	0.0
5. FORESTRY&FISHERY PRODS	4.9	0.0	2.2	0.0	2.0	0.0
6. AGRICULTURAL SERVICES	11.8	0.4	1.8	0.1	2.7	0.1
7. MISC MET & NON-MET MIN	0.0	0.0	0.0	0.0	0.0	0.0
8. CRUDE PETROLEUM	76.7	0.3	42.1	0.2	32.4	0.1
9. NATURAL GAS & LIQ. PET	22.9	0.1	14.6	0.1	11.2	0.0
10. STONE, GRAVEL AND SAND	151.9	2.6	0.4	0.0	37.1	0.6
11. POTASH MINING	0.2	0.0	0.1	0.0	0.1	0.0
12. RESIDENTIAL CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
13. NONRESIDENTIAL CONSTR*	0.0	0.0	0.0	0.0	0.0	0.0
14. ALL OTHER CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
15. CONST. MAINTENANCE	40.3	1.3	46.8	1.5	20.8	0.7
16. FOOD PRODUCTS	99.0	1.6	43.1	0.7	41.2	0.7
17. FABRICS AND APPAREL	2.9	0.1	0.9	0.0	1.8	0.1
18. PAPER PRODUCTS	1.1	0.0	0.8	0.0	1.2	0.0
19. PRINTING	19.7	0.9	11.6	0.5	8.2	0.4
20. CHEMICAL PRODUCTS	8.0	0.1	7.8	0.1	3.6	0.0
21. PLASTIC & PETROLEUM	161.6	0.6	88.1	0.3	67.9	0.3
22. GLASS AND STONE PRODS.	9.6	0.3	0.4	0.0	2.8	0.1
23. PRIMARY METAL PRODS.	0.0	0.0	0.0	0.0	0.0	0.0
24. FABRICATED METAL PRODS	27.5	0.6	0.1	0.0	7.0	0.2
25. MACHINERY	9.3	0.2	15.0	0.4	22.5	0.6
26. ELECTRICAL PRODS.	0.2	0.0	0.6	0.0	0.1	0.0
27. TRNSPRTTN & WRHSING	243.0	6.3	103.7	2.7	130.5	3.4
28. COMMUNICATIONS	194.4	4.8	120.9	3.0	57.9	1.4
29. ELECTRICAL UTILITY	150.8	1.2	70.6	0.6	184.2	1.5
30. GAS UTILITY	95.1	0.8	65.2	0.5	45.2	0.4
31. WATER AND SEWER	29.3	0.2	19.2	0.2	12.7	0.1
32. WHOLESALE TRADE	1,642.4	51.4	201.2	6.3	1,147.6	35.9
33. RETAIL TRADE	884.5	50.9	481.2	27.7	362.2	20.9
34. F. I. & R.E	586.3	21.7	369.5	13.7	227.8	8.4
35. PERSONAL & REPAIR SER.	401.5	23.6	239.7	14.1	185.1	10.9
36. BUSINESS & MISC. SERV.	145.8	4.7	343.2	11.1	70.5	2.3
37. MEDICAL & NON-PROFIT	61.4	4.1	38.9	2.6	26.0	1.8
TOTAL INDIRECT IMPACT	=$5,134.0	=180	=$2,352.5	=87	=$2,733.1	=91

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. subsector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impacts of the construction sub-sector portions cycled through the F.I.R.E. sub-sector are not available.

Source: Larry Adcock and Associates, 1978.

Table L-5

INDIRECT IMPACT IN 1982
DOLLAR VOLUME AND JOBS SUPPORTED (000S 1977 DOLLARS) BY SUB-SECTOR

SUB-SECTOR	ABOVEGROUND CONSTRUCTION		NON-CONSTRUCTION ACTIVITY		BELOWGROUND CONSTRUCTION	
	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED
1. LIVESTK & LIVESTK PROD	$ 94.5	0.6	$ 25.1	0.2	$ 30.6	0.2
2. COTTON	44.7	0.6	11.6	0.1	14.7	0.2
3. GRAINS AND SEEDS	56.4	0.7	15.2	0.2	17.6	0.2
4. FRUITS AND VEGETABLES	18.9	0.2	5.0	0.1	6.1	0.1
5. FORESTRY&FISHERY PRODS	21.1	0.2	5.6	0.0	6.8	0.1
6. AGRICULTURAL SERVICES	32.0	1.2	4.4	0.2	6.7	0.2
7. MISC MET & NON-MET MIN	0.1	0.0	0.1	0.0	0.0	0.0
8. CRUDE PETROLEUM	295.3	1.1	104.5	0.4	96.5	0.4
9. NATURAL GAS & LIQ. PET	91.4	0.3	36.2	0.1	32.1	0.1
10. STONE, GRAVEL AND SAND	312.8	5.3	1.0	0.0	53.4	0.9
11. POTASH MINING	0.5	0.0	0.2	0.0	0.1	0.0
12. RESIDENTIAL CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
13. NONRESIDENTIAL CONSTR*	0.0	0.0	0.0	0.0	0.0	0.0
14. ALL OTHER CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
15. CONST. MAINTENANCE	140.8	4.6	116.3	3.8	50.8	1.7
16. FOOD PRODUCTS	414.7	6.8	107.0	1.7	135.8	2.2
17. FABRICS AND APPAREL	8.8	0.3	2.2	0.1	3.5	0.1
18. PAPER PRODUCTS	3.0	0.1	1.9	0.1	2.1	0.1
19. PRINTING	80.5	3.5	28.9	1.3	26.3	1.1
20. CHEMICAL PRODUCTS	28.4	0.3	19.5	0.2	9.5	0.1
21. PLASTIC & PETROLEUM	621.5	2.4	218.7	0.9	202.4	0.8
22. GLASS AND STONE PRODS.	20.4	0.6	0.9	0.0	4.2	0.1
23. PRIMARY METAL PRODS.	0.0	0.0	0.0	0.0	0.0	0.0
24. FABRICATED METAL PRODS	56.6	1.3	0.2	0.0	10.0	0.2
25. MACHINERY	28.9	0.7	37.3	0.9	35.9	0.9
26. ELECTRICAL PRODS.	0.7	0.0	1.4	0.0	0.3	0.0
27. TRNSPRTTN & WRHSING	757.5	19.8	257.6	6.7	280.9	7.3
28. COMMUNICATIONS	582.2	14.3	300.2	7.4	149.4	3.7
29. ELECTRICAL UTILITY	561.5	4.6	175.5	1.4	355.5	2.9
30. GAS UTILITY	392.8	3.2	162.0	1.3	136.5	1.1
31. WATER AND SEWER	115.5	0.9	47.7	0.4	38.3	0.3
32. WHOLESALE TRADE	3,981.9	124.7	499.6	15.6	1,865.9	58.4
33. RETAIL TRADE	3,730.4	214.8	1,195.1	68.8	1,213.9	69.9
34. F. I. & R.E	1,987.2	73.6	917.5	34.0	610.6	22.6
35. PERSONAL & REPAIR SER.	1,535.2	90.4	595.2	35.1	523.3	30.8
36. BUSINESS & MISC. SERV.	497.0	16.1	852.4	27.6	172.8	5.6
37. MEDICAL & NON-PROFIT	252.3	17.0	96.7	6.5	83.0	5.6
TOTAL INDIRECT IMPACT	=$16,765.4	=610	=$5,842.5	=215	=$6,175.7	=218

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. subsector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impacts of the construction sub-sector portions cycled through the F.I.R.E. sub-sector are not available.

Source: Larry Adcock and Associates, 1978.

Table L-6

INDIRECT IMPACT IN 1983
DOLLAR VOLUME AND JOBS SUPPORTED (000S 1977 DOLLARS) BY SUB-SECTOR

SUB-SECTOR	ABOVEGROUND CONSTRUCTION		NON-CONSTRUCTION ACTIVITY		BELOWGROUND CONSTRUCTION	
	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED
1. LIVESTK & LIVESTK PROD	$ 140.8	0.9	$ 45.4	0.3	$ 41.8	0.3
2. COTTON	56.7	0.8	20.9	0.3	20.0	0.3
3. GRAINS AND SEEDS	84.2	1.1	27.4	0.3	23.9	0.3
4. FRUITS AND VEGETABLES	28.2	0.4	9.0	0.1	8.4	0.1
5. FORESTRY&FISHERY PRODS	31.4	0.2	10.1	0.1	9.3	0.1
6. AGRICULTURAL SERVICES	48.3	1.8	8.0	0.3	8.8	0.3
7. MISC MET & NON-MET MIN	0.2	0.0	0.1	0.0	0.1	0.0
8. CRUDE PETROLEUM	441.1	1.6	188.6	0.7	129.9	0.5
9. NATURAL GAS & LIQ. PET	136.3	0.5	65.3	0.2	43.0	0.2
10. STONE, GRAVEL AND SAND	477.8	8.1	1.8	0.0	61.9	1.0
11. POTASH MINING	0.8	0.0	0.3	0.0	0.2	0.0
12. RESIDENTIAL CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
13. NONRESIDENTIAL CONSTR*	0.0	0.0	0.0	0.0	0.0	0.0
14. ALL OTHER CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
15. CONST. MAINTENANCE	210.9	6.9	210.0	6.9	66.5	2.2
16. FOOD PRODUCTS	618.1	10.1	193.1	3.2	185.0	3.0
17. FABRICS AND APPAREL	13.2	0.4	4.0	0.1	4.5	0.1
18. PAPER PRODUCTS	4.5	0.1	3.4	0.1	2.5	0.1
19. PRINTING	120.0	5.2	52.1	2.3	35.7	1.6
20. CHEMICAL PRODUCTS	42.5	0.4	35.2	0.3	12.6	0.1
21. PLASTIC & PETROLEUM	928.2	3.6	394.9	1.5	272.4	1.1
22. GLASS AND STONE PRODS.	31.1	0.8	1.6	0.0	5.0	0.1
23. PRIMARY METAL PRODS.	0.0	0.0	0.0	0.0	0.0	0.0
24. FABRICATED METAL PRODS	86.5	2.0	0.4	0.0	11.6	0.3
25. MACHINERY	43.4	1.1	67.4	1.7	42.8	1.1
26. ELECTRICAL PRODS.	1.0	0.0	2.5	0.1	0.4	0.0
27. TRNSPRTTN & WRHSING	1,138.2	29.7	465.0	12.1	359.1	9.4
28. COMMUNICATIONS	876.0	21.6	541.9	13.3	196.9	4.8
29. ELECTRICAL UTILITY	839.4	6.9	316.8	2.6	444.6	3.7
30. GAS UTILITY	585.6	4.8	292.5	2.4	184.0	1.5
31. WATER AND SEWER	172.4	1.4	86.1	0.7	51.6	0.4
32. WHOLESALE TRADE	6,038.3	189.1	901.9	28.3	2,239.5	70.1
33. RETAIL TRADE	5,559.0	320.1	2,157.6	124.2	1,656.9	95.4
34. F. I. & R.E	2,978.5	110.3	1,656.5	61.3	809.8	30.0
35. PERSONAL & REPAIR SER.	2,293.4	135.1	1,074.5	63.3	699.2	41.2
36. BUSINESS & MISC. SERV.	744.8	24.1	1,538.8	49.9	226.0	7.3
37. MEDICAL & NON-PROFIT	376.2	25.4	17[illegible].6	11.8	112.7	7.6
TOTAL INDIRECT IMPACT	=$25,158.0	=915	=$10,547.5	=389	=$7,966.5	=284

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. subsector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impacts of the construction sub-sector portions cycled through the F.I.R.E. sub-sector are not available.

Source: Larry Adcock and Associates, 1978.

Table L-7

INDIRECT IMPACT IN 1984
DOLLAR VOLUME AND JOBS SUPPORTED (000S 1977 DOLLARS) BY SUB-SECTOR

SUB-SECTOR	ABOVEGROUND CONSTRUCTION		NON-CONSTRUCTION ACTIVITY		BELOWGROUND CONSTRUCTION	
	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED
1. LIVESTK & LIVESTK PROD	$ 74.0	0.5	$ 65.6	0.4	$ 22.3	0.1
2. COTTON	35.0	0.4	30.2	0.4	10.7	0.1
3. GRAINS AND SEEDS	44.2	0.6	39.6	0.5	12.7	0.2
4. FRUITS AND VEGETABLES	14.8	0.2	13.0	0.2	4.5	0.1
5. FORESTRY&FISHERY PRODS	16.5	0.1	14.5	0.1	5.0	0.0
6. AGRICULTURAL SERVICES	24.9	0.9	11.6	0.4	4.7	0.2
7. MISC MET & NON-MET MIN	0.1	0.0	0.2	0.0	0.0	0.0
8. CRUDE PETROLEUM	231.3	0.9	272.8	1.0	69.2	0.3
9. NATURAL GAS & LIQ. PET	71.6	0.3	94.4	0.4	22.9	0.1
10. STONE, GRAVEL AND SAND	242.7	4.1	2.6	0.0	32.0	0.5
11. POTASH MINING	0.4	0.0	0.5	0.0	0.1	0.0
12. RESIDENTIAL CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
13. NONRESIDENTIAL CONSTR*	0.0	0.0	0.0	0.0	0.0	0.0
14. ALL OTHER CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
15. CONST. MAINTENANCE	110.1	3.6	303.7	10.0	35.3	1.2
16. FOOD PRODUCTS	325.1	5.3	279.3	4.6	98.9	1.6
17. FABRICS AND APPAREL	6.8	0.2	5.8	0.2	2.4	0.1
18. PAPER PRODUCTS	2.3	0.1	4.9	0.1	1.3	0.0
19. PRINTING	63.1	2.8	75.4	3.3	19.1	0.8
20. CHEMICAL PRODUCTS	22.2	0.2	50.9	0.5	6.7	0.1
21. PLASTIC & PETROLEUM	486.7	1.9	571.0	2.2	145.2	0.6
22. GLASS AND STONE PRODS.	15.9	0.4	2.3	0.1	2.6	0.1
23. PRIMARY METAL PRODS.	0.0	0.0	0.0	0.0	0.0	0.0
24. FABRICATED METAL PRODS	43.9	1.0	0.5	0.0	6.0	0.1
25. MACHINERY	22.6	0.6	97.5	2.4	22.3	0.6
26. ELECTRICAL PRODS.	0.5	0.0	3.6	0.1	0.2	0.0
27. TRNSPRTTN & WRHSING	591.7	15.4	672.4	17.5	189.7	4.9
28. COMMUNICATIONS	454.5	11.2	783.6	19.3	104.6	2.6
29. ELECTRICAL UTILITY	439.5	3.6	458.1	3.8	233.8	1.9
30. GAS UTILITY	307.8	2.5	423.0	3.5	98.1	0.8
31. WATER AND SEWER	90.5	0.7	124.5	1.0	27.5	0.2
32. WHOLESALE TRADE	3,098.9	97.1	1,304.3	40.9	1,167.9	36.6
33. RETAIL TRADE	2,923.9	168.3	3,120.1	179.6	885.7	51.0
34. F. I. & R.E	1,553.9	57.5	2,395.4	88.7	430.6	15.9
35. PERSONAL & REPAIR SER.	1,202.1	70.8	1,553.8	91.5	372.3	21.9
36. BUSINESS & MISC. SERV.	388.7	12.6	2,225.3	72.1	119.9	3.9
37. MEDICAL & NON-PROFIT	197.7	13.3	252.4	17.0	60.2	4.1
TOTAL INDIRECT IMPACT	=$13,104.1	=477	=$15,253.0	=562	=$4,214.4	=151

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. subsector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impacts of the construction ...

Table L-8

INDIRECT IMPACT, AVERAGE YEAR, 1985 AFTER
DOLLAR VOLUME AND JOBS SUPPORTED (000S 1977 DOLLARS) BY SUB-SECTOR

SUB-SECTOR	ABOVEGROUND OPERATION		NON-OPERATION ACTIVITY		BELOWGROUND OPERATION	
	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED	ESTIMATED $ VOLUME	JOBS SUPPORTED
1. LIVESTK & LIVESTK PROD	$ 48.2	0.3	$ 9.0	0.1	$ 14.8	0.1
2. COTTON	22.2	0.3	3.9	0.0	7.0	0.1
3. GRAINS AND SEEDS	29.1	0.4	9.4	0.1	8.5	0.1
4. FRUITS AND VEGETABLES	9.6	0.1	1.7	0.0	3.0	0.0
5. FORESTRY&FISHERY PRODS	10.7	0.1	1.9	0.0	3.4	0.0
6. AGRICULTURAL SERVICES	8.5	0.3	1.6	0.1	2.5	0.1
7. MISC MET & NON-MET MIN	0.1	0.0	0.1	0.0	0.0	0.0
8. CRUDE PETROLEUM	200.6	0.7	73.4	0.3	48.6	0.2
9. NATURAL GAS & LIQ. PET	69.4	0.3	29.5	0.1	20.9	0.1
10. STONE, GRAVEL AND SAND	1.9	0.0	0.6	0.0	0.5	0.0
11. POTASH MINING	0.4	0.0	0.0	0.0	0.1	0.0
12. RESIDENTIAL CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
13. NONRESIDENTIAL CONSTR*	0.0	0.0	0.0	0.0	0.0	0.0
14. ALL OTHER CONST.*	0.0	0.0	0.0	0.0	0.0	0.0
15. CONST. MAINTENANCE	223.3	7.3	82.7	2.7	56.1	1.8
16. FOOD PRODUCTS	205.4	3.4	35.9	0.6	64.7	1.1
17. FABRICS AND APPAREL	4.2	0.1	2.0	0.1	1.2	0.0
18. PAPER PRODUCTS	3.6	0.1	0.5	0.0	5.3	0.1
19. PRINTING	55.4	2.4	8.3	0.4	12.6	0.6
20. CHEMICAL PRODUCTS	37.4	0.4	3.8	0.0	4.4	0.0
21. PLASTIC & PETROLEUM	419.8	1.6	152.3	0.6	100.6	0.4
22. GLASS AND STONE PRODS.	1.7	0.0	0.4	0.0	0.4	0.0
23. PRIMARY METAL PRODS.	0.0	0.0	0.0	0.0	0.0	0.0
24. FABRICATED METAL PRODS	0.4	0.0	0.1	0.0	0.0	0.0
25. MACHINERY	71.7	1.8	2.7	0.1	151.4	3.8
26. ELECTRICAL PRODS.	2.7	0.1	0.1	0.0	0.2	0.0
27. TRNSPRTTN & WRHSING	494.4	12.9	329.5	8.6	196.9	5.1
28. COMMUNICATIONS	576.1	14.2	62.4	1.5	85.9	2.1
29. ELECTRICAL UTILITY	336.8	2.8	102.2	0.8	539.0	4.4
30. GAS UTILITY	311.0	2.6	56.5	0.5	86.6	0.7
31. WATER AND SEWER	91.6	0.7	14.2	0.1	18.3	0.1
32. WHOLESALE TRADE	959.0	30.0	186.1	5.8	225.5	7.1
33. RETAIL TRADE	2,294.0	132.1	364.0	21.0	605.2	34.8
34. F. I. & R.E	1,761.2	65.2	215.3	8.0	324.1	12.0
35. PERSONAL & REPAIR SER.	1,142.4	67.3	204.2	12.0	231.3	13.6
36. BUSINESS & MISC. SERV.	1,636.1	53.0	75.8	2.5	72.7	2.4
37. MEDICAL & NON-PROFIT	185.6	12.5	23.9	1.6	50.8	3.4
TOTAL INDIRECT IMPACT	=$11,214.3	=413	=$2,054.0	=68	=$2,942.6	=94

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. subsector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impacts of the construction sub-sector portions cycled through the F.I.R.E. sub-sector are not available.

Source: Larry Adcock and Associates, 1978.

Table L-9

INDIRECT IMPACT IN 1981
DOLLAR VOLUME AND JOBS SUPPORTED BY MAJOR SECTOR

Major Sector	Above Ground Construction: Estimated $ Volume 000S	Above Ground Construction: Jobs Supported	Non-Construction Activity: Estimated $ Volume 000S	Non-Construction Activity: Jobs Supported	Below Ground Construction: Estimated $ Volume 000S	Below Ground Construction: Jobs Supported	Total 1981: Estimated $ Volume Millions	Total 1981: Jobs Supported
Agriculture	$ 68.8	1.0	$ 26.9	0.3	$ 25.6	0.3	$ 0.1	1.6
Mining	251.6	2.9	57.1	0.2	80.7	0.8	0.4	3.9
Construction*	40.3	1.3	46.8	1.5	20.8	0.7	0.1	3.5
Manufacturing	338.8	4.4	168.3	2.1	156.3	2.2	0.7	8.7
Transportation, Communications, and Utilities	712.6	13.4	379.7	7.0	430.6	6.8	1.5	27.2
Trade	2,527.0	102.4	682.4	34.0	1,509.8	56.8	4.7	193.2
Finance, Insurance, and Real Estate	586.3	21.7	369.5	13.7	227.8	8.4	1.2	43.8
Services	608.6	32.5	621.8	27.9	281.6	14.9	1.5	75.3
Sub-Total	≈ $5,134.0	≈ 180	≈ $2,352.5	≈ 87	≈ $2,733.1	≈ 91	≈ $10.2	≈ 358
Government	N/A	≈ 34	N/A	≈ 12	N/A	≈ 14	N/A	≈ 60
Total		≈ 214		≈ 99		≈ 105		≈ 418

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. sector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impact of the Construction sector portion cycled through the F.I.R.E. sector is not available.

Note: Employment multiplier = 1.22 (additive).

Table L-10

INDIRECT IMPACT IN 1982
DOLLAR VOLUME AND JOBS SUPPORTED BY MAJOR SECTOR

Major Sector	Above Ground Construction: Estimated $ Volume 000S	Above Ground Construction: Jobs Supported	Non-Construction Activity: Estimated $ Volume 000S	Non-Construction Activity: Jobs Supported	Below Ground Construction: Estimated $ Volume 000S	Below Ground Construction: Jobs Supported	Total 1982: Estimated $ Volume Millions	Total 1982: Jobs Supported
Agriculture	$ 267.5	3.5	$ 66.8	0.8	$ 82.5	1.0	$ 0.4	5.3
Mining	700.2	6.7	141.9	0.5	182.2	1.4	1.0	8.6
Construction*	140.8	4.6	116.3	3.8	50.8	1.7	0.3	10.1
Manufacturing	1,263.5	16.0	418.0	5.2	430.0	5.7	2.1	26.9
Transportation, Communications, and Utilities	2,409.4	42.9	942.9	17.3	960.6	15.4	4.3	75.6
Trade	7,712.3	339.5	1,694.7	84.5	3,079.7	128.3	12.5	552.3
Finance, Insurance, and Real Estate	1,987.2	73.6	917.5	34.0	610.6	22.6	3.5	130.2
Services	2,284.5	123.6	1,544.2	69.2	779.1	42.0	4.6	234.8
Sub-Total	=16,765.4	=610	=5,842.5	=215	=6,175.7	=218	=$28.7	=1,043
Government	N/A	=98	N/A	=31	N/A	=32	N/A	=161
Total		=708		=246		=250		=1,204

Detail may not equal total due to rounding.

*A portion of construction impact is experienced in the F.I.R.E. sector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impact of the Construction sector portion cycled through the F.I.R.E. sector is not available.

Note: Employment multiplier = 1.41 (additive).

Source: Larry Adcock and Associates, 1978.

Table L-11

INDIRECT IMPACT IN 1983
DOLLAR VOLUME AND JOBS SUPPORTED BY MAJOR SECTOR

Major Sector	Above Ground Construction: Estimated $ Volume 000S	Above Ground Construction: Jobs Supported	Non-Construction Activity: Estimated $ Volume 000S	Non-Construction Activity: Jobs Supported	Below Ground Construction: Estimated $ Volume 000S	Below Ground Construction: Jobs Supported	Total 1983: Estimated $ Volume Millions	Total 1983: Jobs Supported
Agriculture	$ 399.5	5.2	$ 120.7	1.4	$ 112.1	1.3	$ 0.6	7.9
Mining	1,056.2	10.2	256.2	1.0	235.0	1.7	1.5	12.9
Construction*	210.9	6.9	210.0	6.9	66.5	2.2	0.5	16.0
Manufacturing	1,888.7	23.9	754.6	9.3	572.4	7.5	3.2	40.7
Transportation, Communications, and Utilities	3,611.6	64.4	1,702.2	31.2	1,236.2	19.8	6.6	115.4
Trade	11,597.3	509.2	3,059.5	152.5	3,896.4	165.5	18.6	827.2
Finance, Insurance, and Real Estate	2,978.5	110.3	1,656.5	61.3	809.8	30.0	5.4	201.6
Services	3,414.4	184.6	2,787.9	125.0	1,037.0	56.1	7.2	365.7
Sub-Total	≈$25,158.0	≈915	≈$10,547.5	≈389	≈ 7,966.5	≈284	≈$43.6	≈1,588
Government	N/A	≈146	N/A	≈56	N/A	≈44	N/A	≈246
Total		≈1,061		≈445		≈328		≈1,834

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. sector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impact of the Construction sector portion cycled through the F.I.R.E. sector is not available.

Note: Employment multiplier = 1.40 (additive).

Source: Larry Adcock and Associates, 1978.

Table L-12

INDIRECT IMPACT IN 1984
DOLLAR VOLUME AND JOBS SUPPORTED BY MAJOR SECTOR

	Above Ground Construction		Non-Construction Activity		Below Ground Construction		Total 1984	
Major Sector	Estimated $ Volume 000S	Jobs Supported	Estimated $ Volume 000S	Jobs Supported	Estimated $ Volume 000S	Jobs Supported	Estimated $ Volume Millions	Jobs Supported
Agriculture	$ 209.5	2.7	$ 174.5	2.0	$ 59.9	0.7	$ 0.4	5.4
Mining	546.1	5.2	370.5	1.4	124.3	0.9	1.0	7.5
Construction*	110.1	3.6	303.7	10.0	35.3	1.2	0.4	14.8
Manufacturing	989.1	12.5	1,091.2	13.5	304.6	4.0	2.4	30.0
Transportation, Communications, and Utilities	1,884.0	33.5	2,461.6	45.1	653.7	10.5	5.0	89.1
Trade	6,022.8	265.4	4,424.4	220.5	2,053.6	87.6	12.5	573.5
Finance, Insurance, and Real Estate	1,553.9	57.5	2,395.4	88.7	430.6	15.9	4.4	162.1
Services	1,788.5	96.8	4,031.6	180.7	552.4	29.9	6.4	307.4
Sub-Total	≈ $13,104.1	≈ 477	≈ $15,253.0	≈ 562	≈ $4,214.4	≈ 151	≈ $32.5	≈ 1,190
Government	N/A	≈ 77	N/A	≈ 81	N/A	≈ 23	N/A	≈ 181
Total		≈ 554		≈ 643		≈ 174		≈ 1,371

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. sector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impact of the Construction sector portion cycled through the F.I.R.E. sector is not available.

Note: Employment multiplier = 1.46 (additive).

Source: Larry Adcock and Associates, 1978.

Table L-13

INDIRECT IMPACT, AVERAGE YEAR, 1985 AND AFTER
DOLLAR VOLUME AND JOBS SUPPORTED BY MAJOR SECTOR

Major Sector	SURFACE OPERATION Estimated $ Volume 000S	SURFACE OPERATION Jobs Supported	STORAGE OPERATION Estimated $ Volume 000S	STORAGE OPERATION Jobs Supported	MINING OPERATION Estimated $ Volume 000S	MINING OPERATION Jobs Supported	TOTAL AVERAGE YEAR, 1985 AND AFTER Estimated $ Volume Millions	TOTAL AVERAGE YEAR, 1985 AND AFTER Jobs Supported
Agriculture	$ 128.3	1.5	$ 27.5	0.3	$ 39.2	0.4	$ 0.2	2.2
Mining	272.4	1.0	103.7	0.4	70.2	0.3	0.4	1.7
Construction*	223.3	7.3	82.7	2.7	56.1	1.8	0.4	11.8
Manufacturing	802.3	9.9	206.1	1.7	340.9	6.0	1.3	17.6
Transportation, Communications, and Utilities	1,809.8	33.2	564.8	11.6	926.5	12.6	3.3	57.4
Trade	3,252.9	162.1	550.1	26.8	830.8	41.9	4.6	230.8
Finance, Insurance, and Real Estate	1,761.2	65.2	215.3	8.0	324.1	12.0	2.3	85.2
Services	2,964.1	132.9	303.9	16.1	354.8	19.4	3.6	168.4
Sub-Total	≈$11,214.3	≈413	≈$2,054.0	68	≈$2,942.6	≈94	≈$16.1	≈575
Government	N/A	≈59	N/A	≈10	N/A	≈17	N/A	≈86
Total		≈472		≈78		≈111		≈661

Detail may not equal total due to rounding.

* A portion of construction impact is experienced in the F.I.R.E. sector due to the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. Exact impact of the Construction sector portion cycled through the F.I.R.E. sector is not available.

Note: Employment multiplier = 1.49 (additive).

Source: Larry Adcock and Associates, 1978.

Table L-14

JOBS CREATED AND/OR SUPPORTED BY THE CONSTRUCTION AND OPERATION OF THE WASTE ISOLATON PILOT PLANT 1981 THROUGH 1986

Activity	1981	1982	1983	1984	1985	1986
ABOVEGROUND CONSTRUCTION						
Direct jobs	216	540	805	425	0	---
Private, indirect jobs	180	610	915	477	0	---
Government jobs	34	98	146	77	0	---
Total jobs	430	1248	1866	979	0	---
Annual new jobs	430	818	618	(887)	(979)	---
NONCONSTRUCTION ACTIVITY						
Direct jobs	60	149	269	389	0	---
Private, indirect jobs	87	215	389	562	0	---
Government jobs	12	31	56	81	0	---
Total jobs	159	395	714	1032	0	---
Annual new jobs	159	236	319	319	(1032)	---
BELOWGROUND CONSTRUCTION						
Direct jobs	68	164	233	125	0	---
Private, indirect jobs	91	218	284	151	0	---
Government jobs	14	32	44	23	0	---
Total jobs	173	414	561	299	0	---
Annual new jobs	173	241	147	(262)	(299)	---
OPERATION ABOVE GROUND						
Direct jobs	---	---	---	0	286	286
Private, indirect jobs	---	---	---	0	413	413
Government jobs	---	---	---	0	59	59
Total jobs	---	---	---	0	758	758
Annual new jobs	---	---	---	0	758	0
OPERATION STORAGE						
Direct jobs	---	---	---	0	49	49
Private, indirect jobs	---	---	---	0	68	68
Government jobs	---	---	---	0	10	0
Total jobs	---	---	---	0	127	127
Annual new jobs	---	---	---	0	127	0
OPERATION BELOW GROUND						
Direct jobs	---	---	---	0	109	109
Private, indirect jobs	---	---	---	0	94	94
Government jobs	---	---	---	0	17	17
Total jobs	---	---	---	0	220	220
Annual new jobs	---	---	---	0	220	0
TOTAL ALL ACTIVITIES						
Direct jobs	344	853	1307	939	444	444
Private, indirect jobs	358	1043	1588	1190	575	575
Government jobs	60	161	246	181	86	86
Total jobs	762	2057	3141	2310	1105	1105
Annual new jobs	762	1295	1084	(831)	(1205)	0

Bureau of Business and Economic Research (BBER), the official state population projecting agency, were relatively high, indicating that professional demographic researchers felt that the area would continue to grow. Later population projections by the federal government and the BBER indicated somewhat lower levels of population growth. Since 1970 and particularly since the energy crisis, both counties have maintained high levels of growth. Growth in Eddy County is correlated with the cessation of potash "dumping" on the U.S. market by Canadian firms. In Lea County higher levels of oil and gas exploration and production have increased the population.

While the current outlook--particularly during the last 5 or 6 years--has been one of high expectations in terms of population growth in the near future, such population growth is influenced by a number of outside factors. For example, the Arab oil embargo and high prices within the petroleum industry have indirectly created growth in Lea County and in the city of Hobbs. Should the situation with the petroleum industry change, then the degree of growth could also change within the area. In terms of growth within Eddy County the potash industry (the major basic industry) now supplies 93% of all potash sold in U.S. markets. Should the demand for potash decrease, then the activity in the mining sector within Eddy County would be significantly affected.

Personal interviews with the industrial development executives for Hobbs and Carlsbad indicate that a determined effort is under way to diversify the economy of both counties in order to stabilize their economic bases. Because of the high level of activity in the extractive industries, the availability of labor to fill certain occupations within Eddy and Lea Counties may dictate that a number of laborers have to move into the area. However, recent developments while this study was being conducted tend to indicate that there is at least a reasonable labor supply for many of the needed occupations within the area.

Employment applicant records from the Employment Security Commission were examined to determine labor availability for various occupations. From this examination the percentage of individuals needed for those occupations directly connected with the construction and operation of the WIPP was determined. However, events in November 1977 seemed to loosen the labor market. Beker Industries announced that it would close its anhydrous ammonia plant, idling about 100 employees. The Duval Corporation, a potash mining company, announced that it would curtail its sylvite operations at its Carlsbad property by mid-1978. This curtailment rendered approximately 200 individuals unemployed. On the brighter side of the economic picture, the Brantley Dam Project on the Pecos River between Artesia and Carlsbad was rescheduled for construction starting in 1980. Therefore, the Brantley Dam Project construction period will overlap somewhat the proposed schedule for the WIPP. In effect, the availability of construction workers within the area would again be restricted.

These examples serve to point out that the economic activity within an area can change rather rapidly. As the level of economic activity changes, available labor in certain occupations also changes. Migration of individuals to fill positions for a large construction project or to operate a facility such as the WIPP depends on many factors. These include the recruitment procedure for employees, the availability of labor within an area, the construction company subcontracting practices, availability of community facilities, etc.

Many of the major factors affecting immigration can be recognized, but dealing with them in a quantitative manner becomes much more difficult. Researchers therefore tend to rely on previous studies conducted to determine the degree of migration and/or specific analogous case studies of construction projects. Possibly one of the best studies to be produced in recent years is a study entitled Construction Worker Profile, completed for the Old West Regional Commission in early 1976. A large number of the migration factors contained in this appendix have been drawn from this document. However, for the determination of those individuals who are expected to move into the area to the jobs in secondary and tertiary sectors, i.e., spinoff jobs from the construction and operation of the power plant, there is very little information available. These facts should be recognized while reading this appendix.

L.4.1 Population Impact Calculations

In order to determine the extent of impact on population brought about by the construction and operation of the WIPP, calculations are made based on results of the employment portion of this technical procedure. The calculations for each year are too extensive to give here. However, sample calculations and formulas are given below that illustrate the procedure for determining the annual population impact. For illustrative purposes only, the year 1981, the first year of construction, and the year 1985, the first full year of operation, have been used in the sample calculations.

Calculations are made in three major parts. The first part of the calculation is the consideration of the population that is expected to move into the area due to the construction activity of the WIPP. The formulas are as follows:

$AGC_{1981} \times MigCON_A = AGCJM_{1981}$

$[216 \times 0.539 = 116]$

$BGC_{1981} \times MigCON_B = BGCJM_{1981}$

$[68 \times 0.606 = 41]$

$NCE_{1981} \times MigCON_N = NCEJM_{1981}$

$[60 \times 0.498 = 30]$

$AGCJM_{1981} + BGCJM_{1981} = CJM_{1981}$

$[116 + 41 = 157]$

$NCEJM_{1981} = MOWH_{1981}$

$[30 = 30]$

$CJM_{1981} \times HCWF = MCWH_{1981}$

$[157 \times 0.985 = 155]$

$MCWH_{1981} \times CWHSZ = MCP_{1981}$

$[155 \times 2.28 \simeq 353]$

$MOWH_{1981} \times OWHSZ_{1981} = MOP_{1981}$

$[30 \times 2.82 \simeq 85]$

$MCP_{1981} + MOP_{1981} = MDP_{1981}$

$[353 + 85 = 438 \simeq 450]$

where

AGC_{1981} = the total number of WIPP-associated aboveground construction jobs in 1981;

BGC_{1981} = the total number of WIPP-associated belowground construction jobs in 1981;

NCE_{1981} = the total number of WIPP-associated nonconstruction employment jobs in 1981;

$MigCON_A$ = the proportion of total aboveground construction jobs expected to be filled by newcomers to the area. The factor 0.539 was derived from Construction Worker Profile figures for the Four Corners Region in 1975 (Arizona, Colorado, New Mexico, and Utah);

$MigCON_B$ = the proportion of total belowground construction jobs expected to be filled by newcomers to the area. The factor 0.606 was determined by matching needed occupations and skill levels to present availability (first quarter of 1977 and third quarter of 1978) of labor;

$MigCON_N$ = the proportion of total nonconstruction employment jobs expected to be filled by newcomers to the area. The factor 0.498 is the weighted average of the final operational migration factors;

JM_{1981} = the total number of jobs expected to be filled by newcomers to the area; AGCJM = aboveground construction JM; BGCJM = belowground construction JM; NCESJM = nonconstruction employment JM; CJM = construction JM;

HCWF = the factor that accounts for more than one construction worker per household (0.985);

$MCWH_{1981}$ = the number of expected newcomer construction worker households to the area in 1981;

$MOWH_{1981}$ = the number of newcomer nonconstruction worker households in 1981;

CWHSZ = the average size of newcomer construction worker households (2.28--Construction Worker Profile);

$OWHSZ_{1981}$ = the average size of newcomer nonconstruction worker households in 1981 (see page 50);

MCP_{1981} = the expected number of individuals migrating directly due to jobs in construction of the WIPP in 1981.

MOP_{1981} = the expected number of individuals migrating directly due to nonconstruction jobs of the WIPP in 1981; and

MDP_{1981} = the expected number of individuals immigrating due directly to jobs at the WIPP in 1981.

The sources of data are extremely important in computing the population immigrating to take new jobs for construction and operation of the WIPP. The average number of employees by year for construction or operation was derived from data supplied by the Bechtel Corporation (October 20, 1978) and Westinghouse Electric Corporation (October 26, 1978). The proportion of new jobs expected to be filled by newcomers to the area is derived from the Old West Regional Commission (OWRC) study entitled Construction Worker Profile. That study involved 14 large construction projects (six projects in the Four Corners Region) and showed that the percentage of local workers varied from a high of more than 78% to a low of 3.3%. The average percentage of local workers employed on these projects was 46.1%, indicating that 53.9% of the construction workers were not residents of the area before the construction activity (Four Corners Region only). A review of job applicants on computer files of the Employment Security Division of New Mexico supports this distribution. Thus, approximately 54% of the construction workers for these six projects had migrated to the area for construction work. This percentage has been used to compute the number of aboveground jobs that would be filled by individuals not in the area before the construction activity began.

As construction workers move into the area to fill these positions, they bring with them other members of their households. Certain of these members--the older children and spouse--may take up jobs in the construction site area. The OWRC study indicates that about 1.5% of the new households contain two construction workers. This means that 985 households will supply 1000 construction workers to the project, on the average. Thus, the number of needed households has been decreased by 1.5% to account for the two-construction-worker households. This factor of 0.985 is identified in the formula above as HCWF. The final formula above yields the total number of individuals immigrating to take new construction jobs. This number is computed by taking the average household size and multiplying it by the needed number of households to fill construction positions. In this case the average household size of 2.28 is the average household size determined from the OWRC study of all 14 construction projects through the West and Southwest. (For the explanation of the nonconstruction employment immigration see the section below on operation-associated immigrations.)

Having completed the calculations to determine the population immigration due directly to construction activity, the change due to operation must be computed. This is determined in the same way and is given by the following formulas:

1790 096

(Note: The example year is 1985 because full operational impact does not occur before 1985.)

$OAG_{1985} \times MigOPP_{AG} = OAGJM_{1985}$

$[286 \times 0.463 \simeq 132]$

$OBG_{1985} \times MigOPP_{BG} = OBGJM_{1985}$

$[109 \times 0.606 \simeq 66]$

$OST_{1985} \times MigOPP_{OST} = OSTJM_{1985}$

$[49 \times 0.463 \simeq 23]$

$OAGJM_{1985} + OBGJM_{1985} + OCNJM_{1985} = OJM_{1985}$

$[132 + 66 + 23 = 221]$

$OJM_{1985} = MOWH_{1985}$

$[221 = 221]$

$MOWH_{1985} \times AVHSZ_{1985} = MOP_{1985}$

$[221 \times 2.80 \simeq 619 \simeq 650]$

where

OAG_{1985} = the total number of WIPP-associated operation-aboveground jobs in 1985;

OBG_{1985} = the total number of WIPP-associated operation-belowground jobs in 1985;

OST_{1985} = the total number of WIPP-associated operation-storage jobs in 1985;

$MigOPP_{AG}$ = the proportion of total operation-aboveground jobs expected to be filled by newcomers to the area. The factor 0.463 was determined from occupation and skill level data supplied by Sandia and a review of available occupations and skills within the two-county area;

$MigOPP_{BG}$ = the proportion of total belowground operation jobs to be filled by newcomers to the area. The factor of 0.606 is the same factor that was used in the belowground construc- tion projections;

$MigOPP_{OST}$ = the proportion of total operation-storage jobs to be filled by newcomers to the area. The factor of 0.463 was deter- mined from occupation and skill level data supplied by Sandia and a review of the available occupations and skills within the two county area;

JM_{1985} = the number of total operational jobs expected to be filled by newcomers to the area; OAGJM = operation-aboveground JM, OBGJM = operation-belowground JM, OSTJM = operation-storage JM, OJM = total;

$MOWH_{1985}$ = the number of newcomer operational worker households in 1985;

$AVHSZ_{1985}$ = the average size household for the immigrating operational workers; and

MOP_{1985} = the immigrating population due directly to operational jobs connected with the WIPP project. (NOTE: The rounding of 619 to 650 is the result of cumulative rounding errors in the previous years.)

Again, sources of information for the formulas above are extremely important. The direct operational employment is determined from information supplied by Westinghouse. The proportion of aboveground and storage operational jobs to be filled by newcomers to the area is determined to be 0.463. Literature searches indicate no directly applicable research projects which would give the average number of operational jobs filled by newcomers to the area. In order to determine this factor, Employment Security Commission job applicant records, currently available occupational skill levels, and needed occupations and skill levels for the operation phase have been reviewed.

The average size household figures for newcomers have been drawn directly from the Bureau of the Census publications of projected household sizes and family sizes. The figures used within the calculations represent Series I population figures and Series C household sizes. These are the high-range household sizes of the nine projections listed by the Bureau of the Census adjusted for regional influence.

The final set of calculations needed to determine the overall population migration is that of population taking jobs generated indirectly by the construction and operational activities of the WIPP. These population changes are computed in a very similar manner to the previous calculation, with one major exception. Construction workers and operational workers who have moved into the area bring with them other household members. Certain of these household members take up employment in other areas of the economy. These people must be accounted for in determining the overall migration of individuals to the area. Thus, the following formulas differ somewhat from the previous calculations:

$IDE_{1981} \times MigID = IDJM_{1981}$

$[418 \times 0.50 = 209]$

$IDJM_{1981} - ADCE_{1981} - ADOE_{1981} = \text{Net } IDJM_{1981}$

$[209 - 30 - 9 \simeq 170]$

$\text{Net } IDJM_{1981} \times HWF = MIDWH_{1981}$

$[170 \times 0.769 \simeq 131]$

1790 098

$MIDWH_{1981} \times AVHSZ_{1981} = MIDP_{1981}$

$[131 \times 2.82 = 369]$

where

IDE_{1981} = the number of new indirect jobs (private and government) supported by construction or operational activity of the WIPP (example year is 1981);

MigID = the <u>proportion</u> of indirect jobs to be filled by newcomers to the area (0.50);

$IDJM_{1981}$ = the <u>number</u> of indirect jobs to be filled by newcomers to the area in 1981;

$ADCE_{1981}$ = the expected number of indirect jobs filled by members of the construction workers' households moving into the area in 1981 to take new construction jobs (0.195 x MCWH);

$ADOE_{1981}$ = the number of indirect jobs filled by household members moving into the area in 1981 to take the new operational jobs (0.30 x MOWH);

Net $IDJM_{1981}$ = the net number of jobs to be filled by newcomers moving into the area in 1981 to take jobs created in subsectors as an indirect result of the construction and operation of the WIPP;

HWF = the factor which accounts for more than one worker per household in immigrating households (0.769);

$MIDWH_{1981}$ = the number of expected newcomer households to the area in 1981 due primarily to jobs in sectors indirectly affected by the construction and/or operational activity of the WIPP;

$AVHSZ_{1981}$ = the average household size in 1981 of individuals moving into the area for jobs created in the indirectly impacted economic activities; and

$MIDP_{1981}$ = the population moving into the area in 1981 for jobs in sectors indirectly affected by WIPP construction and operation.

From the above formulas, it is apparent that several new characteristics have entered the calculations for determining population. IDE is determined from calculations explained within the employment section of this appendix. It is a direct result of the input-output modeling process. MigID is a subjective number based upon an evaluation of the area in terms of labor availability and needed skill levels associated with indirect new jobs. In this case, the factor is 0.5, which indicates that half of the new jobs created in indirectly affected sectors will be filled by newcomers to the area.

As workers move into the area to take up positions in the construction or operational labor forces, they bring with them households that contain members who also become part of the labor force and are available to fill newly created positions in the area under impact. ADCE accounts for those additional workers brought by construction worker households. The OWRC Construction Worker Profile indicates that between 19 and 29 additional workers for each 100 newcomer construction worker households will take jobs in indirectly affected sectors. In this study, a factor of 0.195 was used to determine the number of additional workers for each household immigrating due directly to construction activity.

ADOE accounts for the number of new workers brought by households immigrating due directly to operational-phase jobs. The OWRC Construction Worker Profile indicates that this number is substantially larger than the factor for the construction workers' households. Between 30 and 31 additional workers will be brought in for each 100 households moving in to take direct operational-phase jobs. A factor of 30% was used in this appendix to account for those additional workers. It is also apparent that when households move in and take up positions in sectors indirectly affected by construction and operational activity, there is also more than one worker per household. Again, this number is approximately 30 to 31 additional workers for each 100 households migrating. Thus, for 100 households, just about 130 workers would be available for positions in indirectly affected sectors. In order to account for these multiple worker households, a factor of 1/1.3 = 0.769 is used to decrease the number of needed households moving into the area.

Finally, in order to determine the actual population of the resulting households moving into the area, the projected average household size from the Bureau of the Census publications of projected household and family size was used, specifically Population Series I and Household Series C.

The final step in determining the population change to the area due to the construction and/or operation of the WIPP project is to add all three parts that determine population change, i.e., population change caused by construction activity, operational activity, and spinoff activity or indirectly affected economic sectors.

Because the economy may be somewhat slow to react to new jobs, population changes are assumed to lag in the indirectly affected sectors. In order to achieve this lag in the model, it is assumed that only one-half of the expected immigration will occur within the first year of impact. The remaining individuals are assumed to immigrate during the next year. This assumption allows for a 6 month to 1-year lag in the spinoff effects of the construction and operational phases.

The total immigrating population for a given year is thus determined by adding the population migrating due to construction, the population migrating due to operation, and the population moving in due to new activity in indirectly affected economic sectors. This is accomplished by the following formula:

$$MCP_{1981} + MOP_{1981} + 0.5\ MIDP_{1981} + 0.5\ MIDP_{1981-1} = MP_{1981}$$

$$[353 + 85 + 184 + 0 = 622 \simeq 600]$$

1790 100

where

MCP_{1981} = population migrating due directly to construction jobs;

MOP_{1981} = population migrating due directly to operational jobs;

$MIDP_{1981}$ = population migrating due to jobs created indirectly by construction and operational activities; and

MP_{1981} = total migrating population for 1981 (= 622 $\simeq$ 600)

$MIDP_{1981-1}$ = 0 because WIPP construction does not begin until 1981.

A final word of caution should be provided. The sample calculations for 1981 above are for impact during the first year of construction. The annual number of people moving into the area in following years is not neces- sarily the same. Calculations must also be made for each succeeding year.

As the construction phase of the WIPP ends and the operational phase begins (1985) the job situation will change drastically. During 1985 a transitional period between construction and operation will cause significant changes in the population. These population changes, i.e., negative changes or outflows, are computed in a similar manner to the previous example. However, other studies, such as the Construction Worker Profile, indicate that individuals do not leave immediately. This lag has been taken into account in determining the transitional phase of the project. The final results of all of the calculations appear in Tables L-15 through L-18.

These predictions have made for two different population distribution scenarios. The first scenario assumes that 99% of the direct impact and 90% of the indirect impact will go to Eddy County, with only 1% of the direct impact and 10% of the indirect impact going to Lea County. The second scenario assumes that 42% combined impact will go to Lea County and 58% combined impact will go to Eddy County.

The two different scenarios are the result of interviews conducted with six large potash mining operations in the area. Carlsbad is the center of potash mining activity and more than 95% of the present potash miners live in the Eddy County area. However, one company recruits mainly in the Hobbs area, and as a result 42% of its employees live in Lea County.

WIPP construction and operation will be similar to a combination of construction, mining and warehousing operations. Thus the WIPP project should operate similarly to the potash mining companies in the area. Thus, the first scenario assumes that the major impact will be felt in the Eddy County area, including about 88% in Carlsbad. It was assumed that the contractors would recruit employees from the Carlsbad area for construction and operation of the Waste Isolation Pilot Plant.

Subsequent discussions indicated that it was possible that the yet-to-be-announced construction and operation contractors might recruit from the Hobbs

Table L-15

BASELINE
POPULATION ESTIMATES AND PROJECTIONS
(without WIPP project)

Year	Eddy County[1,2]	Carlsbad[1,3]	Carlsbad School District[1,3]	Lea County[1,2]	Hobbs[1,3]	Hobbs School District[1,3]
1970	41,119	21,297	25,498	49,554	26,025	29,858
1975	42,900	N/A	N/A	51,600	N/A	33,300
1976	45,300	25,500	29,300	54,400	31,300	35,600
1977	46,200	26,600	30,400	55,500	32,200	36,900
1978	47,300	27,900	31,600	56,600	32,650	37,400
1979	48,200	28,600	32,400	57,700	33,150	37,950
1980	49,300	29,500	33,300	58,800	33,600	38,400
1981	50,200	30,200	34,100	60,200	34,450	39,350
1982	51,600	31,300	35,300	61,600	35,300	40,250
1983	52,000	31,600	35,700	63,100	36,150	41,150
1984	52,900	32,300	36,400	64,500	37,100	42,200
1985	53,800	32,800	37,000	65,900	38,000	43,150
1986	55,100	33,600	37,900	67,600	39,000	44,200
1987	56,400	34,400	38,800	69,400	40,000	45,300
1988	57,800	35,300	39,800	71,200	41,050	46,400
1989	59,200	36,100	40,700	73,000	42,100	47,550
1990	60,600	37,000	41,700	74,900	43,200	48,800
1995	64,300	39,200	44,200	81,100	47,900	53,750
2000	68,300	41,700	47,000	87,800	52,850	59,100
2010	72,200	44,100	49,700	92,800	55,900	62,500

N/A Not available.

[1] <u>1970 Census of Population</u> data.

[2] 1975-1990 data, modified by the Bureau of Business and Economic Research, University of New Mexico projection, April 1976.

[3] 1975-2010 data, new data this report.

1790 102

Table L-16

POPULATION MIGRATION PROJECTIONS
RESULTING FROM DIRECT AND INDIRECT JOBS
(with WIPP project)

Year	Annual Migration Due to Direct Jobs	Cumulative Migration Due to Direct Jobs	Annual Migration Due to Indirect Jobs	Cumulative Migration Due to Indirect Jobs	Annual Migration Due to Total Jobs	Cumulative Migration Due to Total Jobs
1981	450	450	150	150	600	600
1982	650	1100	550	700	1200	1800
1983	600	1700	650	1350	1250	3050
1984	(450)	1250	50	1400	(400)	2650
1985	(600)	650	(550)	850	(1150)	1500
1986	-0-	650	(300)	550	(300)	1200
1987	-0-	650	-0-	550	-0-	1200
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
2010	-0-	650	-0-	550	-0-	1200

SOURCE: Larry Adcock and Associates, 1978.

Table L-17

SCENARIO I
POPULATION ESTIMATES AND PROJECTIONS
CARLSBAD ALTERNATIVE
(with WIPP project)

Year	Eddy County (99%-90%)*	Carlsbad (88%-80%)*	Carlsbad School District (93%-85%)*	Lea County (1%-10%)*
1970	41,119	21,297	25,498	49,554
1975	42,900	N/A	N/A	51,600
1976	45,300	25,500	29,300	54,400
1977	46,200	26,600	30,400	55,500
1978	47,300	27,900	31,600	56,600
1979	48,200	28,600	32,400	57,700
1980	49,300	29,500	33,300	58,800
1981**	50,790	30,720	34,650	60,210
1982	53,320	32,830	36,920	61,680
1983	54,900	34,180	38,430	63,250
1984	55,400	34,520	38,750	64,650
1985	55,200	34,050	38,320	66,000
1986**	56,240	34,610	38,970	67,660
1987	57,540	35,410	39,870	69,460
1988	58,940	36,310	40,870	71,260
1989	60,340	37,110	41,770	73,060
1990	61,740	38,010	42,770	74,960
1995	65,440	40,210	45,270	81,160
2000	73,340	45,110	50,770	92,860
2010	69,440	42,710	48,070	87,860

N/A Not available

* Figures given for each area are the percentages of the direct and indirect population migration allocated to each area as the result of the WIPP II project. Percentages may vary because of rounding.

**Beginning year of construction assumed to be 1981. All impacts assumed to be static after 1986.

SOURCE: Larry Adcock and Associates, 1978.

1790 104

Table L-18

SCENARIO II
POPULATION ESTIMATES AND PROJECTIONS
HOBBS ALTERNATIVE
(with WIPP II project)

Year	Eddy County (58%)*	Carlsbad (54%)*	Remainder of Eddy County (4%)*	Lea County (42%)*	Hobbs (36%)	Remainder of Lea County (6%)	Hobbs School District (39%)
1970	41,119	21,297	19,822	49,554	26,025	23,529	29,858
1975	42,900	N/A	N/A	51,600	N/A	N/A	33,300
1976	45,300	25,500	19,800	54,400	31,300	23,100	35,600
1977	46,200	26,600	19,600	55,500	32,200	23,300	36,900
1978	47,300	27,900	19,400	56,600	32,650	23,950	37,400
1979	48,200	28,600	19,600	57,700	33,150	24,550	37,950
1980	49,300	29,500	19,800	58,800	33,600	25,200	38,400
1981**	50,550	30,520	20,030	60,450	34,670	25,780	39,580
1982	52,640	32,270	20,370	62,360	35,950	26,410	40,950
1983	53,770	33,250	20,520	64,380	37,250	27,130	42,340
1984	54,440	33,730	20,710	65,610	38,050	27,560	43,230
1985	54,670	33,610	21,060	66,530	38,540	27,990	43,730
1986**	55,800	34,250	21,550	68,100	39,430	28,670	44,670
1987	57,100	35,050	22,050	69,900	40,430	29,470	45,770
1988	58,500	35,950	22,550	71,700	41,480	30,220	46,870
1989	59,900	36,750	23,150	73,500	42,530	30,970	48,020
1990	61,300	37,650	23,650	75,400	43,630	31,770	49,270
1995	65,000	39,850	25,150	81,600	48,330	33,270	54,220
2000	69,000	42,350	26,650	88,300	53,280	35,020	59,570
2010	72,900	44,750	28,150	93,300	56,330	36,970	62,970

N/A Not available.

* Figures given for each area are the percentages of the gross population migration allocated to each area as the result of the WIPP II project. Percentages may vary because of rounding.

**Begining year of construction assumed to be 1981. All impacts assumed to be static after 1986.

SOURCE: Larry Adcock and Associates, 1978.

area, with the major impact being on Lea County and the city of Hobbs. To provide predictions for this possibility, a second scenario was undertaken as outlined above.

It should also be noted that population predictions for the cities listed include only population within the incorporated limits and do not include the fringe areas. In the cases of Hobbs and Carlsbad these fringe areas contain from 3,000 to 5,000 additional people each.

L.5 PERSONAL INCOME

L.5.1 General

The change in total annual personal income in the two-county area is determined from the direct wages paid during the construction and operational phases of the WIPP, allowing for a certain amount of fringe benefits. Indirect total personal income generated is computed by determining what proportion of labor costs will enter the total personal income stream from the total number of dollars allocated to labor costs.

In addition to wages, dividends, interest, and rents also account for a portion of the total personal income. That proportion has been estimated after examination of unpublished regional printouts for the two-county area provided by the Bureau of Economic Analysis to the Bureau of Business and Economic Research at the University of New Mexico. (Tables L-19 and L-20.)

From these two tables it is apparent that total labor and proprietors' income in 1976 (the latest year available) amounted to some $449,925,000 in the two-county area. Interest, dividends, and rents accounted for $67,401,000 (15.0%) additional income based upon total labor and proprietors income. Further calculations indicate a plus or minus 3% variation (approximately) from this figure, depending on which portion of total personal income was used to determine the average interest, dividends, and rents accrued. The actual figure used was 15.29%.

The other major factor taken into consideration in total annual personal income is transfer payments. As a previously cited printout from the Bureau of Economic Analysis indicates, the flow of transfer payments to the area is positive. However, during the construction phase of the WIPP, the impact of transfer payments on the total personal income stream is assumed to be negative because more Social Security payments will flow out than flow in from those additional jobs created and supported by the construction phase. During the operational phase, however, the impact of transfer payments on the total personal income stream may be either negative or positive. In the early years of operation it should be positive; however, as individuals retire from jobs or positions created by the operation of the WIPP, the transfer payments will return. Therefore, it is assumed that the transfer payments are neutral during the operation of the WIPP. An explanation and values for total personal income change can be found on the following pages.

Table L-19

PERSONAL INCOME OF MAJOR SOURCES 1971-1976 (THOUSANDS OF DOLLARS)

LEA　　　NEW MEXICO　　　PERSONAL INCOME BY MAJOR SOURCES 1971-76 (THOUSANDS OF DOLLARS)

ITEM	1971 1/	1972 1/	1973 1/	1974 1/	1975 2/	1976 2/
TOTAL LABOR AND PROPRIETORS INCOME BY PLACE OF WORK 3/						
BY TYPE						
WAGE AND SALARY DISBURSEMENTS	114,801	121,107	133,089	163,925	190,713	206,415
OTHER LABOR INCOME	9,793	10,982	12,343	16,397	20,339	23,110
PROPRIETORS INCOME 4/	15,081	21,399	24,521	37,549	33,473	35,946
FARM	5,655	7,993	13,766	13,746	12,350	12,915
NON-FARM 4/	9,426	13,406	10,755	23,803	21,123	23,031
BY INDUSTRY						
FARM	7,189	9,579	15,673	15,689	14,517	15,331
NON-FARM	132,486	143,909	154,280	202,182	230,008	250,140
PRIVATE	117,955	127,968	137,470	184,385	209,338	226,448
AG.SERV.,FOR.,FISH.,AND OTHER 5/	516	635	694	(D)	(D)	708
MINING	35,366	42,573	46,162	74,419	81,378	84,947
CONSTRUCTION	9,319	8,287	8,498	13,051	14,413	14,700
MANUFACTURING	7,392	7,545	8,284	10,021	12,591	14,146
NON-DURABLE GOODS	5,453	5,172	6,127	7,775	9,563	11,306
DURABLE GOODS	1,939	2,373	2,157	2,246	3,028	2,840
TRANSPORTATION AND PUBLIC UTILITIES	20,436	22,591	23,552	27,343	32,406	36,027
WHOLESALE TRADE	8,402	9,162	9,972	12,329	15,517	17,742
RETAIL TRADE	15,507	15,846	16,810	18,342	21,261	24,707
FINANCE,INSURANCE, AND REAL ESTATE	4,417	4,838	5,296	(D)	(D)	7,838
SERVICES	16,438	16,491	17,802	22,090	24,611	25,633
GOVERNMENT AND GOVERNMENT ENTERPRISES	14,531	15,941	16,810	17,797	20,670	23,692
FEDERAL, CIVILIAN	1,226	1,294	1,428	1,575	1,816	1,970
FEDERAL, MILITARY	484	494	534	537	564	591
STATE AND LOCAL	12,821	14,153	14,848	15,685	18,290	21,131
DERIVATION OF PERSONAL INCOME BY PLACE OF RESIDENCE						
TOTAL LABOR AND PROPRIETORS INCOME BY PLACE OF WORK	139,675	153,488	169,953	217,871	244,525	265,471
LESS: PERSONAL CONTRIBUTIONS FOR SOCIAL INSURANCE BY PLACE OF WORK	6,542	7,050	8,651	11,376	12,745	13,572
NET LABOR AND PROPRIETORS INCOME BY PLACE OF WORK	133,133	146,438	161,302	206,495	231,780	251,899
PLUS: RESIDENCE ADJUSTMENT	699	807	-114	-1,689	-997	-944
NET LABOR AND PROPRIETORS INCOME BY PLACE OF RESIDENCE	133,832	147,245	161,188	204,806	230,783	250,955
PLUS: DIVIDENDS, INTEREST, AND RENT 7/	16,529	18,505	19,678	23,907	27,447	30,711
PLUS: TRANSFER PAYMENTS	13,865	15,440	18,055	20,878	24,664	29,644
PERSONAL INCOME BY PLACE OF RESIDENCE	164,226	181,190	198,921	249,591	282,894	311,310
PER CAPITA PERSONAL INCOME (DOLLARS)	3,271	3,643	4,028	5,014	5,479	5,722
TOTAL POPULATION (THOUSANDS)	50.2	49.7	49.4	49.8	51.6	54.4

1/ ESTIMATES BASED ON 1967 SIC.　　2/ ESTIMATES BASED ON 1972 SIC.
3/ CONSISTS OF WAGE AND SALARY DISBURSEMENTS, OTHER LABOR INCOME, AND PROPRIETORS' INCOME.
PRIMARY SOURCE FOR PRIVATE NON-FARM WAGES: ES-202 COVERED WAGES -NEW MEXICO EMPLOYMENT SECURITY COMMISSION
4/ INCLUDES THE CAPITAL CONSUMPTION ADJUSTMENT FOR NON-FARM PROPRIETORS.
5/ INCLUDES WAGE AND SALARIES OF U.S. RESIDENTS WORKING FOR INTERNATIONAL ORGANIZATIONS.
7/ INCLUDES THE CAPITAL CONSUMPTION ADJUSTMENT FOR RENTAL INCOME OF PERSONS.
(D) NOT SHOWN TO AVOID DISCLOSURE OF CONFIDENTIAL INFORMATION, DATA ARE INCLUDED IN TOTALS.

TABLE 5.00　　　JULY, 1978　　　REGIONAL ECONOMICS INFORMATION SYSTEM
BUREAU OF ECONOMIC ANALYSIS

POOR ORIGINAL

1790 107

POOR ORIGINAL

Table L-20

PERSONAL INCOME OF MAJOR SOURCES 1971-1976 (THOUSANDS OF DOLLARS)

EDDY — NEW MEXICO — PERSONAL INCOME BY MAJOR SOURCES 1971-76 (THOUSANDS OF DOLLARS)

ITEM	1971 1/	1972 1/	1973 1/	1974 1/	1975 2/	1976 2/
TOTAL LABOR AND PROPRIETORS INCOME BY PLACE OF WORK 3/						
BY TYPE						
WAGE AND SALARY DISBURSEMENTS	79,561	85,032	91,738	103,723	131,945	147,687
OTHER LABOR INCOME	5,612	6,294	7,229	8,999	12,169	14,323
PROPRIETORS INCOME 4/	13,662	16,270	19,194	21,864	19,256	22,449
FARM	5,220	5,258	9,482	7,227	5,073	7,136
NON-FARM 4/	8,442	11,012	9,712	14,637	14,183	15,318
BY INDUSTRY						
FARM	7,008	6,975	11,392	9,041	7,100	9,400
NON-FARM	91,627	100,621	106,769	125,545	156,270	175,054
PRIVATE	78,272	86,225	91,476	109,280	137,514	153,410
AG.SERV.,FOR.,FISH.,AND OTHER 5/	376	426	425	486	451	423
MINING	27,608	33,166	32,344	41,966	51,541	54,888
CONSTRUCTION	4,604	5,744	6,771	7,631	13,776	15,554
MANUFACTURING	5,690	5,844	6,655	8,430	11,787	15,024
NON-DURABLE GOODS	4,463	4,459	5,041	6,547	9,697	11,410
DURABLE GOODS	1,227	1,385	1,614	1,883	2,090	3,614
TRANSPORTATION AND PUBLIC UTILITIES	6,902	7,355	8,860	9,612	11,046	13,229
WHOLESALE TRADE	3,231	3,522	4,012	4,959	7,705	7,317
RETAIL TRADE	11,533	12,370	13,227	15,300	16,669	19,366
FINANCE,INSURANCE, AND REAL ESTATE	3,043	3,295	3,397	3,616	4,266	5,106
SERVICES	15,625	14,503	15,785	17,080	20,273	22,503
GOVERNMENT AND GOVERNMENT ENTERPRISES	13,555	14,396	15,293	16,265	18,756	21,644
FEDERAL, CIVILIAN	2,388	2,447	2,583	2,794	3,142	3,669
FEDERAL, MILITARY	443	478	526	531	540	574
STATE AND LOCAL	10,724	11,471	12,184	12,940	15,074	17,402
DERIVATION OF PERSONAL INCOME BY PLACE OF RESIDENCE						
TOTAL LABOR AND PROPRIETORS INCOME BY PLACE OF WORK	98,835	107,596	118,161	134,586	163,370	184,454
LESS: PERSONAL CONTRIBUTIONS FOR SOCIAL INSURANCE BY PLACE OF WORK	4,630	5,085	6,102	7,194	8,855	9,732
NET LABOR AND PROPRIETORS INCOME BY PLACE OF WORK	94,205	102,511	112,059	127,392	154,515	174,722
PLUS: RESIDENCE ADJUSTMENT	254	201	218	425	-74	-214
NET LABOR AND PROPRIETORS INCOME BY PLACE OF RESIDENCE	94,459	102,712	112,277	127,817	154,441	174,508
PLUS: DIVIDENDS, INTEREST, AND RENT 7/	18,544	20,098	22,278	26,687	32,743	36,690
PLUS: TRANSFER PAYMENTS	16,945	18,529	21,646	25,236	29,249	35,574
PERSONAL INCOME BY PLACE OF RESIDENCE	129,946	141,339	156,201	179,740	216,433	246,772
PER CAPITA PERSONAL INCOME (DOLLARS)	3,189	3,442	3,781	4,332	5,044	5,453
TOTAL POPULATION (THOUSANDS)	40.7	41.1	41.3	41.5	42.9	45.3

1/ ESTIMATES BASED ON 1967 SIC. 2/ ESTIMATES BASED ON 1972 SIC.
3/ CONSISTS OF WAGE AND SALARY DISBURSEMENTS, OTHER LABOR INCOME, AND PROPRIETORS' INCOME.
PRIMARY SOURCE FOR PRIVATE NON-FARM WAGES: ES-202 COVERED WAGES -NEW MEXICO EMPLOYMENT SECURITY COMMISSION
4/ INCLUDES THE CAPITAL CONSUMPTION ADJUSTMENT FOR NON-FARM PROPRIETORS.
5/ INCLUDES WAGE AND SALARIES OF U.S. RESIDENTS WORKING FOR INTERNATIONAL ORGANIZATIONS.
7/ INCLUDES THE CAPITAL CONSUMPTION ADJUSTMENT FOR RENTAL INCOME OF PERSONS.

TABLE 5.06 — JULY, 1978 — REGIONAL ECONOMICS INFORMATION SYSTEM BUREAU OF ECONOMIC ANALYSIS

L.5.2 Explanation and Values

Table L-21 summarizes some of the information presented in this section. Details appear in the text below.

Table L-21

PERSONAL INCOME DUE TO WIPP
(in millions of 1977 dollars)

Income type	1981	1982	1983	1984	Construction period total[a]	Operation each year 1985 and after
Direct wages and salaries	$ 5.2	$22.5	$34.0	$23.2	$ 84.9	$ 9.1
Indirect wages and salaries	3.3	9.0	13.7	10.1	36.1	4.8
Interest, dividends, rents	1.4	5.1	7.7	5.3	19.5	2.3
Total private sector income	$ 9.9	$36.6	$55.4	$38.6	$140.5	$16.2
Public sector income	0.6	1.5	2.3	1.7	6.1	0.8
Transfer payments	(0.5)	(2.0)	(3.0)	(2.1)	(7.6)	0[2]
Net personal income	$10.0	$36.1	$54.7	$38.2	$139.0	$17.0

[1]The figures for the construction period (1981 through 1984) include both construction and nonconstruction activity.
[2]Transfer payments during the operational phase are assumed to be neutral over time.

SOURCE: Larry Adcock and Associates, 1978.

During the 42-month construction period, it is expected that a total of nearly $90 million will flow directly into wages and salaries from the construction of the plant and associated nonconstruction employment. In addition, there will be slightly more than $36 million in wages and salaries in those businesses indirectly affected by the construction.

Personal income from interest, dividends, and rent is expected to total an additional $19.5 million during the three and one-half year period. A total of about $140.5 million is expected to be derived both directly and indirectly in the private sector. In the public sector, about $6.1 million in personal income will come from the increased activity in the area and additional State and local government employment required for support. Thus, total personal income added to the area during the construction phase of the WIPP project is expected to be $146.6 million spread over a 38-month period. However, net loss from transfer payments (generally Social Security payments) will decrease this total to $139.0 million.

The personal income to be derived from the operation of the WIPP project will be significantly different from that derived in the construction phase.

The amount of money flowing directly into the local economy during a normal year of operation will be approximately $14.3 million. Although this amount may vary with expenditure patterns in the operation of the plant, this appendix uses a constant figure of $18.2 million. This figure is significantly different from the total direct expenditures of more than $50 million annually during the peak years of the construction period.

The estimated $14.3 million annual flow directly associated with the operation of the plant will mean that (1) approximately $9.1 million will be realized in personal income by those individuals connected directly with the plant; (2) wages and salaries derived from the indirect effect on businesses within the area will amount to almost $4.8 million; (3) government expenditures required by additional activity and flowing into personal income will total about $0.8 million per year; (4) new dividends, interest, and rents will create approximately $2.3 million in personal income; and (5) during the first years of operation, net transfer payments will be negative and later they will have a net positive effect. Because of this balancing effect, transfer payments for an average year have been considered neutral. The net result, therefore, will be an increase in total personal income on an annual basis of approximately $17.0 million.

L.6 HOUSING AND LAND USE

The demand for new housing depends on population and household size. The housing demand projections developed for the impact analysis prepared in conjunction with this appendix are based on population projections discussed previously and household size projections derived from several sources.

Household size for the baseline population is based on household size projections in Bureau of the Census Publication P-25, No. 607, adjusted to 1970 household size in the impact area (derived from the 1970 Census of Housing). Thus, if 1970 household size in the impact area is above the U.S. average in that year, projected household size in the impact area will be adjusted upward from the projected U.S. average.

Household sizes for project induced population changes come from two basic sources. For construction workers and their families, household size is based on information contained in the Construction Worker Profile (Old West Regional Commission, Washington, 1975). For operations employees and families as well as for induced and indirect population changes, household size depends on the likely place of origin of the individuals moving into the area. If there is no obvious or logical single place of origin, then U.S. average household size (from Bureau of Census Publication P-25, No. 607) will be used. If it appears that most of the individuals will be likely to come from elsewhere in New Mexico, then U.S. household size projections will be adjusted to account for past State differences with the U.S. average.

Once household sizes have been projected, the demand for housing units is determined by dividing the household size into the appropriate population component. For baseline population changes, the population component is essentially the entire population, with a small adjustment for the portion of the population not living in housing units. This latter group is generally a small fraction of the total population, comprised primarily of people living in nursing homes. The population components for project related populations are derived using methods discussed earlier in this appendix.

The demand for occupied housing units provides the base for a second set of calculations which indicate the housing stock necessary to maintain a 3% vacancy rate. This is found simply by dividing the demand for occupied units by 0.97.

The amount of construction activity needed to meet the demand for housing at a 3% vacancy rate is then calculated, based on present assessment of housing and vacancy rate figures and projected housing requirements.

Finally, housing requirements are allocated to housing types (single family, multifamily, and mobile home) based on information in the Construction Worker Profile (op. cit.). Table L-22 indicates housing type preferences of three classes of population: newcomer construction workers, other newcomers, and long-time residents. Baseline populations are assumed to have the same housing type preferences as the "long-time residents," while preferences of "newcomer construction workers" are used to allocate housing types for project induced construction newcomers. Other induced and indirect immigrants resulting from the project are assumed to have the same preferences as those of "other newcomers."

Table L-22

HOUSING PREFERENCES (PERCENT)

Type of Unit	Newcomer Construction Workers	Other Newcomers	Long Time Residents
Single family	46	70	87
Multifamily	9	11	4
Mobile home and other	46	18	10
TOTALS*	101	99	101

*Totals do not sum to 100 due to rounding.

SOURCE: Old West Regional Commission, Construction Worker Profile, Washington, D.C., 1975, p. 103.

Methods used to calculate land requirements for projected population increases depend on the relative scale of population changes, both under baseline and impact conditions. For small relative changes in population (and therefore, small changes in housing demand) the principal demand for land is for housing units and roads. In this case, land use requirements are calculated on the basis of a relatively generous average lot size (e.g., one-quarter acre) per housing unit. The assumption is that relatively small increases in population will not require proportional increases in all municipal land use categories. For example, a 5% population increase should not require a 5% increase in land requirements associated with such public facilities as city hall, police stations, and fire stations. In essence, it is assumed that there is some excess capacity in the land associated with such facilities.

For larger relative population increases, the basic assumption is that land requirements for virtually all types of land use will grow in proportion to the housing stock. In this situation, total land occupied in the municipality is divided by the amount of housing to obtain land required for each unit of housing.

Finally, it should be noted that for different purposes, either of the methods above may be appropriate in determining land use requirements. For example, baseline population growth may be substantial, calling for the use of a large figure for land required for each housing unit, while the marginal change associated with the impact population is small, thus requiring only a small land use figure. Conversely, there are instances in which baseline growth is expected to be small while project impact is expected to be large, which indicates that a small baseline land figure and a large impact figure are appropriate.

L.6.1 Community Services and Facilities

In the analysis of the impacts of population or other changes on the demand for community services and facilities, there are basically two sorts of impacts that may emerge. First, in most cases there will be an increase in the demand for service more or less in proportion to population or housing increased. For example, more people will require more water, generate more sewage, and need more medical assistance. As a result of the increased demand for the service, personal requirements and operating expenses generally rise. (For a discussion of operating expenses see the following section on fiscal impact analysis.)

The second sort of impact that may emerge is an overloading of some part of the system that has a fixed capacity. Generally, fixed capacity implies some type of capital facility such as a school or sewage treatment plant, but it also includes water rights.

The analysis of impacts on community services and facilities then requires two basic steps. First, changes in the demand for variable parts of the system (e.g., personnel, cubic feet of natural gas) must be projected. Then, projected increases in demand must be compared to the existing capacity of those parts of the system which are not readily varied in small increments. In other words, an important part of the analysis is to determine if one of the impacts of a proposed action is to require the construction of, e.g., a new sewage treatment plant.

Two basic methods are used to project the demand for services: the per capita multiplier method and the per household (or its equivalent--per occupied housing unit) multiplier method. (For a discussion of the appropriate application and the advantages and disadvantages of these methods, see Robert Burchell, David Listokin et al., The Fiscal Impact Handbook, Center for Urban Policy Research, New Brunswick, New Jersey, 1978.) Generally, the latter method is used to project demands for natural gas, electricity, and telephone service while the former is used to project the demands for water, sewage treatment, solid waste disposal, fire and police protection, medical service, and education. With slight modification, the per capita multiplier method is used to project traffic flows as well.

The multipliers used in each approach are based on recent actual per capita or per household figures in the impact area, with adjustments made where appropriate. Adjustments are made when national, regional, or local data indicate that recent per capita or per household levels may not remain unchanged over time. For example, in projecting water demand for New Mexico communities, per capita use rates are changed over time in the same proportion as the changes projected by the New Mexico State Engineer in the County Profile series (New Mexico Interstate Stream Commission and New Mexico State Engineer Office, County Profile (various counties), Santa Fe, New Mexico, 1975).

Adjustments are also made if very recent changes in some key factor have caused historical per capita or per household use rates to be unreliable for future projections. For example, if a water rate (price) increase has occurred within the past year, resulting in less than a full year's data at the new rate, per capita use rates will be adjusted based on water demand price elasticity estimates. (For a discussion of water demand price elasticity estimates, see Gilbert Bonem, Micha Gisser, John Myers, and Mark Resta, Water Demand and Supply in the Albuquerque Greater Urban Area, Bureau of Business and Economic Research, University of New Mexico, December 1977.)

Once demand for a service has been projected, it is compared to the service capacity of the fixed components of the system. This is generally a straightforward numerical comparison, e.g., acre feet per year of water demand versus annual water rights. Those areas in which demand exceeds existing capacity are identified and the implications of the excess demand are noted.

For several reasons, the level of detail varies considerably in the analysis of each community service category. First, after investigation of the existing service capacity in some area it sometimes becomes evident that considerable excess capacity exists relative to any potential change in demand resulting from baseline or impact population changes. A similar situation arises when the impact area is small relative to the service area, as is often the case with natural gas, electric, and telephone service. In this case, even relatively large baseline or impact population changes in the impact area have little effect on the overall service area. In both situations (significant excess capacity and small impact area relative to service area) a detailed analysis is generally unwarranted.

At the other extreme, sometimes the relative impact on the demand for a service of a proposed action is large. In this instance, every effort is made to determine in detail the extent of the impact. This often involves extensive interviews with the manager or other personnel of the department or company providing the service.

Finally, in many cases baseline projections use less sophisticated techniques (e.g., unadjusted per capita multipliers) than those for impact projections. This is because baseline projections generally are intended to provide a background against which impact is evaluated, and not to be a precise projection of service level demands under baseline conditions. The key factor in the analysis of baseline projections is the effect on system capacity. If a new sewage treatment plant or school is required under baseline conditions during the period under analysis, then the capital cost of the facility is not assigned to the proposed action whose impact is being studied. On the other hand, if capital facilities or water rights are adequate under baseline conditions but inadequate under impact conditions, the burden of reduced service levels or increased capital costs rests on the proposed action. A more detailed discussion of the treatment of costs is presented in Section L.7.

L.7 FISCAL IMPACT ANALYSIS

L.7.1 Revenues

Projection techniques for county and municipal revenues are essentially the same. The first step is to collect data on past revenue levels. For New Mexico counties the source is generally the Department of Finance and Administration, New Mexico County Governments, Annual Report. For New Mexico Municipalities the source is the equivalent annual report series, New Mexico Municipal Governments. During that part of the year after the end of the fiscal year, but before the publication of the annual reports, county and municipal governments are contacted to obtain reports for the most recent fiscal year.

Once data covering several years have been collected, a preliminary analysis is made. This involves putting each major revenue category (fund) in constant dollars, using the Gross National Product Price Index as a deflator, and examining the record for pronounced trends or major changes. If such trends or changes are found, they are considered in making projections. However, trends generally are gradual and they are usually ignored. Major changes usually result from increases in revenues which are not expected to continue each year. These are generally revenues from bond sales or from special government transfers (e.g., drought relief). Such changes are noted and considered in subsequent stages of the projection process, as described below.

After the preliminary examination of the budget is completed, the most recent fiscal year revenues are separated into the categories indicated in Table L-23. These categories present a clear picture of the type and source of revenues, a picture that is not evident when revenues are classified by fund as they generally are in municipal or county budgets.

Once revenues have been allocated to the proper categories, projections are made. The revenue projection method is based on modifications of methods suggested in The Fiscal Impact Handbook, op. cit. For baseline projections, most revenue items are projected on a per capita basis. A smaller group are projected on a per housing unit basis, and occasionally a revenue item is projected to show no change.

For most revenue items the most recent actual annual per capita or per housing unit level is taken as the most reliable guide to future levels. Although budgeted levels for the coming fiscal year are checked for major changes from past amounts, budgets are felt to be an unreliable basis for making projections. For one thing, they are themselves projections, and their

Table L-23
REVENUE CATEGORIES AND PROJECTION METHODS
USED FOR NEW MEXICO MUNICIPALITIES AND COUNTIES

Own Source Revenues	Municipal	County
Taxes		
Property	PH	PH
Franchise	PC	PC
Occupation	PC	PC
Oil and gas (C)		NC
Charges and Miscellaneous		
Licenses and permits	PH	PH
Charges for services	PC	PC
Fines and forfeits (M)	PC	
Utilities (M)	PH	
Debt Service	PC	PC
Miscellaneous (C)		PC
INTERGOVERNMENTAL TRANSFERS		
State		
Gasoline taxes	PC	PC
Auto license distribution (M)	PC	
Cigarette taxes	PC	PC
Gross receipts taxes (M)	PC	
Motor vehicle (C)		PC
Fire allotment (M)	PC	
Grants	PC	PC
Miscellaneous (C)		PC
Federal		
Revenue sharing and grants	PC	PC
Miscellaneous (C)		PC
Other*		PC
Fire protection fund interest	PC	
Lodgers' tax fund	PC	
Solid waste disposal fund	PC	
Cemetery fund	PC	
State park fund	PC	
Golf fund	PC	
Airport fund contribution, fees, and misc.	PC	
EDA drought aid bond proceeds	PC	
1977 sales tax-lodgers tax bond proceeds	PC	
Street improvement fund	PC	
Downtown parking fund	PC	
Insurance fund	PC	

C = County revenue item only.
M = Municipal revenue item only.
PH = Projection on per housing unit basis.
PC = Projection on per capita basis.
NC = No change projected.
* = Items included in "other" represent entries in this category for Carlsbad.

SOURCE: Adcock and Associates, 1978.

accuracy depends on the skill of the municipal or county officials making them. There is also a tendency for budgets to include a rather large "other" category with unspecified components. Finally, comparison of past budgeted revenues with actual revenues shows a rather large discrepancy between budgeted and actual amounts.

In choosing the most recent actual revenue levels as the guide to the future, several assumptions are made. First, it is assumed that tax rates will not change. While this is probably not a reliable assumption, the alternative is to project the behavior of elected officials, many of whom have not yet been elected, since it is these office holders who set tax rates. The "no change" assumption seems the more conservative of the two alternatives.

A similar set of assumptions (that is, no change) applies to the level of charges for services, such as utility rates, and distribution formulas for State and Federal transfers. Again, it is not felt that these items will never change, but that predicting the direction and timing of such changes is less reliable than assuming no change.

In essence, the use of the most recent actual revenue level combined with the per capita or per housing unit projection method indicates what revenue levels would be if current conditions continue into the future.

There are some exceptions to the use of the per capita or per housing unit projection method. Some revenue sources are clearly independent of local population or household levels, due either to the nature of the tax base or to the distribution formula. For example, in some counties in New Mexico, oil and gas production (severance) taxes are an important revenue source. These taxes are based on the level of oil and gas production in these counties, a tax base which is not influenced by population or the housing stock.

Four alternatives are available for the projection of such a revenue source. First, an independent projection of the tax base may be utilized. However, such projections are frequently unavailable. A second possibility is to generate a projection of the base, a process which is usually too time-consuming (and expensive) for purposes of an impact analysis. The third approach is to rely on recent trends in the base--or in the tax revenue itself. This is often the best alternative given the limits of time and budget, but there are situations in which it is not appropriate. For example, in the case of the oil and gas production taxes mentioned above, the recent history of the industry shows great fluctuations in this source of revenue. As a result, no statistically reliable recent trend can be isolated. This makes it necessary to use the fourth method, which is to assume no change in the total (as opposed to per capita) level of this source of revenue. While this is the most conservative assumption under the circumstances, it leads to problems when projected revenues are compared to projected expenditures. More will be said about this problem after expenditure projection methods are discussed below.

There are also exceptions to the use of the most recent actual revenue level for projections, even when per capita or per housing unit projections are used. These exceptions are generally made for those nonrecurring revenue items mentioned above (bond proceeds and government transfers) which may have occurred in the most recent year. In the case of bond proceeds, generally a long-term average per capita figure is used as the basis of projections. This avoids the problem of predicting the timing of the next major bond issue and results in the overstatement of revenues in some years and understatement of them in others. However, it does present a fairly reliable picture of the long-term revenue prospects for the governmental unit.

In some cases a specific bond issue may be excluded from the average used in the projection process. In the most recent year there may have been a very large single issue which was used for a purpose not likely to be repeated throughout the period of projection. For example, a bond issue to pay for a new sewage treatment plant that will be adequate for loads projected for the period under analysis would be excluded, since no new bonds for this purpose would be needed. The decision concerning inclusions and exclusions is subjective, but as a general rule bonds to pay for street improvements, park development, and other capital items that may be associated with population growth are included, while bonds for major items such as sewage treatment plants (but not sewer expansion) are excluded.

For government transfers, the general rule is that the most recent year is used except for those programs which are obviously not recurring.

The same general methods are used to project revenues resulting from the impact of the proposed action. However, if major capital expenditures were required under impact conditions that would not be required under baseline conditions, an attempt is made to project the magnitude and timing of bond revenues to finance the expenditures.

Table L-23 indicates the specific projection methods used for municipalities and counties in New Mexico. In most instances the per capita multiplier method is used. There are three reasons for choosing this method. First, in many cases (e.g., gross receipts taxes) it is clearly the best available alternative.

In some cases it is used even though some other method is clearly better. An example of this is Taylor Grazing Act fees (a Federal transfer) going to the county. Since the base is independent of population, these fees would not be expected to rise in proportion to county population. However, the actual amount of revenue from this source is so small that making an independent projection or assuming no change would involve computational complexities not offset by measurable improvement in the reliability of the overall revenue projection. Therefore, this source is included with other federal transfers and the entire sub-group is projected on a per capita basis.

A third group of revenue items is projected on a per capita basis even though population represents only one of the determining factors in the revenue level. This group includes gasoline tax, cigarette tax, and auto license distributions from the State, all of which have distribution formulas in which population is only one factor. However, it can be shown that if the other items in the distribution formula increase in proportion to population, then per capita projection methods are appropriate. This condition is likely to be met fairly closely when comparing revenues under baseline and impact conditions. For example, in calculating gasoline tax distributions the ratio of roads in the local jurisdiction to roads in the State is used along with population. If the number of miles of road in a local area (e.g., municipality) is higher under impact conditions than under baseline conditions in rough proportion to the relative population levels under the two conditions, then the per capita share of gasoline tax distributions will be the same under both conditions. Thus, the use of the per capita projection method may somewhat bias the baseline revenue projections, but will be relatively accurate in comparing baseline and impact conditions.

Revenue items projected on the basis of housing units include utility fees, property taxes, and fees (e.g., building permits), since these are more closely related to the number of housing units than to population.

The only item projected to show no change in the total revenue level in the two examples shown is the oil and gas tax category for the county.

L.7.2 Expenditures

As with revenues, the projection methods used for county and municipal expenditures are essentially the same. The process begins with the acquisition of data from the same sources as those for revenues. Spending for several years is then converted to constant dollars using the Gross National Product Price Index. Municipal expenditures are allocated by fund while county expenditures are allocated to service functions (e.g., public works, public safety) as dictated by the format of the original data.

Once the data are in constant dollars, they are examined for major trends and non-recurring items, which are noted and accounted for in the projection process.

After preliminary analysis of the data, the projections are made. The methods used are a combination of the per capita multiplier method and the case study method, as set forth in The Fiscal Impact Handbook, op. cit. Basically, this involves projecting future expenditures on the basis of the most recent actual per capita levels, with the exception that non-recurring capital spending items are excluded.

The projections made in the analysis of the demands for community services and facilities provide the basis for the capital spending forecasts. If these projections indicate excess capacity for a particular capital facility for the period under analysis, only recurring capital expenditures are included in the fund or service function. For example, if a recent sewage treatment plant expansion has provided excess capacity, an attempt is made to isolate capital spending for sewer system expansion and maintenance, and to exclude spending on the plant itself, from projections of future utility or public works spending. On the other hand, if a capital facility is projected to become inadequate in the future, estimates of expansion costs are included in the forecasts.

The same general methods apply to baseline and impact projections. In both cases the approach is to isolate those factors which will result in deviations from recent per capita spending levels and to incorporate those changes in spending projections.

L.7.3 Net Fiscal Impacts

The underlying philosophy used to make baseline projections of revenues and expenditures is somewhat different from that used to make impact projections, although the methods used in each case are similar. Baseline projections are used to judge impacts. As a result, less detail goes into the baseline projections. For example, for counties, all spending is projected to grow in proportion to population under baseline conditions, while some revenue items may not be projected to grow. This can result in a projected deficit for a county. However, the proper interpretation of this result is not that the county is necessarily facing fiscal difficulties, but rather that if spending grows in proportion to population, some revenue sources will have to increase by more than the projected amount. A likely candidate for this is oil and gas taxes, projected to show no change, but it is also possible that other taxes, charges, or transfers could increase. As an alternative, spending (and service) levels may be reduced from current per capita levels.

No matter what fiscal adjustments may be made under baseline conditions, the baseline projections are intended to indicate orders of magnitude for spending and revenues during the period under analysis.

On the other hand, impact fiscal projections are intended to show, with as much accuracy as possible, given historical data and information obtained in interviews with local officials, the actual likely fiscal effect of the proposed action. Every effort is made to include in the analysis only those fiscal impacts associated with the proposed action. Thus, a projected fiscal deficit or surplus associated with the proposed action should be interpreted as such. Not only is greater detail incorporated into impact projections, but generally these projections can be made with greater reliability than can baseline projections. For example, projecting no change in oil and gas taxes causes problems under baseline conditions, but since oil and gas production generally is not expected to be affected by the changes associated with a proposed project, no change in these revenues is attributable to the project, regardless of what happens to oil and gas taxes.

BIBLIOGRAPHY

Association for University Business and Economic Research. Proceedings 1975 Conference. "Federal Data for University Research." Williamsburg, Virginia, 1975. Pages 110-137.

Association of Western Railways. Railroad Facts, 1977 (Chicago: Association of Western Railways, 1977).

Bonem, Gilbert, Micha Gisser, John Myers, and Mark Resta, Water Demand and Supply in the Albuquerque Greater Urban Area. Bureau of Business and Economic Research, University of New Mexico, Albuquerque, New Mexico, December 1977.

Burchell, Robert W., David Listokin, et al., The Fiscal Impact Handbook. Center for Urban Policy Research, New Brunswick, New Jersey, 1978.

Bureau of Business and Economic Research. New Mexico Statistical Abstract. 1977 Edition. New Mexico: The University of New Mexico, 1977.

Bureau of Economic Analysis, Regional Economic Information System. "Employment by Type and Broad Industrial Sources 1971-1975, Full and Part-time Wage and Salary Employment Plus Number of Proprietors." New Mexico. (Xeroxed tables).

Bureau of Economic Analysis, Regional Economic Information System. "Per Capita Personal Income in SMSAs, Counties and Independent Cities, In Selected Years, 1967-1975." New Mexico. (Xeroxed tables).

Bureau of Economic Analysis, Regional Economics Information System. "Personal Income by Major Sources 1970-1975." New Mexico. (Xeroxed tables).

Employment Security Commission. Various unpublished information. New Mexico: 1972-1978.

Gleason, Ken. 1978. Hobbs Assistant City Manager. Interview (with Larry Adcock).

Herkenhoff, Gordon and Associates, Inc. 1976. Water and Wastewater Master Plan, 1975-1995, Water Supply Study, City of Hobbs, New Mexico: December 1975.

Industrial Development Corporation of Lea County. Hobbs, New Mexico. Hobbs, New Mexico.

Leahman, Charles. Manpower Economist. Personal interview (with Larry Adcock). 1977 and 1978.

Lyon, Edgar P., 1977-1978. Director, Department of Development, Carlsbad, New Mexico. Interview (with Larry Adcock).

McNabb, Dan. 1978. Hobbs Director of Development. Interview (with Larry Adcock).

1790 120

Mountain West Research, Inc. Final Report. A Study for the Old West Regional Commission. Construction Worker Profile. December 1975.

New Mexico Department of Finance and Administration. New Mexico County Governments, Annual Report (various years), Santa Fe, New Mexico.

New Mexico Department of Finance and Administration. New Mexico Municipal Governments, Annual Report (various years), Santa Fe, New Mexico.

New Mexico Employment Security Commission. "Estimates of Average Size of Household and Family, 1940 to 1974, and Projections, 1975 to 1990, for the United States." Page 16. (Xeroxed Table 3).

New Mexico Interstate Stream Commission and New Mexico State Engineer Office, County Profile (various counties), Santa Fe, New Mexico.

U.S. Bureau of Mines. Minerals Yearbook, 1974, Vols. 1-3. (Washington, D.C.: U.S. Government Printing Office, 1974.)

U.S. Bureau of the Budget. Standard Industrial Classification Manual, 1967 and 1972. (Washington, D.C.: U.S. Government Printing Office, 1967 and 1972.)

U.S. Bureau of the Census. Census of Manufacturers. "1972 Area Series, New Mexico." MC72(3)-32. U.S. Government Printing Office, Washington, D.C. 1975.

U.S. Bureau of the Census. Census of Manufacturers. "1972 Industry Series." MC72. U.S. Government Printing Office, Washington, D.C. 1974-1975.

U.S. Bureau of the Census. Census of Mineral Industries. "1972 Area Series Mountain States." MIC72(2)-8. U.S. Government Printing Office, Washington, D.C. 1975.

U.S. Bureau of the Census. Census of Mineral Industries. "1972 Subject Series." MIC72. U.S. Government Printing Office, Washington, D.C., 1975.

U.S. Bureau of the Census. Census of Population: 1970. General Population Characteristics. Final Report PC(1)-B33, New Mexico. U.S. Government Printing Office, Washington, D.C., 1971.

U.S. Bureau of the Census. Census of Population: 1970. General Social and Economic Characteristics. Final Report PC(1)-B33, New Mexico. U.S. Government Printing Office, Washington, D.C., 1971.

U.S. Bureau of the Census. U.S. Census of Population: 1970. Number of Inhabitants. Final Report PC(1)-A33, New Mexico. U.S. Government Printing Office, Washington, D.C., 1971.

U.S. Bureau of the Census. Current Population Reports. Series P-25, No. 640. "Estimates of the Population of States with Components of Change: 1970 to 1975." U.S. Government Printing Office, Washington, D.C., 1976.

U.S. Bureau of the Census. Current Population Reports. Series P-25, No. 607. "The Number of Households and Families, 1975-1990." U.S. Government Printing Office, Washington, D.C., 1976.

U.S. Bureau of the Census, Census of Housing, General Housing Characteristics, New Mexico, June, 1971.

U.S. Department of Agriculture. Agricultural Statistics, 1975. U.S. Government Printing Office, Washington, D.C., 1975.

U.S. Department of Commerce. Bureau of the Census. Federal - State Cooperative Program for Population Estimates. Series P-26, No. 76-31. U.S. Government Printing Office, Washington, D.C., 1977.

U.S. Department of Labor. Employment and Wages, 1975. U.S. Government Printing Office, Washington, D.C., 1976.

Tiebout, Charles M. The Community Economic Base Study. New York: Committee For Economic Development. 1962.

Zink, Lee B. "A Note on Population Projections." New Mexico Business. August 1972. Pages 23-29.

1790 122

ANNEX

A NON-SURVEY TECHNIQUE FOR CONSTRUCTING A DIRECT REQUIREMENTS REGIONAL INPUT-OUTPUT TABLE

by

Larry Adcock, Associate Director & Economist
Bureau of Business & Economical Research
University of New Mexico

Larry Waldman, Doctoral Candidate
Department of Economics
University of New Mexico

In an article entitled "An Appraisal of Non-Survey Techniques for Estimating Regional Input-Output Models," David G. McMenamin and Joseph Haring state that:

> "Non-survey or minimum-survey methods for constructing regional input-output tables are attractive to model builders because of the relatively small cost involved as compared with full survey models." (9)

McMenamin and Haring go on to state that many of the non-survey techniques have not been highly successful in the past, but recently accuracy seems to have improved by the use of newly developed techniques. Indeed, the full survey method of building input-output tables is costly. While records are rather poor, it is estimated that the 1960 New Mexico table cost approximately $100,000 to construct and work was accomplished over a three-year period. Recent estimates indicate that a new table for New Mexico of the full-survey type would probably cost well over $100,000.

Such costs for a full-survey table for relatively small states makes the non-survey technique desirable in terms of available resources. However, the level of accuracy of the non-survey technique table is still in question. Therefore, in this study, an in-depth examination of several aspects of the location quotient adjustment process for deriving a non-survey input-output table from national coefficients was undertaken. In performing the task, two basic questions were answered: (1) can the table be constructed with available data and available techniques? and (2) how does the table compare with a full-survey based table?

The results of this study could be extremely important not only to the research work being conducted at the University of New Mexico, but to the State in general. Since the 1960 New Mexico full-survey table was compiled, little updating has occurred (2, Appendix A). In early 1970 an examination was made of this original survey-based table to determine if a household sector could be added to the direct coefficients table given the information available from the national level. This was accomplished in 1971. Basically, this constitutes the updating of the original 1960 table.

It is apparent that since the economic sector mix and the level of sophistication of the economy has changed significantly since 1960, the value of the 1960 table for research work is questionable. In this study, a non-survey 1960 table was derived from available information and then compared to the full-survey table in order to determine the level of accuracy of the non-survey technique. Since the tests proved positive, the BBER used the technique to construct a non-survey 1972 table for the State.

METHOD

The basic method employed in this study centers around the use of loca-

1790 124

tion quotients for determining the adjustment to be made to the direct coefficients of the United States input-output table in order to produce a regional direct coefficient input-output table. The result is a non-survey input-output table of direct coefficients for the New Mexico economy of 1960. Consequently, the location quotients were those for the period 1960 while the national survey coefficients are from 1963. The method therefore makes the naive assumptions that the coefficients did not change between 1960 and 1963, and that on the average the techniques of production in New Mexico are similar to those in the United States, at least in the 1960-1963 period.

The objective of this paper is not to engage in a digression of the relative positive and negative aspects of the input-output technique itself, but it does seem in order to discuss the assumption that the techniques used in production are constant to a specific industry regardless of its geographic location or size. Basically, a survey-derived input-output table for a specific region should point out the various techniques used in production when that table is compared with a table compiled for any other region. We would expect some differences; for example, the use of labor as a quantity input to production would vary from region to region depending upon the alternative costs in the production of a product, recognizing the fact that the producer minimizes his cost and that the labor costs relative to the price of other inputs vary from region to region.

The non-survey technique employed in this study, however, cannot take the varying techniques of production under consideration because the process of adjustment does not account for them. In this way the non-survey table differs from the region-specific survey type model.

Although many other minor dissimilarities can be distinguished, one other major distinction in this method exists. This variation concerns an assumption that normally occurs, not in the building of the model but in its use. In employing an I-O model for deriving the impact of changes to a specific industry in terms of size or production levels, or for the addition or deletion of industries in an area, normally we make the assumption that a specific industry or firm buys input products from other firms in the area that appear to produce those needed products for the production of the buyer's products. In other words, under normal conditions, the input-output process is not refined to the degree needed to adjust for the absence of a specific product needed from the existing industry that appears to produce the input simply because the Standard Industrial Classification code listing encompasses that specific input.

In the building of a survey-type input-output model this assumption is not needed, since the inputs are traced to domestic producers in the existing economy or the input is designated as an import. However, in the non-survey technique of building the input-output model, an assumption is also made that if the industry exists in the area, the product is bought in the area, and thus it is available. The location quotient does nothing more than adjust the level of purchasing of that specific input. Therefore, under normal conditions, it may be assumed that the non-survey technique employed in this study could slightly overestimate the purchasing of the required input-product from existing industries in the area by another existing industry. This could possibly underestimate the importation of needed inputs by any one specific industry. On the other hand, since a firm is classified by the major product (or service) it produces, then some product identification is obscured through classification and the result is an underestimate of available products. The latter situation appears to be the lesser of the two-sided problem.

Turning to the specific method used in this study, the first matter to consider is that of the adjustment technique, specifically, the location-quotient derivation and its application to the U.S. table. Two types of location quotients were used in this study. The first is the traditional type, which is a comparison of the relative importance of an industry in a region with its relative importance in the Nation, by use of employment figures. Secondly, the output-location quotient accomplishes the same comparison; however, instead of employment, the dollar volume of output is used.

The following is a description of the location quotients employed.

LOCATION QUOTIENTS

Employment Location Quotient

In its simplest form the employment-location quotient is defined for the i^{th} industry as:

$$ELQ = \frac{e_i/e}{E_i/E}$$

where:

ELQ is defined as the Employment-Location Quotient;
e_i is the regional (New Mexico) employment in the i^{th} industry;
e is the total employment in the region (New Mexico);
E_i is the national (total) employment in the i^{th} industry;
E is the total national employment (13,14).

If the location quotient is equal to 1, we assume that the region is self-sufficient in that industry. That is, on the average, the region is producing its domestic needs specific to that industry. If the location quotient is less than 1, the region is probably not producing its domestic needs in relation to that industry, and therefore part of the industry-specific consumption of that region is necessarily imported. On the other hand, if the location quotient is more than one, we assume that the region is producing goods for export. Several basic qualifications are necessary in order for the location quotient to be a realistic tool.

One necessary assumption is that the consumption patterns for each region are analogous to those of the nation as a whole, and that all production in the United States is consumed domestically. We can easily see that if the consumption is not 100 percent domestic, then a location quotient for any specific industry which is equal to unity does not necessarily mean that that industry is just self-sufficient. It may in fact be a net exporter.

Moreover, if national consumption of a specific product warrants importation of that product, a location quotient greater than unity may be needed for an industry to be self-sufficient in the production of that specific product. However, if we assume that the consumption patterns are fairly equal from region to region, and that imports and exports are small relative to total production, then the location quotient concept is intuitively a logical tool for the adjustment process.

Output-Location Quotients

Basically, those deficiencies and positive aspects of the employment-location quotient hold true for the output-location quotient. The output-location quotient is defined as:

$$XLQ = \frac{x_i/x}{X_i/X}$$

where:

XLQ is defined as the dollar output-location quotient;
x_i is the dollar output of the i^{th} industry in the region (New Mexico);
x is the dollar output of all industry (Gross State Product) in the region (New Mexico);
X_i is the dollar output nationally of the i^{th} industry;
X is the total dollar output of all industry (Gross National Product) in the nation.

We should note at this point that the output-location quotient is a non-traditional location quotient. The use of the output-location quotient is necessary in this study simply because employment location quotients do not properly represent an adjustment factor for certain industries. This is true because of the incompleteness of data on employment in certain industries or the simple non-existence of certain types of data needed to make the employment-location quotient a workable tool for other industries (particularly agriculture).

Direct Coefficients

The objective of this study is to produce a table of direct coefficients for a region by adjusting the national technical direct coefficients from the 1963 national study. The U.S. study used in this research consists of 352 endogenous sectors plus 27 exogenous sectors including such things as household, inventory-evaluation adjustment, net inventory change and government expenditures in addition to net exports and imports (23).

Procedure for Adjustment

Theoretically, the use of location quotients to adjust the national input-output coefficients can be justified by the assumption that if an industry in an area is not of average size, then it cannot supply all of the needs of other industries in terms of product inputs. The adjustment procedure using location quotients assumes that the selling industries are able to supply a product to the buying industries in relation to their size. Their size in the study is determined by both the industry's employment and output.

The location quotients, having once been computed, are used as adjustment factors on a row-by-row basis to the national table. Any location quotient which is greater than 1 indicates in the most basic terms that that industry is an exporting industry. That is, since it produces more, or employs more people than the average industry employs for the domestic location in which it is set, then the excess product is exported and it becomes a net exporting industry. For those industries which had a location quotient greater than 1, we assumed that they continued to buy input products in a similar fashion to that of the average industry across the United States; therefore, any upward adjustment in the direct coefficients on the national table would indicate that that specific industry is selling more of a product, percentage-wise, to a region-specific industry than that industry can use. This assumption, of course, would be unrealistic. Therefore, all location quotients which were greater than 1 were set to a constant factor of unity. This situation means that the selling industry, with a location quotient of unity, provides no more or no less than the products needed as inputs to other industries.

Data Limitations and Location-Quotient Computation

In trying to gather data to compute the needed location quotients for 352 endogenous sectors, the obvious conclusion is that the finer the break-out of the sub-industries of any major industry, the more limited the data. For example, excellent wage- and salary-employment statistics are available for a complete year at the two-digit SIC code level for all manufacturing industries. However, when the industries are disaggregated to a basic four-digit SIC code level, then the data becomes harder to obtain. Those employment data which are available at the four-digit SIC code level are published only once a year for the first quarter of the year. Therefore, when computing the employment location quotients, use of year-round data at the four-digit SIC code level was impossible, and only first-quarter information was used.

This situation could lead to a problem: the first quarter may not be representative of the employment in the industry, since (1) the industry may expand or contract throughout the year and the level in the first quarter is not the average for the year and (2) many industries are beset with seasonal employment and the first quarter nationwide is normally the slowest quarter of the year. Therefore, employment in the first quarter in many cases would not be representative of the total year because of seasonal fluctuation.

To eliminate part of the problem of using first-quarter data, the 1960 first-quarter data could be averaged with the 1961 data to produce a figure which probably would be closer to the 1960 average than that produced by using the first-quarter data. However, since this procedure would involve averaging two quarters from the same time of the year, no adjustment would be made for seasonal fluctuation. The effort in making such an averaging adjustment appeared to be a fruitless task since in computation of the location quotients by both methods, very little difference occurs in the results. This fact can

1790 128

be accounted for because a region in most cases would experience the same fluctuations in employment for any specific industry that the nation would in the very short run. Therefore, it was decided that the use of first-quarter data for 1960 would be as relevant to the situation as the average of the first quarters of 1960 and 1961. The employment-location quotients were therefore applied to all of the manufacturing sectors.

While it would have been preferable to use employment-location quotients for all sectors defined in the national table, such a plan was not possible considering the limitations of the data. For example, very little information is available on employment in the agricultural sector for the sub-industry categories listed on the national table. A figure for employment in all agriculture, of course, is available (24). However, when trying to locate employment in dairy farms, or for poultry and egg production, or in meat animal and miscellaneous livestock products, or in cotton, etc., the task is highly difficult if not impossible. Furthermore, if figures can be located, there is no guarantee that those figures are inclusive of the total employment in that industry, since many of the production units in the agricultural industry are nothing more than "ma and pa" operations, with employment of the proprietor rarely counted in the employment statistics at the sub-industry level. Therefore, after careful examination of the problems involved in trying to use employment-location quotients for the agricultural sector, a decision was made to use a non-traditional location quotient which we have called an output-location quotient (as explained in the foregoing section of this paper).

AGGREGATION OF THE NATIONAL TABLE

While the objective of this study is to produce a nonsurvey input-output table, the overall result of the study can be said to include a comparison of the nonsurvey table with a survey data table for New Mexico of 1960. The 1960 New Mexico table contained 42 endogenous sectors (2). In order to make such a comparison, the 352 endogenous sectors in the national table must be aggregated to the 42 sector level. Note that 292 of the 352 sectors are specific to manufacturing basically at the four-digit SIC code level. Therefore, the manufacturing portion of the table makes up nearly 83 percent of the total sectors defined in the national table. While aggregation is necessary due to the objective of the study, it should also be desirable for any region which could be defined below the national level because a high probability exists that something less than the 292 defined manufacturing sectors exist in that region. This premise is particularly true in New Mexico with its small manufacturing sector that comprised approximately 7 percent of total wage and salary employment in 1960 (33).

The aggregation process could have been accomplished using several means. First, a simple averaging of the coefficients for each by adding together each of the national sectors into its respective New Mexico sector, and then dividing by the number of sectors included. Obviously, this is a naive approach. Secondly, the sectors could have been averaged by weighting them as to their employment, which was apparently done in previous research (Shaffer, etc.) using the location-quotient method (13, 14). However, a third method exists which appeared to be better. Estimated output for each of the identified national sectors was computed and these sectors were weighted by their output. Obviously, one of the effects of this method would be the same as using employment as a weight -- that is, to give the larger industries in the state more influence in the determination of the direct coefficients than the smaller industries when two or more industries of unequal size are aggregated together. However, the third method did something more than the aggregation by employment size was able to accomplish. The aggregation by volume of output accounted for varying levels of productivity which exist from industry to industry. For those industries which had been adjusted by output location quotients the output figures already existed for the aggregation process.

For other industries which had been adjusted by employment-location quotients, estimating output in 1960 was necessary. Luckily, output data for 1958 and 1963 existed from the various detailed Censuses of Manufacturing, Business, etc. for those industries which had been adjusted by employment-location quotients (26). Therefore, the procedure was to arrive at an estimated level of output per employee (productivity) using a weighted average for the two data years. That output per employee is applied to the number of employees to get an estimated total output for that industry or sub-industry in 1960. Where possible, the level of productivity was specific to that State. However, some sub-industries were so small that no information on a state level was given in the various censuses. Therefore, productivity at the regional or national level had to be used.

The question arose as to how productivity at the national level compares with productivity for the individual states. In order to determine whether or not national productivity would be valid measure of local productivity, a random sample of five industries was chosen and an analysis was completed with from 10 to 20 observations, by state. The results of this analysis showed that the variation in productivity was negligible in the five industries among the states tested. Therefore, based on this random selection of five industries, we concluded that national productivity was a valid alternative to statewide productivity when necessary for use in computing estimated output.

COMPARISON

In this portion of the study, a description of the comparison between the 1960 survey-based table and the 1960 non-survey table is given. This comparison was performed with 39 and not 42 columns. Three sectors from the survey-based 1960 New Mexico table had to be deleted as they were defined differently in the non-survey table. A comparison test was performed that was similar to the test described by Shaffer and Chu in their article on non-survey based input-output techniques (14).

To test the accuracy of the non-survey table, χ^2 was computed for each column in the direct requirements table, taking as the true values the technical coefficients from the survey-based 1960 New Mexico Input-Output Table published by the UNM Bureau of Business Research. Two comparisons were made between the survey-based table and the direct requirements table with function weights: (1) a non-survey table aggregated without the use of location quotients to the 1960 survey-based table; and (2) a direct requirements table with both function weights and location quotients to the 1960 survey-based table. The null hypothesis was that the non-survey technique would yield direct requirements coefficients which were the same as those in the survey-based table. An evaluation was made of the results of the tests at the 95 percent level with 38 degrees of freedom. The results of the tests were as follows: for the direct requirements table without location quotients the χ^2 statistic in 22 of 39 columns was in the rejection interval,[1] indicating that function weights alone are not enough to produce reasonable accuracy. However, for the table with the location quotients, the χ^2 statistic was in the rejection interval in only 8 of the 39 columns. This figure indicates that the location-quotient method produces results that are reasonably close to the 1960 survey value.

CONCLUSION

In the introduction we stated that two questions were to be answered in this study: (1) can the table be constructed with available data and techniques? and (2) how does the table compare with a full survey-based table?

First, a non-survey based table obviously can be constructed in the manner by which it was accomplished in this project. The methodology in this study was considerably more time consuming and difficult than the location-quotients adjustment procedure described in the recent literature (9, 11, 13, 14). The procedure of adjusting coefficients previous to aggregation should be more accurate. Unfortunately, the study cannot attest to a difference in accuracy; however, obtaining data for the 352 endogenous sectors listed in the national input-output tables of 1963 and 1967 is more detailed and difficult than locating data for the more highly aggregated sectors, such as those appearing in the New Mexico and Washington state tables (1, 3, 4).

The advantage of the lower-cost non-survey technique is significant. Compared with a survey-based table, the total time involved in producing a non-survey based table is minimal. (A 1972 New Mexico non-survey table was produced in five weeks using this technique. The cost was less than $5,000).

The comparison of the location-quotient adjusted non-survey based table with the full survey table showed that some columns were significantly different. However, analysis of the columns which varied significantly in the two tables indicates that certain major sectors accounted for a large portion of that variation. For example, five of the six sub-sectors in agriculture showed significant variation, and one of the six sub-sectors of the mining industry varied significantly. Both of these major sectors were adjusted by output-location quotients and since the mining sector

---

[1] $\chi^2_{.05}$ with 38 d.f. was computed according to the formula:

$$\chi^2_\alpha = n\left(1 - \frac{2}{9n} + Z_\alpha \frac{2}{9n}\right)^3 \text{ where } n = 38 \text{ and } Z_\alpha = 1.645.$$

(Z_α is the normal deviate at the 95 percent level.)
Thus $\chi^2_{.05} = 53.380$.

Column Number	Industry	χ^2 Value Without Location Quotient Adjustment	χ^2 Value With Location Quotient Adjustment
1	Meat Animals	1837.86908	1836.52435
2	Dairy Products	3.91990	1.98851
3	Feed Grains	121.61327	110.09386
4	Cotton	68.22235	63.40295
5	Other Farm Products	79.11645	66.52820
6	Agricultural Services	1500.84171	535.16665
7	Copper Mining	156.29900	18.90447
8	Non-ferrous Ores Mining	126.60604	11.98700
9	Crude Oil & Petroleum	19.60852	11.60208
10	New Construction, Other	569.80825	70.58260
11	Chemical Mining	9.83117	0.80598
12	Coal, Stone & Clay Mining & Quarrying	157.44106	15.11602
13	Meat Products, Processed	334.29984	54.75327
14	Dairy Products, Processed	64.18916	0.17410
15	Grain Mill & Baked Products	466.76550	8.19718
16	Miscellaneous Food Products	107.07334	3.11619
17	Lumber, Wood & Furniture	56.70250	9.85470
18	Printing & Publishing	1155.28348	11.25779
19	Chemicals, Plastics & Rubber	94.98391	11.31261
20	Petroleum Refining	29.28434	0.92766
21	Concrete & Stone Products	10.50268	2.07352
22	Electrical Equipment & Machinery	95.06541	0.28200
23	Fabricated Metal Products	613.84833	0.25926
24	Miscellaneous Manufacturing	153.26054	0.92913
25	Railroads	20.06416	3.00616
26	Other Transportation	7.69775	0.51413
27	Gas & Oil Pipelines	17.40511	15.08370
28	Communications	11.00637	6.57453
29	Electric & Water Utilities	39.57436	2.81252
30	Gas Utilities	3321.07094	3320.87176
31	Wholesale Trade	21.68048	4.12142
32	Retail Trade	4.84526	0.13118
33	Finance & Insurance	2.77826	0.67102
34	Real Estate	4.20676	1.98422
35	Hotels & Motels	3.75628	0.28428
36	Personal Services	69.65323	1.18209
37	Business Services	1.58041	0.22846
38	Auto Repair	340.81264	1.46602
39	Medical & Educational	28.18200	0.15089

1790 132

fared well in the test there is no reason to believe that the output-location quotient adjustment accounted for the variation in agriculture. Therefore, concerning agriculture and mining, six of the twelve columns varied significantly between the two tables. These columns account for three quarters of the total columns which had χ^2 in the unacceptable range.

In manufacturing, only one column showed significant variation between the two tables. This column was meat packing (closely related to the agricultural sector). This χ^2 (54.75) could be said to be in a marginal range of acceptance. The gas-utilities column had the largest χ^2 of any of the columns. The variation in the gas-utilities column could be expected since the gas-utilities in New Mexico are different in activity compared with the national average. The New Mexico gas utilities are both producers and distributors and therefore the national coefficients should not and do not reflect this vertical integration.

Considering these results, we believe that the non-survey based technique used to build a 1960 table for New Mexico is an acceptable procedure and gives valid results in a majority of the columns. For those columns that have χ^2 significantly different from the survey-based 1960 table, most problems occur in the one sector (agriculture) for which data is very limited.

REFERENCES

1. Association of Western Railways, Railroad Facts, 1961 (Chicago: Association of Western Railways, 1961).

2. Blumenfeld, Arthur A., et al, "A Preview of the Input-Output Study," New Mexico Business (October, 1965).

3. Bourque, Philip J., "Forecasting with Input-Output," Business Studies, No. 5 (Seattle: University of Washington, 1971).

4. Bourque, Philip J., et al, "The Washington Economy: An Input-Output Study," Business Studies, No. 3 (Seattle: University of Washington, 1967).

5. Eastern Railroad Presidents Conference, Yearbook of Railroad Information, 1961 (New Jersey, 1961).

6. Harmston, Floyd K., and Lunc, Richard E., Application of an Input-Output Framework to a Community Economic System (Columbia, Missouri: University of Missouri Press, 1967).

7. Isard, Walter, Methods of Regional Analysis: An Introduction to Regional Science (Boston, Massachusetts: The MIT Press, 1960).

8. McPhee, Gordon, Local Economic Base Studies Using Input-Output Analysis (U.S. Department of Commerce, 1969).

9. McMenamin, David, and Haring, Joseph, "An Appraisal of Nonsurvey Techniques for Estimating Regional Input-Output Models," J Regional Science (August, 1974).

10. Miernyk, William H., A Primer of Input-Output Economics (Boston: Northeastern University, 1957).

11. Morrison, W. I., and Smith, P., "Nonsurvey Input-Output Techniques at the Small Area Level: An Evaluation," J Regional Science (April, 1974).

12. New Mexico Department of Agriculture, New Mexico Agricultural Statistics, Vol. 1 (Las Cruces, New Mexico: New Mexico State University, 1966).

13. Schaffer, William A., "Estimating Regional Input-Output Coefficients," Review of Regional Studies (Volume 2, 1972).

14. Schaffer, William A., and Chu, Kong, "Nonsurvey Techniques for Constructing Regional Interindustry Models," The Regional Science Association Papers (Volume 23).

15. The United States Bureau of the Budget, Standard Industrial Classification Manual, 1957 (Washington, D. C.: U.S. Government Printing Office, 1957).

16. The United States Bureau of the Budget, Standard Industrial Classification Manual, 1967 (Washington, D.C.: U.S. Government Printing Office, 1967).

17. The United States Bureau of Mines, Minerals Yearbook, 1960, Vols. 1-3 (Washington, D. C.: U.S. Government Printing Office, 1960).

18. The United States Department of Agriculture, Agricultural Statistics, 1960 (Washington, D. C.: U.S. Government Printing Office, 1960).

19. The United States Department of Agriculture, Agricultural Statistics, 1961 (Washington, D.C.: U.S. Government Printing Office, 1961).

20. The United States Department of Agriculture, Agricultural Statistics, 1963 (Washington, D. C.: U.S. Government Printing Office, 1963).

21. The United States Department of Agriculture, Seeds, The Yearbook of Agriculture, 1961 (Washington, D. C.: U.S. Government Printing Office, 1961).

22. The United States Department of Commerce, Bureau of the Census, County Business Patterns, 1962 (Washington, D. C.: U.S. Government Printing Office, 1963).

23. The United States Department of Commerce, Input-Output Structure of the U.S. Economy: 1963, Vols. 1 - 3 (Washington, D.C.: U.S. Government Printing Office, 1969).

24. The United States Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1961 (Washington, D. C.: U.S. Government Printing Office, 1961).

25. The United States Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1962 (Washington, D. C.: U.S. Government Printing Office, 1962).

26. The United States Department of Commerce, Bureau of the Census, 1963 Census of Business, various volumes (Washington, D. C.: U.S. Government Printing Office, 1966).

27. The United States Department of Commerce, Bureau of the Census, 1958 Census of Manufactures, Vols. 1 - 3 (Washington, D. C.: U.S. Government Printing Office, 1961).

28. The United States Department of Commerce, Bureau of the Census, 1963 Census of Manufactures, various volumes (Washington, D. C.: U.S. Government Printing Office, 1965).

29. The United States Department of Commerce, Bureau of the Census, 1963 Census of Mineral Industries, various volumes (Washington, D.C.: U.S. Government Printing Office, 1963).

30. The United States Department of Commerce, Bureau of the Census, United States Census of Agriculture, 1959, various volumes (Washington D.C.: U.S. Government Printing Office, 1962).

31. The United States Department of Commerce, Bureau of the Census, United States Census of Agriculture, 1964, various volumes (Washington, D.C.: U.S. Government Printing Office, 1967).

32. The United States Department of Labor, Bureau of Labor Statistics, Employment and Earnings, United States, 1909-71 (Washington, D.C.: U.S. Government Printing Office, 1972).

33. The United States Department of Labor, Employment and Wages, 1960 (Washington, D.C.: U.S. Government Printing Office, 1960).

34. Tiebout, Charles M., The Community Economic Base Study (New York: Committee for Economic Development, 1962).

35. F. W. Dodge Division, McGraw-Hill Information Systems Co., "Region VIII Bulletin," Dodge Construction Potentials Bulletins, appropriate years.

Attachment A

TABLE B.—TECHNICAL COEFFICIENTS: DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT, NEW MEXICO, 1960

(Each entry shows direct purchases by the sector at top, per dollar of its output, from sector at left.)

INDUSTRY PURCHASING

INDUSTRY SELLING

Industry selling		Agriculture: Meat animals 1	Dairy & poultry 2	Food grains & field crops 3	Cotton & cottonseed 4	Vegetables, fruits, et al. 5	Agricultural services 6	Mining: Copper 7	Uranium 8	Petroleum & natural gas 9	Oil & gas field services 10	Potash 11	Other mining 12
Agriculture	Meat animals 1												
	Dairy & poultry 2		.0164							*	*	*	.0001
	Food grains & field crops 3	.1113	.3229	.0163	.0020	.0032							
	Cotton & cottonseed 4		.0046		.0025								
	Vegetables, fruits, et al. 5					.0038	*	*	*	*	.0002	*	
	Agricultural services 6	.0070	.0099	.0590	.1681	.0296							
Mining	Copper 7							.0166					
	Uranium 8								.1926				
	Petroleum & natural gas 9									.0004			
	Oil & gas field services 10									.0702	.0592		
	Potash 11											.0369	
	Other mining 12							.0570	.0177			.0091	.0034
Manufacturing	Meat packing 13						.0001	*	*	.0001	.0008	.0001	.0001
	Processed dairy products 14						*	*	*	*	.0004	.0001	.0001
	Grain mill & bakery products 15	.0445	.1396	.0010	.0006	.0010			*	*	.0001	*	
	Miscellaneous food products 16	.0017	.0059				*	*	*	*	.0002	*	*
	Lumber & wood products 17	.0014	.0019	.0017	.0011	.0007		.0027	.0020			.0006	
	Printing & publishing 18						.0006	.0002	*		.0037	.0009	.0003
	Chemicals 19	.0009	.0019	.0015	.0027	.0018						.0008	
	Petroleum refining 20	.0064	.0050	.0246	.0126	.0138	.0209	.0013	.0041	.0099	.0252	.0033	.0150
	Concrete & stone products 21	.0009	.0013	.0011	.0008	.0005						.0002	
	Machinery & Electrical equipment 22			.0005	.0004						.0013	.0005	
	Fabricated metal products 23										.0014	.0003	
	Miscellaneous manufacturing 24												
Transport & Utilities	Railroads 25	.0012					.0001	.0404	.0013	.0006	.0019	.0119	.0013
	Trucking & other transportation 26	.0035	.0054		.0346		.0001	.0004	.0039	.0011	.0190	.0029	.0031
	Gas & petroleum pipelines 27									.0005			
	Telephone & telegraph 28	.0025	.0038	.0034	.0043	.0030	.0050	.0011	.0014	.0024	.0058	.0028	.0054
	Electric light & power 29	.0036	.0036	.0036	.0036	.0036	.0164	.0024	.0046	.0022	.0001	.0246	.0116
	Gas utilities 30						.0315	.0196	.0097		.0018	.0180	.0016
Trade	Wholesale 31	.0144	.0298	.0083	.0052	.0060	.0064	.0115	.0243	.0308	.0487	.0177	.0403
	Gasoline service stations 32	.0061	.0048	.0233	.0119	.0130	.0198	*	.0003	.0002	.0021	.0003	.0005
	Eating & drinking places 33						.0004	.0002	.0003	.0005	.0059	.0009	.0009
	Other retail trade 34	.0432	.0896	.0248	.0155	.0180	.0291		.0003	.0010	.0007	*	.0001
FIRE	Finance & insurance 35	.0300	.0201	.0282	.0410	.0147	.0219	.0099	.0007	.0009	.0219	.0094	.0142
	Real estate 36	.0105	.0118	.0062	.0082	.0015	.0038	.0010	.0034	.0035	.0046	.0066	.0006
Services	Hotels & motels 37						.0004	.0002	.0002	.0004	.0010	.0009	.0008
	Personal services 38						.0006						
	Business services 39					.0002	.0059	.0008	.0007	.0025	.0225	.0002	.0188
	Auto & other repair services 40	.0054	.0102	.0268	.0114	.0151	.0581	.0007	.0010		.0112	.0008	.0177
	Medical & professional 41						.0028						
	Research & development 42							.0008	.0088	.0060	.0044	.0073	.0031

Industry selling		Manufacturing: Meat packing 13	Processed dairy products 14	Grain mill & bakery products 15	Miscellaneous food products 16	Lumber & wood products 17	Printing & publishing 18	Chemicals 19	Petroleum refining 20	Concrete & stone products 21	Machinery & electrical equipment 22	Fabricated metal products 23	Miscellaneous manufacturing 24
Agriculture	Meat animals 1	.5630											
	Dairy & poultry 2	.0436	.3385	.0075	.0005				*				
	Food grains & field crops 3	.0231		.3211									
	Cotton & cottonseed 4				.0544								
	Vegetables, fruits, et al. 5	*	*	*	.0358	*	.0001	*	*	*	*	*	*
	Agricultural services 6												
Mining	Copper 7												
	Uranium 8												
	Petroleum & natural gas 9							.1450	.2760				
	Oil & gas field services 10												
	Potash 11									.0109			
	Other mining 12								.0052	.0170			
Manufacturing	Meat packing 13	*	*	*	.0001	.0001	.0002	.0002	.0002	.0002	.0002	.0001	.0002
	Processed dairy products 14	*	.0587	*	*	.0001	.0001	.0001	.0001	.0001	.0001	*	.0001
	Grain mill & bakery products 15			.0159		*	*	*	*	*	*	*	*
	Miscellaneous food products 16	.0005	*	*	.0101	*	.0001	.0001	.0001	.0001	.0001	*	.0001
	Lumber & wood products 17					.1777						.0011	.0006
	Printing & publishing 18	.0014	.0011	.0020	.0028	.0013	.0044	.0017	.0004	.0013	.0016	.0020	.0018
	Chemicals 19		.0003					.0046				.0013	
	Petroleum refining 20	.0015	.0043	.0039	.0060	.0023	.0021	.0023	.0380	.0035	.0027	.0005	.0036
	Concrete & stone products 21									.1158			
	Machinery & Electrical equipment 22			.0002		.0017				.0058	.0117	.0144	.0098
	Fabricated metal products 23									.0058	.0018	.0431	.0098
	Miscellaneous manufacturing 24												.0196
Transport & Utilities	Railroads 25	.0019	.0006	.0002	.0004	.0106	.0007	.0280	.0003	.0009	.0004	.0019	.0016
	Trucking & other transportation 26	.0010	.0020	.0036	.0017	.0130	.0021	.0017	.0011	.0026	.0012	.0028	.0058
	Gas & petroleum pipelines 27							.1584	.3047				
	Telephone & telegraph 28	.0021	.0029	.0043	.0037	.0068	.0079	.0075	.0026	.0075	.0061	.0062	.0040
	Electric light & power 29	.0028	.0150	.0046	.0255	.0111	.0065	.0147	.0060	.0056	.0043	.0056	.0034
	Gas utilities 30	.0030	.0068	.0054	.0101	.0021	.0019	.0028	.0054	.0061	.0018	.0028	.0017
Trade	Wholesale 31	.0052	.0047	.0173	.0377	.0121	.0206	.0094	.0073	.0168	.0264	.0042	.0085
	Gasoline service stations 32	.0015	.0041	.0037	.0056	.0022	.0020	.0022	.0020	.0030	.0025	.0006	.0034
	Eating & drinking places 33	.0004	.0003	.0003	.0004	.0009	.0017	.0016	.0016	.0013	.0013	.0006	.0016
	Other retail trade 34	.0002	.0005	.0006	.0015	.0032	.0016	.0016	.0007	.0055	.0057	.0005	.0012
FIRE	Finance & insurance 35	.0100	.0060	.0115	.0177	.0138	.0227	.0203	.0048	.0112	.0092	.0022	.0136
	Real estate 36	.0017	.0180	.0110	.0205	.0040	.0210	.0181	.0061	.0080	.0147	.0024	.0228
Services	Hotels & motels 37	.0003	.0003	.0004	.0004	.0008	.0026	.0014	.0017	.0003	.0005	.0004	.0013
	Personal services 38	.0019	.0027	.0019	.0012	.0004	.0069			.0016	.0016	.0010	.0002
	Business services 39	.0011	.0241	.0140	.0128	.0240	.0152	.0051	.0074	.0070	.0062	.0079	.0136
	Auto & other repair services 40	.0025	.0121	.0036	.0120	.0204	.0070	.0014		.0162	.0047	.0049	.0005
	Medical & professional 41	.0035	.0040	.0019	.0056	.0075	.0063	.0111	.0111	.0099	.0100	.0026	.0053
	Research & development 42												

Industry selling		Transport & Utilities: Railroads 25	Trucking & other transportation 26	Gas & petroleum pipelines 27	Telephone & telegraph 28	Electric light & power 29	Gas utilities 30	Trade: Wholesale 31	Gasoline service stations 32	Eating & drinking places 33	Other retail trade 34	FIRE: Finance & insurance 35	Real estate 36
Agriculture	Meat animals 1		.0021										
	Dairy & poultry 2		*	*	*			*	*	.0001	*	*	*
	Food grains & field crops 3												
	Cotton & cottonseed 4												
	Vegetables, fruits, et al. 5		.0004	.0001	.0002	*		.0002	.0001	.0003	.0001	.0001	.0007
	Agricultural services 6												
Mining	Copper 7												
	Uranium 8												
	Petroleum & natural gas 9						.3611						
	Oil & gas field services 10												
	Potash 11												
	Other mining 12												
Manufacturing	Meat packing 13	*	.0023	.0004	.0005	*		.0036	.0004	.0011	.0005	.0005	.0003
	Processed dairy products 14		.0009	.0002	.0003	*		.0003	.0002	.0007	.0003	.0002	.0002
	Grain mill & bakery products 15		.0003	.0001	.0001			.0001	.0001	.0002	.0001	.0001	.0001
	Miscellaneous food products 16	.0097	.0138	.0001	.0002	*		.0002	*	.0004	.0002	.0002	.0001
	Lumber & wood products 17		.0029				.0004						
	Printing & publishing 18	.0003	.0053	.0003	.0046	.0027		.0183	.0099	.0109	.0115	.0113	.0110
	Chemicals 19					.0008	.0001						
	Petroleum refining 20	.0383	.0132	.0012	.0009	.0010	.0011		.0106	.0022	.0028	.0030	.0014
	Concrete & stone products 21	.0019		.0042				.0009					
	Machinery & Electrical equipment 22						.0002		.0001		.0012		.0003
	Fabricated metal products 23						.0001		.0001		.0012		.0002
	Miscellaneous manufacturing 24					.0012		.0005		.0016	.0031		
Transport & Utilities	Railroads 25	.0054	.0005	.0004	.0003	.0007	.0015	.0103			*	*	*
	Trucking & other transportation 26		.0266	.0035	.0002	.0009	.0021	.0111	.0077	.0003	*	.0006	.0002
	Gas & petroleum pipelines 27						.0269						
	Telephone & telegraph 28	.0014	.0159	.0054	.0132	.0115	.0006	.0169	.0167	.0180	.0012	.0148	.0122
	Electric light & power 29	.0008	.0051	.0038	.0062	.0533	.0025	.0042	.0082	.0194	.0096	.0034	.0035
	Gas utilities 30	.0005	.0029		.0010	.1116		.0029	.0058	.0174	.0056	.0011	.0025
Trade	Wholesale 31	.0096	.0145	.0039	.0091	.0044	.0032	.0211	.0054	.0053	.0056	.0021	.0009
	Gasoline service stations 32	*	.0162	.0011	.0008	.0009	.0011	.0059	.0100	.0021	.0026	.0028	.0013
	Eating & drinking places 33	*	.0043	.0026	.0043	.0002		.0044	.0030	.0088	.0036	.0038	.0025
	Other retail trade 34	.0020	.0038	.0027	.0027	.0002	.0002	.0044	.0018	.0027	.0071	.0028	.0049
FIRE	Finance & insurance 35	.0002	.0153	.0194	.0018	.0383	.0013	.0090	.0245	.0327	.0202	.0251	.0269
	Real estate 36	.0016	.0243	.0040	.0092	.0025	.0043	.0298	.0442	.0475	.0588	.0233	.0160
Services	Hotels & motels 37	*	.0010	.0025	.0037	.0002		.0018	.0023	.0002	.0023	.0034	.0005
	Personal services 38	.0004	.0038		.0002			.0017	.0010	.0277	.0032	.0001	.0010
	Business services 39	.0045	.0258	.0061	.0071	.0012	.0011	.0036	.0148	.0125	.0157	.0193	.0118
	Auto & other repair services 40	.0005	.0153		.0051		.0037	.0068	.0024		.0023	.0024	.0028
	Medical & professional 41	.0142	.0045	.0079	.0081	.0042	.0050	.0101	.0120	.0105	.0115	.0204	.0074
	Research & development 42												

Industry selling		Services: Hotels & motels 37	Personal services 38	Business services 39	Auto & other repair services 40	Medical & professional 41	R & D: Research & development 42	
Agriculture	Meat animals 1						*	1
	Dairy & poultry 2		*	*		.0003		2
	Food grains & field crops 3	.0010						3
	Cotton & cottonseed 4							4
	Vegetables, fruits, et al. 5	*	*	.0001	*	.0014		5
	Agricultural services 6							6
Mining	Copper 7							7
	Uranium 8							8
	Petroleum & natural gas 9							9
	Oil & gas field services 10							10
	Potash 11							11
	Other mining 12							12
Manufacturing	Meat packing 13	.0001	.0002	.0003	.0001	.0004	*	13
	Processed dairy products 14	.0001	.0001	.0002	.0001	.0028	*	14
	Grain mill & bakery products 15	*	*	.0001	*	.0008	.0001	15
	Miscellaneous food products 16	*	.0001	.0001	*	.0008		16
	Lumber & wood products 17			.0070			.0007	17
	Printing & publishing 18	.0099	.0080	.0070	.0050	.0058	.0007	18
	Chemicals 19			.0012			.0009	19
	Petroleum refining 20	.0022	.0030	.0043	.0068	.0034	.0001	20
	Concrete & stone products 21			.0045				21
	Machinery & Electrical equipment 22		*	.0105		.0003	.0077	22
	Fabricated metal products 23		*	.0105			.0066	23
	Miscellaneous manufacturing 24		.0020				.0004	24
Transport & Utilities	Railroads 25	*	.0013	.0012	*	.0002	.0010	25
	Trucking & other transportation 26	.0001	.0021	.0056	.0004	.0011	.0008	26
	Gas & petroleum pipelines 27							27
	Telephone & telegraph 28	.0256	.0130	.0202	.0094	.0132	.0044	28
	Electric light & power 29	.0410	.0152	.0031	.0068	.0082	.0017	29
	Gas utilities 30	.0325	.0105	.0016	.0031	.0050	.0001	30
Trade	Wholesale 31	.0160	.0179	.0111	.0161	.0116	.0017	31
	Gasoline service stations 32	.0021	.0028	.0028	.0065	.0032	.0004	32
	Eating & drinking places 33	.0006	.0011	.0014	.0007	.0024	.0004	33
	Other retail trade 34	.0051	.0043	.0064	.0050	.0037	.0002	34
FIRE	Finance & insurance 35	.0104	.0122	.0120	.0200	.0114	.0007	35
	Real estate 36	.0268	.0539	.0187	.0276	.0242	.0007	36
Services	Hotels & motels 37	.0009	.0006	.0007	.0006	.0029	.0001	37
	Personal services 38	.0463	.0139	.0006	.0013	.0120	.0120	38
	Business services 39	.0112	.0081	.0413	.0120	.0127	.0010	39
	Auto & other repair services 40	.0091	.0077	.0015	.0014	.0040	*	40
	Medical & professional 41	.0134	.0147	.0087	.0052	.0486	.0012	41
	Research & development 42						.0007	42

* Less than .00005

Source: *New Mexico Business*, October 1965, "A Preview of the Input-Output Study", Arthur A. Blumenfeld et al, Bureau of Business Research, University of New Mexico.

With Location Quotient Adjustment

NEW MEXICO INPUT-OUTPUT MODEL, 1960
TECHNICAL COEFFICIENTS: DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT

INDUSTRY PURCHASING

INDUSTRY SELLING		1	2	3	4	40	41	42		**** ROW SUMS ****
MEAT ANIMALS	1	0.27096	0.00000	0.05196	0.0441	0.00000	0.00000	0.00000	1	0.94268
DAIRY PRODUC	2	0.00295	0.00000	0.01007	0.006	.00000	0.00000	0.00000	2	0.34722
FEED GRAINS	3	0.20623	0.23408	0.02256	0.00	00000	0.00010	0.00000	3	0.66950
COTTON	4	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	4	0.23377
OTHER FARM P	5	0.00355	0.00002	0.00000	0.00	0000	0.00379	0.00000	5	0.19605
AGRICULTURAL	6	0.00000	0.03689	0.02692	0.115	0000	0.00004	0.00000	6	0.21494
COPPER MININ	7	0.00000	0.00000	0.00000	0.000	0000	0.00000	0.00000	7	0.29950
NONFERROUS O	8	0.00000	0.00000	0.00000	0.0000	0000	0.00000	0.00000	8	0.16612
CRUDE OIL &	9	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	9	0.67426
NEW CONSTRUC	10	0.00000	0.00000	0.00000	0.0000	.00000	0.00000	0.00000	10	0.00000
CHEMICAL MIN	11	0.00000	0.00000	0.00173	0.000	.00000	0.00000	0.00000	11	0.07378
COAL, STONE	12	0.00003	0.00014	0.00261	0.001	00000	0.00806	0.00000	12	0.13382
MEAT PRODUCT	13	0.00000	0.00000	0.00000	0.00	00000	0.00000	0.00000	13	0.06155
DAIRY PRODUC	14	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	14	0.12100
GRAIN MILL &	15	0.05223	0.16519	0.00000	0.00	0000	0.00000	0.00000	15	0.34171
MISC. FOOD P	16	0.00613	0.00648	0.00000	0.00	00000	0.00001	0.00000	16	0.06534
LUMBER, WOOD	17	0.00000	0.00000	0.00000	0.00	.00000	0.02505	0.00000	17	0.26494
PRINTING & P	18	0.00001	0.00001	0.00001	0.00	.00080	0.00000	0.00395	18	0.02796
CHEMICALS, P	19	0.00121	0.00116	0.01625	0.010	.00008	0.00220	0.00022	19	0.17898
PETROLEUM RE	20	0.00379	0.00635	0.03232	0.020	.00375	0.01244	0.00462	20	0.39807
CONCRETE & S	21	0.00000	0.00000	0.00008	0.0000	00000	0.06121	0.00000	21	0.26486
ELECTRICAL &	22	0.00007	0.00009	0.00049	0.0003	0006	0.00056	0.00002	22	0.11071
FABRICATED M	23	0.00000	0.00001	0.00002	0.0000	0000	0.02206	0.00000	23	0.06663
MISC. MANUFA	24	0.00044	0.00025	0.00032	0.0007	000	0.00093	0.00000	24	0.09434
RAILROADS	25	0.00495	0.00716	0.00545	0.003	036	0.01320	0.00055	25	0.29136
OTHER TRANSP	26	0.01225	0.02493	0.00489	0.003	049	0.01913	0.00070	26	0.40760
GAS & OIL PI	27	0.00010	0.00017	0.00086	0.000	0006	0.00014	0.00009	27	0.04018
COMMUNICATIO	28	0.00161	0.00269	0.00311	0.002	1182	0.00272	0.01021	28	0.26010
ELECTRIC & W	29	0.00240	0.00471	0.00458	0.0082	.01233	0.00229	0.03280	29	0.43888
GAS UTILITIE	30	0.00000	0.00089	0.00000	0.0000	.00296	0.00040	0.00300	30	0.51581
WHOLESALE TR	31	0.01563	0.01606	0.01339	0.0097	00480	0.02921	0.00508	31	0.58733
RETAIL TRADE	32	0.00718	0.01308	0.01322	0.013	01906	0.03863	0.00786	32	0.32881
FINANCE & IN	33	0.00332	0.00385	0.00664	0.009	0438	0.00362	0.00286	33	0.37696
REAL ESTATE	34	0.01030	0.01234	0.08643	0.12	5412	0.00475	0.10525	34	1.43631
HOTELS & MOT	35	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	35	0.00432
PERSONAL SER	36	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00204	36	0.19501
BUSINESS SER	37	0.00566	0.00050	0.03871	0.02	01606	0.00694	0.01607	37	0.53671
AUTO REPAIR	38	0.00273	0.00355	0.00591	0.00	00659	0.00363	0.00803	38	0.18152
MEDICAL & ED	39	0.00181	0.00408	0.00000	0.000	.00000	0.00000	0.00491	39	0.02043
MISC. PROFES	40	0.0012	0.00145	0.00156	0.001	.06982	0.04089	0.01416	40	0.33638
NEW CONSTRUC	41	0.00666	0.00933	0.01467	0.0141	00046	0.00026	0.04110	41	0.55663
NONPROFIT OR	42	0.00027	0.00503	0.00038	0.000	00074	0.00085	0.00067	42	0.04476
*** COLUMN SUMS ***		0.62377	0.56049	0.36507	0.426	0874	0.30309	0.26408		

Complete tables will be furnished upon request to the Bureau of Business and Economic Research, University of New Mexico, Albuquerque, NM 87131.

POOR ORIGINAL

Attachment B-2

POOR ORIGINAL

Without Location Quotient Adjustment

NEW MEXICO INPUT-OUTPUT MODEL, 1960
TECHNICAL COEFFICIENTS: DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT

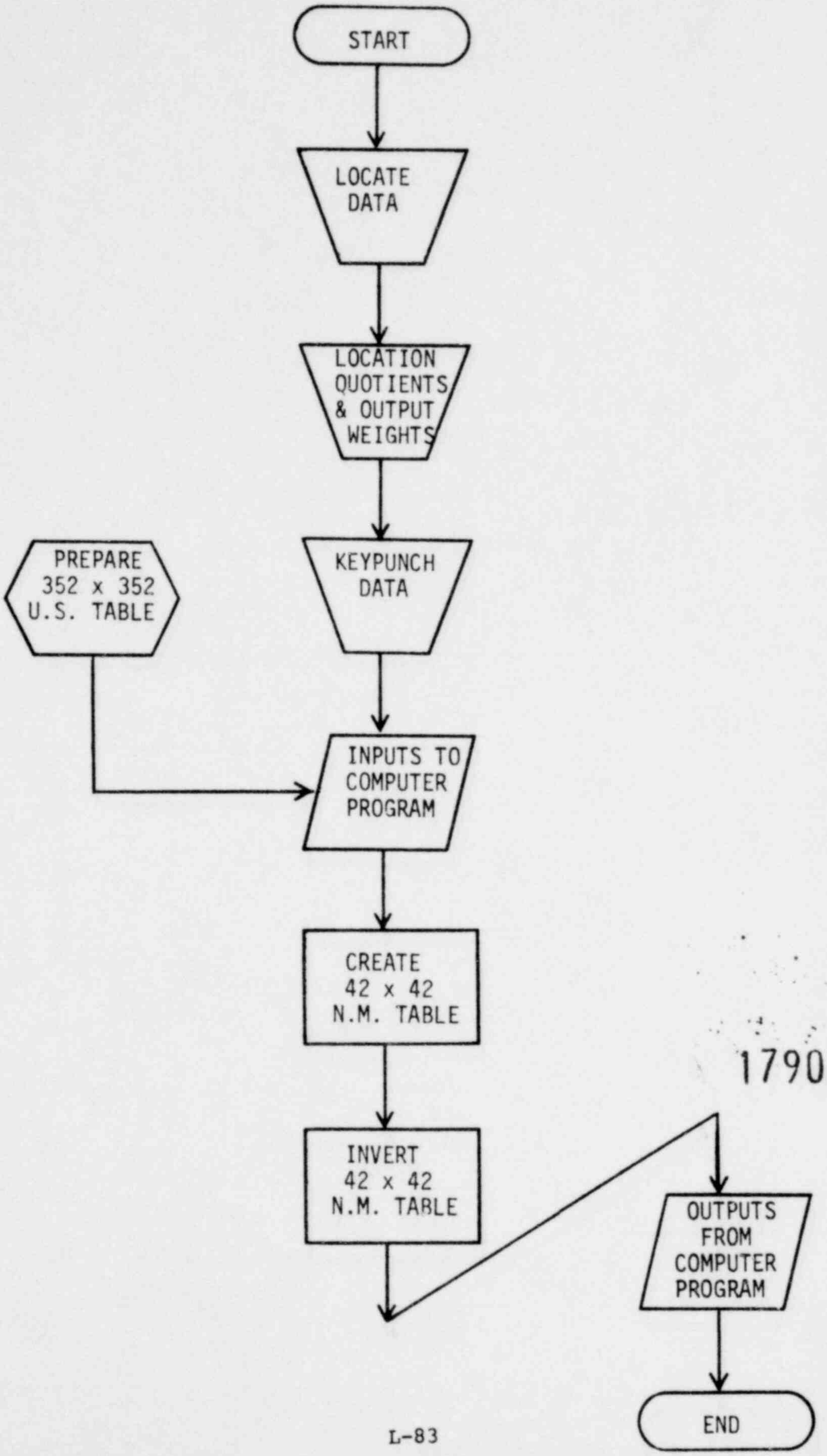
INDUSTRY SELLING / INDUSTRY PURCHASING

		1	2	3	4	40	41	42	****	ROW SUMS ****
MEAT ANIMALS	1	0.27096	0.00000	0.05196	0.04418	0.00000	0.00000	0.00000	1	0.94268
DAIRY PRODUC	2	0.00521	0.00000	0.01934	0.0124	.00000	0.00000	0.00000	2	0.69955
FEED GRAINS	3	0.28783	0.32670	0.03148	0.000	.00000	0.00015	0.00000	3	0.93440
COTTON	4	0.00000	0.00000	0.00000	0.00	00000	0.00000	0.00000	4	0.23377
OTHER FARM P	5	0.00425	0.00003	0.00000	0.00	00000	0.00382	0.00000	5	0.27395
AGRICULTURAL	6	0.00000	0.03689	0.02692	0.11	0000	0.00004	0.00000	6	0.21494
COPPER MININ	7	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	7	0.30597
NONFERROUS O	8	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00000	8	0.16612
CRUDE OIL &	9	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	9	0.67426
NEW CONSTRUC	10	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	10	0.00000
CHEMICAL MIN	11	0.00000	0.00000	0.00173	0.0009	.00000	0.00000	0.00000	11	0.07378
COAL, STONE	12	0.00004	0.00051	0.00395	0.0026	.00000	0.01222	0.00000	12	0.26821
MEAT PRODUCT	13	0.00000	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	13	0.15089
DAIRY PRODUC	14	0.00000	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	14	0.18967
GRAIN MILL &	15	0.05816	0.18486	0.00000	0.000	0.00000	0.00000	0.00000	15	0.47391
MISC. FOOD P	16	0.01635	0.02272	0.00000	0.000	0.00000	0.00036	0.00000	16	0.43149
LUMBER, WOOD	17	0.00011	0.00116	0.00012	0.000	0.00082	0.05798	0.00035	17	1.01735
PRINTING & P	18	0.00016	0.00022	0.00028	0.00	0.00837	0.00003	0.01948	18	0.21111
CHEMICALS, P	19	0.00434	0.00599	0.06076	0.06	.00010	0.01131	0.00069	19	0.89618
PETROLEUM RF	20	0.00511	0.00858	0.04352	0.02	00506	0.02149	0.00623	20	0.54868
CONCRETE & S	21	0.00014	0.00130	0.00139	0.00	00020	0.13758	0.00000	21	1.07423
ELECTRICAL &	22	0.00081	0.00090	0.01389	0.00	0057	0.04247	0.00059	22	1.23212
FABRICATED M	23	0.00022	0.00375	0.00180	0.000	0005	0.10477	0.00000	23	0.48542
MISC. MANUFA	24	0.00235	0.00284	0.00727	0.004	0107	0.01086	0.00312	24	0.59791
RAILROADS	25	0.00495	0.00716	0.00545	0.003	0036	0.01320	0.00055	25	0.29136
OTHER TRANSP	26	0.01308	0.02553	0.00676	0.0053	0064	0.02065	0.00095	26	0.58462
GAS & OIL PI	27	0.00010	0.00017	0.00086	0.0005	0006	0.00014	0.00009	27	0.04018
COMMUNICATIO	28	0.00161	0.00269	0.00311	0.0027	01182	0.00272	0.01021	28	0.26010
ELECTRIC & W	29	0.00243	0.00475	0.00830	0.0097	.01434	0.00269	0.03411	29	0.48629
GAS UTILITIE	30	0.00000	0.00089	0.00000	0.00000	.00295	0.00040	0.00300	30	0.51581
WHOLESALE TR	31	0.02229	0.02291	0.01910	0.01390	.00685	0.04165	0.00724	31	0.83761
RETAIL TRADE	32	0.00718	0.01308	0.01322	0.0135	.01906	0.03863	0.00786	32	0.32881
FINANCE & IN	33	0.00561	0.00671	0.01204	0.0152	.00682	0.00651	0.00634	33	0.57405
REAL ESTATE	34	0.01030	0.01234	0.08643	0.1241	05412	0.00475	0.10525	34	1.43631
HOTELS & MOT	35	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	35	0.00432
PERSONAL SER	36	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00241	36	0.19902
BUSINESS SER	37	0.00571	0.00050	0.03871	0.021	1801	0.00783	0.01760	37	0.75762
AUTO REPAIR	38	0.00273	0.00355	0.00591	0.005	0659	0.00363	0.00803	38	0.18152
MEDICAL & ED	39	0.00371	0.00639	0.00000	0.000	0000	0.00000	0.00746	39	0.03568
MISC. PROFES	40	0.00129	0.00145	0.00156	0.001	06982	0.04089	0.01416	40	0.33638
NEW CONSTRUC	41	0.00666	0.00933	0.01467	0.0141	00046	0.00026	0.04110	41	0.55663
NONPROFIT OR	42	0.00028	0.00522	0.00040	0.0006	.00075	0.00088	0.00069	42	0.04641
COLUMN SUMS ***		0.74399	0.72111	0.48092	0.51685	0.22892	0.58791	0.29752		

Complete tables will be furnished upon request to the Bureau of Business and Economic Research, University of New Mexico, Albuquerque, NM 87131.

1790 139

FLOW CHART FOR CREATING A NON-SURVEY REGIONAL INPUT-OUTPUT MODEL



1790 140

Appendix M

SOCIOECONOMIC EFFECTS OF PLANT CONSTRUCTION AND OPERATION: SUPPORTING DATA

CONTENTS

Table M-1. Population Estimates and Projections: Scenario I for the Reference Case[a]

Year	Eddy County (99%, 90%)[b]	Carlsbad (88%, 80%)[b]	Carlsbad School District (93%, 85%)[b]	Lea County (1%, 10%)[b]
1970	41,119	21,297	25,498	49,554
1975	42,900	NA	NA	51,600
1976	45,300	25,500	29,300	54,400
1977	46,200	26,600	30,400	55,500
1978	47,300	27,900	31,600	56,600
1979	48,200	28,600	32,400	57,700
1980	49,300	29,500	33,300	58,800
1981[c]	50,790	30,720	34,650	60,210
1982	53,320	32,830	36,920	61,680
1983	54,900	34,180	38,430	63,250
1984	55,400	34,520	38,750	64,650
1985	55,200	34,050	38,320	66,000
1986	56,240	34,610	38,970	67,660
1987	57,540	35,410	39,870	69,460
1988	58,940	36,310	40,870	71,260
1989	60,340	37,110	41,770	73,060
1990	61,740	38,010	42,770	74,960
1995[d]	65,440	40,210	45,270	81,160
2000	69,440	42,710	48,070	87,860
2010	73,340	45,110	50,770	92,860

NA = not available.

[a]In scenario I, the direct impact of the reference case (construction and operation) is assumed to be distributed as follows: Carlsbad, 88%; rest of Eddy County, 11%, Lea County, 1%. The indirect impact is distributed as follows: Carlsbad, 80%; rest of Eddy County, 10%; Lea County, 10% (Adcock and Associates, 1977-1978).

[b]The percentages given in parentheses are the direct and indirect population migration, respectively, resulting from the reference case. Percentages may vary because of rounding.

[c]Construction of the WIPP reference repository assumed to begin in 1981. All impacts assumed to be static after 1986.

[d]Projections for years beyond 1995 assume continued activity in the oil and gas industry at a stable but constant level. Present production levels measured against proved oil and gas reserves and recovery rates indicate that activity could decrease before 1990. However, secondary and tertiary (oil only) recovery procedures could prolong activity beyond the year 2010.

Table M-2. Population Estimates and Projections: Scenario II for the Reference Case[a]

Year	Eddy County (58%)[b]	Carlsbad (54%)[b]	Remainder of Eddy County (4%)[b]	Lea County (42%)[b]	Hobbs (36%)[b]	Remainder of Lea County (6%)[b]	Hobbs School District (39%)[b]
1970	41,119	21,297	19,822	49,554	26,025	23,529	29,858
1975	42,900	NA	NA	51,600	NA	NA	33,300
1976	45,300	25,500	19,800	54,400	31,300	23,100	35,600
1977	46,200	26,600	19,600	55,500	32,200	23,300	36,900
1978	47,300	27,900	19,400	56,600	32,650	23,950	37,400
1979	48,200	28,600	19,600	57,700	33,150	24,550	37,950
1980	49,300	29,500	19,800	58,800	33,600	25,200	38,400
1981[c]	50,550	30,520	20,030	60,450	34,670	25,780	39,580
1982	52,640	32,270	20,370	62,360	35,950	26,410	40,950
1983	53,770	33,250	20,520	64,380	37,250	27,130	42,340
1984	54,440	33,730	20,710	65,610	38,050	27,560	43,230
1985	54,670	33,610	21,060	66,530	38,540	27,990	43,730
1986	55,800	34,250	21,550	68,100	39,430	28,670	44,670
1987	57,100	35,050	22,050	69,900	40,430	29,470	45,770
1988	58,500	35,950	22,550	71,700	41,480	30,220	46,870
1989	59,900	36,750	23,150	73,500	42,530	30,970	48,020
1990[d]	61,300	37,650	23,650	75,400	43,630	31,770	49,270
1995	65,000	39,850	25,150	81,600	48,330	33,270	54,220
2000	69,000	42,350	26,650	88,300	53,280	35,020	59,570
2010	72,900	44,750	28,150	93,300	56,330	36,970	62,970

NA = not available.

[a]In scenario II, the distribution of direct and indirect impacts is assumed to be as follows: Carlsbad, 54%; rest of Eddy County, 4%; Hobbs, 36%; rest of Lea County, 6%.

[b]The percentages given in parentheses are the gross population migration resulting from the reference case. Percentages may vary because of rounding.

[c]Construction of the WIPP reference repository assumed to begin in 1981. All impacts assumed to be static after 1986.

[d]Projections for years beyond 1995 assume continued activity in the oil and gas industry at a stable but constant level. Present production levels measured against proved oil and gas reserves and recovery rates indicate that activity could decrease before 1990. However, secondary and tertiary (oil only) recovery procedures could prolong activity beyond the year 2010.

Table M-3. 1980 Resident Population Within 50 Miles of the Reference Site

Sector	Miles from site 0-5	5-10	10-20	20-30	30-40	40-50	Total
N	0	0	25	20	170	25	240
NNE	0	0	25	5	50	6,055	6,135
NE	0	0	0	25	70	7,090	7,185
ENE	0	0	10	70	185	31,145	31,410
E	0	0	5	15	3,575	160	3,755
ESE	0	0	5	10	3,210	270	3,495
SE	0	0	5	20	20	30	75
SSE	0	0	0	25	10	40	75
S	0	0	5	15	50	15	85
SSW	6	0	5	25	95	15	145
SW	0	5	45	15	10	40	115
WSW	0	0	1595	160	50	65	1,870
W	0	0	60	32,560	35	30	32,685
WNW	0	10	5	150	45	40	250
NW	0	0	25	15	55	12,260	12,355
NNW	0	0	15	5	215	10	245
Radius total	6	15	1830	33,135	7,845	57,290	100,120
Cumulative total	6	21	1850	34,985	42,830	100,120	----

1790 145

Table M-4. 1990 Resident Population Within 50 Miles of the Reference Site: Scenario I[a]

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	160	20	230
NNE	0	0	20	5	50	7,455	7,530
NE	0	0	0	20	65	8,425	8,510
ENE	0	0	10	65	185	44,155	44,415
E	0	0	5	15	4,335	140	4,495
ESE	0	0	5	10	4,030	255	4,300
SE	0	0	5	15	20	25	65
SSE	0	0	0	25	10	40	75
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	50	15	10	40	120
WSW	0	0	2075	175	50	65	2,360
W	0	0	65	41,325	40	35	41,425
WNW	0	10	5	185	50	45	290
NW	0	0	30	20	60	15,975	16,085
NNW	0	0	15	5	235	10	265
Radius total	6	15	2325	41,950	9,445	76,715	130,450
Cumulative total	6	21	2345	44,290	53,735	130,450	---

[a]In scenario I, the direct impact of the reference case (construction and operation) is assumed to be distributed as follows: Carlsbad, 88%; rest of Eddy County, 11%; Lea County, 1%. The indirect impact is distributed as follows: Carlsbad, 80%; rest of Eddy County, 10%; Lea County, 10% (Adcock and Associates, 1977-1978).

Table M-5. 1990 Resident Population Within 50 Miles of the Reference Site: Scenario II[a]

Sector	Miles from site 0-5	5-10	10-20	20-30	30-40	40-50	Total
N	0	0	30	20	160	20	230
NNE	0	0	20	5	50	7,480	7,555
NE	0	0	0	20	65	8,455	8,540
ENE	0	0	10	65	175	44,520	44,755
E	0	0	5	15	4,350	140	4,510
ESE	0	0	5	10	4,030	255	4,300
SE	0	0	5	15	20	25	65
SSE	0	0	0	25	10	40	75
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	50	15	10	40	120
WSW	0	0	2060	175	50	65	2,360
W	0	0	65	40,975	40	35	41,075
WNW	0	10	5	185	50	45	290
NW	0	0	30	20	55	15,920	16,025
NNW	0	0	15	5	235	10	265
Radius total	6	15	2310	41,595	9,445	77,080	130,450
Cumulative total	6	21	2330	43,925	53,370	130,450	---

[a]In scenario II, the distribution of direct and indirect impacts is assumed to be distributed as follows: Carlsbad, 54%; rest of Eddy County, 4%; Hobbs, 36%; rest of Lea County, 6%.

1790 147

Table M-6. 2000 Resident Population Within 50 Miles of the Reference Site: Scenario I[a]

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	150	20	220
NNE	0	0	20	5	45	8,565	8,635
NE	0	0	0	20	60	9,460	9,540
ENE	0	0	10	60	175	53,035	53,280
E	0	0	5	15	4,950	135	5,105
ESE	0	0	5	10	4,665	240	4,920
SE	0	0	5	15	15	25	60
SSE	0	0	5	20	10	35	70
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	60	15	10	50	140
WSW	0	0	2555	195	50	70	2,865
W	0	0	75	46,405	40	35	46,515
WNW	0	10	5	205	60	50	325
NW	0	0	30	20	70	14,915	15,035
NNW	0	0	15	5	260	5	285
Radius total	6	15	2830	47,050	10,705	86,670	147,280
Cumulative total	6	21	2850	49,905	60,610	147,280	---

[a]In scenario I, the direct impact of the reference case (construction and operation) is assumed to be distributed as follows: Carlsbad, 88%; rest of Eddy County, 11%, Lea County, 1%. The indirect impact is distributed as follows: Carlsbad, 80%; rest of Eddy County, 10%; Lea County, 10% (Adcock and Associates, 1977-1978).

1790 148

Table M-7. 2000 Resident Population Within 50 Miles of the Reference Site: Scenario II[a]

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	150	20	220
NNE	0	0	20	5	45	8,590	8,660
NE	0	0	0	20	60	9,490	9,570
ENE	0	0	10	60	165	53,390	53,610
E	0	0	5	15	4,965	135	5,120
ESE	0	0	5	10	4,665	240	4,920
SE	0	0	5	15	15	25	60
SSE	0	0	5	20	10	35	70
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	60	15	10	50	140
WSW	0	0	2540	195	50	70	2,865
W	0	0	75	46,055	40	35	46,165
WNW	0	10	5	205	65	50	330
NW	0	0	30	20	70	14,860	14,980
NNW	0	0	15	5	260	5	285
Radius total	6	15	2815	46,705	10,715	87,025	147,280
Cumulative total	6	21	2835	49,555	60,255	147,280	---

[a]In scenario II, the distribution of direct and indirect impacts is assumed to be distributed as follows: Carlsbad, 54%; rest of Eddy County, 4%; Hobbs, 36%; rest of Lea County, 6%.

1790 149

Table M-8. 2010 Resident Population Within 50 Miles of the Reference Site: Scenario I[a]

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	160	20	230
NNE	0	0	25	5	50	8,800	8,850
NE	0	0	0	25	70	10,310	10,405
ENE	0	0	10	70	195	56,025	56,300
E	0	0	5	15	5,250	135	5,405
ESE	0	0	5	10	4,930	240	5,185
SE	0	0	5	20	20	25	70
SSE	0	0	0	20	10	35	65
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	65	15	10	50	145
WSW	0	0	2705	205	55	75	3,040
W	0	0	80	49,645	40	35	49,800
WNW	0	10	5	230	65	55	355
NW	0	0	30	20	75	15,770	15,895
NNW	0	0	15	5	275	5	300
Radius total	6	15	2990	50,350	11,350	91,610	156,320
Cumulative total	6	21	3010	53,360	64,710	156,320	---

[a]In scenario I, the direct impact of the reference case (construction and operation) is assumed to be distributed as follows: Carlsbad, 88%; rest of Eddy County, 11%, Lea County, 1%. The indirect impact is distributed as follows: Carlsbad, 80%; rest of Eddy County, 10%; Lea County, 10% (Adcock and Associates, 1977-1978).

1790 150

Table M-9. 2010 Resident Population Within 50 Miles of the Reference Site: Scenario II[a]

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	160	20	230
NNE	0	0	20	5	50	8,825	8,905
NE	0	0	0	25	70	10,340	10,435
ENE	0	0	10	70	145	56,390	56,665
E	0	0	5	15	5,260	135	5,415
ESE	0	0	5	10	4,940	240	5,195
SE	0	0	5	20	20	25	70
SSE	0	0	5	20	10	35	65
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	65	15	10	50	145
WSW	0	0	2695	205	55	75	3,030
W	0	0	80	49,270	40	35	49,425
WNW	0	10	5	230	65	55	365
NW	0	0	30	20	75	15,715	15,840
NNW	0	0	15	5	275	5	300
Radius total	6	15	2980	49,975	11,370	91,975	156,320
Cumulative total	6	21	3000	52,975	64,345	156,320	---

[a]In scenario II, the distribution of direct and indirect impacts is assumed to be distributed as follows: Carlsbad, 54%; rest of Eddy County, 4%; Hobbs, 36%; rest of Lea County, 6%.

1790 151

Table M-10. Carlsbad Municipal Finances: Baseline

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	410	420	430	440	450	460
Charges and miscellaneous	3,290	3,380	3,450	3,510	3,580	3,670
Intergovernmental transfers						
State	2,680	2,740	2,780	2,830	2,890	2,960
Federal	1,540	1,570	1,600	1,630	1,660	1,700
Other	2,520	2,570	2,610	2,660	2,720	2,780
TOTAL	10,430	10,690	10,870	11,070	11,290	11,570
EXPENDITURES (thousands of dollars)						
General	3,040	3,110	3,160	3,220	3,280	3,360
Fire protection	10	10	10	10	20	20
Recreation	0	0	0	0	0	0
Revenue sharing	250	260	260	270	270	280
Utility	1,820	1,860	1,890	1,930	1,960	2,010
Other	4,990	5,100	5,180	5,280	5,380	5,520
Debt service	760	780	790	800	820	840
TOTAL	10,870	11,120	11,300	11,510	11,740	12,020

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-11. Carlsbad Municipal Finances: Impact of the Reference Case

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	12	27	34	26	16	14
Charges and miscellaneous	73	195	307	254	138	111
Intergovernmental transfers						
State	89	179	209	151	98	88
Federal	51	103	120	87	56	50
Other	40	81	94	68	44	40
TOTAL	274	599	782	598	362	310
EXPENDITURES (thousands of 1977 dollars)						
General	101	203	237	172	112	100
Fire	(a)	1	1	1	1	(a)
Recreation	0	0	0	0	0	0
Revenue sharing	8	17	20	14	9	8
Utilities	61	122	142	103	67	60
Other	40	81	94	68	40	40
Debt service	25	51	59	43	28	25
TOTAL	236	474	554	400	260	233

[a]Less than $500.
Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-12. Eddy County Finances: Baseline

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	2,120	2,130	2,140	2,160	2,180	2,200
Charges and miscellaneous	260	260	270	270	280	280
Intergovernmental transfers						
State	630	640	650	660	670	690
Federal	990	1,010	1,020	1,040	1,060	1,080
Other	30	30	30	30	30	30
TOTAL	4,020	4,070	4,110	4,160	4,220	4,290
EXPENDITURES (thousands of 1977 dollars)						
General government	1,520	1,550	1,560	1,590	1,630	1,660
Public safety	500	510	520	530	540	550
Public works	1,150	1,170	1,190	1,210	1,230	1,260
Health and welfare	60	60	70	70	70	70
Recreation and culture	30	30	40	40	40	40
TOTAL	3,270	3,330	3,370	3,440	3,500	3,590

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-13. Eddy County Finances: Impact of the Reference Case

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	13	37	62	52	28	22
Charges and miscellaneous	6	12	14	10	7	6
Intergovernmental transfers						
State	14	28	33	24	16	14
Federal	22	45	52	38	25	22
Other	1	1	2	1	1	1
TOTAL	56	124	163	125	75	65
EXPENDITURES (thousands of 1977 dollars)						
General government	34	69	81	58	38	34
Public safety	11	23	27	19	12	11
Public works	26	52	61	44	29	26
Health and welfare	1	3	3	2	2	1
Recreation and culture	1	2	2	1	1	1
TOTAL	74	148	174	125	82	73

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-14. Hobbs Municipal Finances: Baseline

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	350	360	370	380	380	400
Charges and miscellaneous	2,240	2,310	2,370	2,440	2,520	2,590
Intergovernmental transfers						
State	4,100	4,200	4,310	4,420	4,530	4,650
Federal	520	530	550	560	580	590
Other	3,480	3,560	3,560	3,740	3,840	3,940
TOTAL	10,690	10,960	11,260	11,540	11,840	12,170
EXPENDITURES (thousands of 1977 dollars)						
General	3,920	4,020	4,120	4,230	4,330	4,440
Fire protection	90	100	100	100	100	100
Recreation	30	30	30	40	40	40
Revenue sharing	180	180	190	200	200	200
Utility	1,310	1,340	1,380	1.410	1.450	1,490
Other	1,160	1,190	1,220	1,250	1,280	1,320
Debt service	360	360	370	380	390	400
TOTAL	7,060	7,230	7,420	7,600	7,800	8,000

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-15. Hobbs Municipal Finances: Impact of the Reference Case

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	4	8	11	8	5	4
Charges and miscellaneous	20	51	78	64	36	28
Intergovernmental transfers						
State	51	103	121	88	57	51
Federal	6	13	15	11	7	6
Other	11	22	25	18	12	11
TOTAL	92	197	250	189	118	100
EXPENDITURES (thousands of 1977 dollars)						
General	49	98	115	84	55	48
Fire protection	1	2	3	2	1	1
Recreation	(a)	1	1	1	(a)	(a)
Revenue sharing	2	4	5	4	2	2
Utility	16	33	39	28	18	16
Other	11	29	26	19	12	11
Debt service	4	9	10	8	5	4
TOTAL	85	170	200	145	95	84

[a]Less than $500.

Detail may not equal total because of rounding.

SOURCE: Larry Adcock and Associates (1978).

Table M-16. Lea County Finances: Baseline

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	2040	2060	2080	2090	2110	2130
Charges and miscellaneous	340	350	360	370	380	390
Intergovernmental transfers						
State	520	540	550	560	570	590
Federal	1470	1500	1540	1570	1610	1650
Other	90	90	90	90	100	100
TOTAL	4460	4540	4610	4680	4760	4850
EXPENDITURES (thousands of 1977 dollars)						
General	1410	1440	1470	1500	1540	1580
Public safety	430	440	450	460	470	480
Public works	1670	1710	1750	1790	1830	1880
Health and welfare	40	40	40	40	40	40
Recreation and culture	30	30	30	30	30	30
TOTAL	3570	3660	3740	3820	3910	4020

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-17. Lea County Finances: Impact of the Reference Case

Revenue source or expenditure	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
REVENUES (thousands of 1977 dollars)						
Own source						
Taxes	4	11	18	15	8	6
Charges and miscellaneous	3	6	7	5	3	3
Intergovernmental transfers						
State	4	9	10	8	5	4
Federal	12	25	29	21	14	12
Other	1	1	2	1	1	1
TOTAL	24	51	65	50	31	26
EXPENDITURES (thousands of 1977 dollars)						
General	12	24	28	20	13	12
Public safety	4	7	8	6	4	4
Public works	14	28	33	24	16	14
Health and welfare	(a)	1	1	1	(a)	(a)
Recreation and culture	(a)	(a)	(a)	(a)	(a)	(a)
TOTAL	30	60	70	51	33	29

[a]Less than $500.

Detail may not equal total because of rounding.

SOURCE: Larry Adcock and Associates (1978).

Table M-18. Carlsbad School District Finances

	Baseline						Change due to reference case					
	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
EXPENDITURES (thousands of 1977 dollars)												
Operational	8,600	8,790	8,940	9,090	9,300	9,510	262	525	617	457	297	263
Other	1,290	1,320	1,340	1,360	1,390	1,420	0	0	0	0	0	0
TOTAL	9,890	10,110	10,280	10,450	10,690	10,940	262	525	617	457	297	263
INCOME (thousands of 1977 dollars)												
Operational	8,600	8,940	9,090	9,280	9,440	9,660	178	499	621	679	357	294
Other	1,570	1,600	1,630	1,660	1,690	1,730	48	96	112	83	54	48
TOTAL	10,170	10,540	10,720	10,940	11,130	11,400	226	595	733	762	411	342

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates (1978).

Table M-19. Hobbs School District Finances

	Baseline						Change due to reference case					
	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
EXPENDITURES (thousands of 1977 dollars)												
Operational	9,460	9,670	9,910	10,150	10,380	10,620	117	221	268	198	128	105
Other	2,850	2,910	2,990	3,060	3,130	3,200	0	0	0	0	0	0
TOTAL	12,310	12,580	12,900	13,200	13,510	13,830	117	221	268	198	128	105
INCOME (thousands of 1977 dollars)												
Operational	9,040	9,290	9,580	9,860	10,170	10,480	75	198	326	285	150	116
Other	1,600	1,640	1,680	1,720	1,760	1,800	20	37	45	33	22	18
TOTAL	10,640	10,920	11,260	11,570	11,920	12,270	95	235	371	318	172	134

Detail may not equal total because of rounding.
SOURCE: Larry Adcock and Associates, 1978.

REFERENCE

Adcock, Larry, and Associates, 1977-1978. Demographic analysis using personal interviews with county officials; (Clerk, Lea County, New Mexico, February 1978; Clerk, Eddy County, New Mexico, February 1978; Clerk, Loving County, New Mexico, February 1978; Clerk, Winkler County, Texas, March 1978); various U.S. Geological Survey maps; Bureau of Land Management land-use maps; and quadrangles of the State of New Mexico, 1963 and 1965, from the New Mexico Highway Department, Planning Division.