Open-File Report 189

Report to the
Radioactive Waste Consultation Committee
of the
New Mexico State Legislature

on

SITE IDENTIFICATION FOR LOW-LEVEL RADIOACTIVE WASTE DISPOSAL IN NEW MEXICO

by

John W. Hawley, Senior Environmental Geologist
New Mexico Bureau of Mines and Mineral Resources,
New Mexico Institute of Mining and Technology
Socorro, New Mexico

February 18, 1983

SUMMARY

In accordance with provisions of the "Site Identification Act", HENRCS/House Bill 397 (1981), five possible sites for a low-level radioactive waste disposal facility have been identified in New Mexico. National, regional and state criteria for site selection are shown in Tables 1 and 2. Site locations are shown on Figure 1. Major terrain and hydrogeologic features at each site are shown in figures 2 to 8; and site descriptions are given in tables 3 to 6. Please note that this is an identification of possible sites based on 1) review of published and unpublished information on hydrology, geology, and soils; and 2) brief visits to areas with site potential. Onsite characterization work, and evaluation of socioeconomic and legal factors have not been done. This is a state-of-the-art effort that needs input and constructive criticism from public as well as professional sectors of society.

INTRODUCTION

This is a report to the Radioactive Waste Consultation Committee of the New Mexico State Legislature relating to site identification for disposal of low-level radioactive wastes as required by the "Site Identification Act", HENRCS/House Bill 397 (1981). According to Section 3: "The purpose of the Site Identification Act is to permit New Mexico opportunity to avail itself of the lead time before 1984-1989 when the present out-of-state disposal facilities will be closed to the disposal of New Mexico's low-level waste by establishing criteria for selection of a disposal facility and by requiring the study and identification of at least three possible regional sites for disposal facilities in this state." According to Section 5 of the Act the New Mexico Bureau of Mines and Mineral Resources, in consultation with the Environmental Improvement Division and the Environmental Improvement Board, shall:

A. study low-level waste disposal requirements of this state and shall report its findings to the committee;

B. investigate all geographical areas in this state determined to be feasible sites for a disposal facility for low-level waste generated in this state, and after such investigation and analysis of the results, identify at least three possible sites for a disposal facility compatible with the criteria provided for in the Site Identification Act; and

C. report its findings and identified sites to the committee and to the first session of the thirty-sixth legislature.

Preliminary reports were made to the Radioactive Waste Consultation Committee on July 31 and December 2, 1981.

The July (1981) report contained a tabulation of low-level radioactive waste shipments by New Mexico licensees in 1978, 1979, 1980 prepared by the Radiation Protection Bureau of the Environmental Improvement Division. This tabulation (as of April 1, 1981) provided basic documentation on the waste disposal requirements of the state as requested in Section 5, Item A. Additional documentation on waste shipments in 1981 and 1982 is given in an appendix to this report.

The July (1981) report also established provisional criteria for selection of possible sites for a disposal facility in accordance with Section 3 and Section 5-Item B of the Act. General guidance for site selection at a national level is provided by U.S. Nuclear Regulatory Commission (1981) "Licensing Requirements for Land Disposal of Radioactive Waste" 10 CFR Part 61, Sections 61.40-44 and 61.50 (Federal Register 46FR38081); and basic criteria for site selection in New Mexico are in accordance with the performance objectives of 10 CFR 61:

"Protection of the public health and safety over the long term is most important and long-term performance of the land disposal facility after [disposal] operations cease should be given greater emphasis than short-term considerations and conveniences..."

"Assuring safety over the long term involves three considerations: (1) protection of individuals from inadvertent intrusion into the site and coming in contact with the waste at some point in the future; (2) protection of the general public from potential releases to the environment; and (3) stability of the disposed waste and the site to eliminate the need for ongoing maintenance of the site following closure."

Disposal site "requirements are intended to eliminate, to the extent practicable, those areas with certain characteristics that are known to lead to or have high potential to lead to problems over the long term (e.g., flooding or rapid erosion of the site)".

The 10 CFR 61 site suitability criteria are listed in table 1a. Performance objectives, assumptions about waste management systems, and more specific siting criteria are outlined in table 1b. This information, which applies particularly well to arid lands of the southwest, is taken from a recent recommendation by staff members of the Idaho National Engineering Laboratory (Falconer, Hull, and Mizell, 1982).

Criteria used for site selection in New Mexico are listed in table 2. These criteria follow 10 CFR 61 guidelines (table 1a) and the recommendations of Falconer and others (table 1b). They are designed to be compatible with environmental conditions in New Mexico, particularly those relating to geology, hydrology, and geomorphic processes. With minor modification, the criteria listed in table 2 follow the guidelines proposed by Longmire, Gallaher, and Hawley (1981) for landfill disposal of (nonradioactive) hazardous wastes. While wastes such as toxic organic chemicals and metals cannot be placed at the same disposal site as low-level wastes (and pose a much more serious environmental threat), it seems reasonable to use similar criteria for site selection. The guidelines proposed by Longmire and others (1981) and the criteria listed in table 2 are relatively restrictive when compared with those developed for use in other regions of the country (Post, 1982, v. 2; and Yalcintas, 1982, v. 2). Strict adherence to these criteria should ensure that low-level waste repositories will be placed at least 5 miles from even small centers of population or farming, mining, and industrial activity.

The site selection process as applied in New Mexico attempts to locate those areas of the state where natural conditions (e.g. climate, landforms, geology, and subsurface hydrology) provide multiple barriers that assure long-term waste containment. There should be no degradation of land, water, and air quality in surrounding areas for thousands of years; and opportunities for human intrusion for resource development (e.g. soil, water, mineral, energy) should be minimal.

Shallow burial of solid waste in a secure landfill is the basic disposal strategy envisioned in this study. Such a landfill operation would be located in the upper part of a very thick zone of essentially-unsaturated earth material (vadose zone). Subsurface water-flow paths should be very long in both horizontal and vertical directions. Siting criteria require that the unsaturated zone contain a large percentage of fine-grained materials, such as clay or shale, which would physically and chemically retain waste components. Interbedded layers of clean sand or gravel, which provide effective barriers to capillary-water movement, should also be present in the unsaturated zone (Winograd, 1974, 1981).

IDENTIFICATION OF POSSIBLE DISPOSAL SITES

The December (1981) report to the Committee illustrated the results of a preliminary screening process which eliminated large areas of the state that clearly did not meet combined geologic and hydrologic siting criteria. A generalized map in the report showed remaining areas that appeared to meet general siting criteria and merited further consideration as possible disposal sites.

Final selection of possible sites was made in 1982 after study of the relatively small geographical areas that appear to meet basic siting criteria. All areas of the state were evaluated except for Indian lands, Federally protected areas (table 1b, item 12), and most lands administered by the Departments of Energy and Defense. Several areas shown in the December (1981) report were eliminated and one area was added. Location of the sites is shown on figures 1 to 6 and table 3. The sites are numbered according to their increasing distance from Albuquerque. The order does not reflect a ranking of sites. New Mexico already has a low-level waste site at Los Alamos (LASL-figure 1) where research has been done during the past 4 decades on site performance (Balo and others, 1982). A second area of interest noted on figure 1 is the Colfax locality where a large body of hydrogeologic information has been collected that is pertinent to disposal facilities in shale (Herkenhoff and Associates, Summers and Associates, 1977).

The site selection process involved 1) review of published and unpublished information on geology, hydrology, and soils and 2) brief visits to areas with site potential. It should be emphasized that no onsite characterization work has been done. Funding and time limitations precluded detailed geologic and hydrologic study of specific localities. The selection of possible sites definitely reflects the professional experience and opinion of the principal investigator, who has been making local and statewide investigations of geology-soil relationships for the U.S. Soil Conservation Service and the Bureau of Mines and Mineral Resources since 1962. Other areas that meet siting criteria probably exist in the state; but the basic geologic and hydrologic data needed for site identification are not available. The possible sites listed in this report definitely contain areas that will ultimately prove to be unsuited for any type of waste disposal. However, the sites shown on figure 1 also include many of the best locations in New Mexico for the secure-landfill type of disposal operation. These areas also deserve consideration as places for processing and temporary storage of other types of hazardous wastes. They definitely deserve immediate professional and public scrutiny (table 1b, items 8-12).

A very large amount of background information has been collected and evaluated during this study. Items pertinent to the six areas discussed are outlined in Tables 3 to 6. Detailed location data, and important institutional and cultural features of general areas that include sites are covered in Table 3. This table also lists major sources of published information on individual site areas. Table 4 deals with the physiographic setting of each possible site (e.g. climate, landforms, drainage network, and soils). Structural geologic setting, geologic hazards, and major energy and mineral resources are covered in Table 5; and Table 6 is an outline of the major hydrogeologic factors considered.

The tabular format provides a matrix for making relatively unbiased site comparisons. Type and factual quality of data in the tables 3-6 obviously varies greatly. Many items will be easily understood by nonspecialists in the earth sciences (e.g. distances to rivers, towns, irrigated farm land, and climatological data). Other items are expressed in obscure jargon that will have special significance to a very limited technical audience. The material presented in tables 3-6 (factual and speculative) clearly indicates the major areas where there will be conflicts between the public need for secure waste-disposal sites for low-level and other hazardous wastes, and other types of land use. Many of the legitimate conflicts will not be easily resolved (e.g. urban expansion or energy resource development versus siting activities), but at least these potential areas of conflict are now documented and such problem areas can be addressed in future studies.

In the following discussion of very diverse individual sites there are several common themes: No single site meets all siting criteria (Table 2). However, each area listed has certain environmental characteristics that essentially mandate its consideration as a viable site candidate. In New Mexico (as in any arid region) hydrology and geology are powerful socioeconomic, cultural, political forces. Historically there has been no intensive land use without a water-, mineral- or soil-resource base. Water availability obviously is the key factor. A valid question remains: Is the worst place for economic survival in this region the best place for low-level (or any type of toxic) waste disposal?

Area 1 -- Llano de Albuquerque (figs. 2, 8a)

Llano de Albuquerque refers to the summit plain of the extensive tableland (or mesa) located between the valleys of the Rio Grande and Rio Puerco. The tableland is bounded on the west and east by steep valley-side slopes, respectively, designated Ceja del Rio Puerco and Cejita Blanca (Bryan and McCann, 1937, 1938; Lambert, 1968). The Llano de Albuquerque is a remnant of a once-more-extensive surface of basin fill deposited mainly by streams ancestral to the Rio Grande-Puerco drainage system. During the past half million years the present river and arroyo system has cut deep valleys below the Llano surface. The early constructional phase lasted for millions of years and resulted in deposition of thousands of feet of fill in a deep structural basin of the Rio Grande rift (Hawley, 1978; Kelley, 1977). Much of this basin fill, designated the Santa Fe Formation (or Group) is saturated with fresh water and forms a major aquifer.

The northern part of the Llano de Albuquerque and flanking river valleys are shown in figure 2; and a cross section of the area is included as figure 8a. The deeply-incised Rio Grande valley and serves as a giant drainage channel, has provided a base-level for the water saturated basin-fill deposits in adjacent mesa areas. Water table depths exceed 500 ft over most of the Llano surface (fig. 2) and probably exceed 1000 ft in a few areas (Bjorklund and Maxwell, 1961). Recent research on hydrology of desert basins (Winograd, 1974, 1981) indicates that 500 to 1,000 ft of unsaturated sand, gravel, silt and clay (vadose zone) would be an extremely effective barrier to waste migration. Moreover, studies of soils and dated volcanic units of the Llano area indicate the summit plain has not been subject to significant erosion or deposition for the past 500,000 years (Hawley and others, 1976; Machette, 1978). There also appears to be only limited potential for development of geothermal energy in the area (Jiracek and others, 1982).

The major negative aspects of a possible disposal site on the Llano de Albuquerque include 1) proximity to the major regional urban center, 2) an extensive but deep aquifer zone to the east of the site, and 3) the clear evidence of local seismic and volcanic activity during the past 200,000 years (Bachman and Mehnert, 1978; Machette, 1978, 1982). If a disposal site could be engineered to withstand seismic shocks, then Site 1 should be considered as a viable candidate for low-level waste disposal. Note that volcanic eruptions on the Llano de Albuquerque area are a constructional process that probably will not adversely effect long-term site performance.

Site 2 - Prieta (Figs. 3, 8b)

The area of site 2 contrasts markedly with the Albuquerque intermontane basin (site 1). Sandstones and marine shales (Mancos Shale) of Cretaceous age underlie an extensive erosional surface cut by the Rio Puerco and the Rio Salado (a tributary to Jemez River). The eastern and southern part of this valley system also occupies a structurally downdropped zone adjacent to the Nacimiento Mountains and the Rio Grande rift (Baltz, 1967, 1978; Slack and Campbell, 1976; Woodward and Martinez, 1974). The area is flanked on the southwest by basalt-flow-capped Mesa Prieta; and to the northwest, there are scattered volcanic necks, such as Cabezon Peak (Ti, fig. 8b), which are erosion remnants of early eruptic centers of basaltic rocks.

Adjacent to the southwest corner of Site 2 is a plugged, 700-ft test hole (15N.2W.3) that did not yield any water for aquifer tests by the U.S. Geolgoical Survey and Bureau of Land Management. Examination of well cuttings from this test boring (on file at the State Bureau of Mines and Mineral Resources) shows that the penetrated section is mostly clayey to silty shale. The area north of the well site is underlain by very thick deposits of the Mancos Shale, with very few lenticular beds of sandstone (Molenaar, 1974). The Mancos contains abundant magnesium-rich clay minerals (smectities or montmorillonites) with expansive or swelling (bentonitic) properties and high ionic adsorptive capacity. Geochemically the Mancos Shale is an ideal host media for toxic-chemical as well as low-level radioactive wastes (Longmire and others, 1981). As documented by studies of test hole 15N.2W.3, the Mancos is a very impermeable unit in the immediate site area.

The northern part of the site (dashed outline on fig. 3) is only tentatively being considered because of its proximity to the more deeply entrenched valley of the upper Rio Puerco (here an intermittent to ephemeral stream). However, (geomorphically) it is the most stable part of the area because of its position near the crest of the broad divide between the Puerco-Salado (Jemez) stream systems. Also, known faults are located only in the southern part of general area shown on fig. 2 (fig. 8b, Slack and Campbell, 1976). Well-developed soils on the Puerco-Salado divide indicate presence of a few areas where the surface has been relatively stable with no significant erosion for 10,000 to 100,000 years.

There are two major drawbacks to repository siting in the Mesa Prieta-Cabezon area. First, exposed shaly rocks are very susceptible to erosion (Table 4-part 2); and second, the area west of the Nacimiento structural uplift includes a general belt of relatively high seismicity (Sanford and others, 1981).

Site 3 - Huerfano (figs. 4, 8c)

The Huerfano site in the San Juan Basin south of Bloomfield (SW of Farmington) represents a combination of a number of features found at sites 1 and 2. As in the case of the Llano de Albuquerque the major landform is a tableland (mesa) summit situated hundreds of feet above adjacent valleys of the San Juan River system. Moreover, the site is underlain by thick shales of continental origin, with many similarities to the Mancos Shale. These ancient floodplain, swamp, and lake deposits of Paleocene age are designated the Nacimiento Formation. This unit locally contains lenticular sandstone beds that form discontinuous aquifer zones (Brimhall, 1972). Most water wells drilled in the Nacimiento have very low yields (Stone and others, 1983) and the unit is generally not considered to be an aquifer. Furthermore, because of the upland topographic setting of Site 3, water-saturated conditions only sporadically exist and the water table is at least 300 ft below the surface (fig. 8c).

The main aquifer in this part of the San Juan Basin is the Ojo Alamo Sandstone. This ancient river (fluvial) deposit forms a confined water-bearing unit that locally qualifies as a major aquifer (>100 gpm sustained yield of freshwater). The approximate piezomentric surface representing the artesian pressure head in the Ojo Alamo aquifer is shown in profile on figure 9c and is about 500 ft below the site surface. Flow in both the unconfined (Nacimiento) and confined aquifer systems is northward toward the San Juan River.

While the mesa summit north of Huerfano Peak is basically an erosion surface, it is capped with ancient alluvial deposits and soils, at least 100,000 years old, and a veneer of young windblown (eolian) deposits (mostly <10,000 yrs in age). The broad tableland summit has low local relief and it has not been the site of significant erosion for tens of thousands of years. No geologically-young faults (<500,000 yrs) have been noted in this local area of the Colorado Plateau province. The major problem in site selection is finding a place where a disposal facility would not conflict with development of the proven oil and gas resources of the area (Parker and others, 1977). Even considering this very important factor, the Huerfano site should be evaluated as a possible area for low-level waste disposal.

Site 4 - Jornada (figs. 5, 8d) and Site 5 - Desert (figs. 6, 8e)

The topographic setting of Sites 4 and 5 in south-central New Mexico contrasts markedly with the landscape positions of the other sites discussed. Both sites are located in very broad intermontane basins (bolsons) where surface drainage is not yet integrated with the adjacent Rio Grande valley system.

Site 4 in the Jornada del Muerto Basin is on a broad piedmont slope constructed by coalescing alluvial fans of streams heading in the San Andres Mountains. The gravelly to sandy clay piedmont alluvium interfingers westward with gypsiferous sand and clay deposited in ancient river-channels and backswamps. These features were marginal to a broad fluvial plain constructed by the ancestral Rio Grande more than 500,000 years ago. Deposits are very similar in age and origin to upper Santa Fe Group units exposed in river-valley walls of the Albuquerque basin (fig. 8a). However, clays are common, and both sand and clay units have thick gypsum-impregnated zones (King and others, 1971; Seager and others, 1982, 1983).

Recent work by Wilson and others (1981) shows that there is an area of about 25 mi^2 extent in northeastern Doña Ana County where the water table is at least 500 ft below the surface. This area is designated as Site 4 (figs. 5 and 8). Geomorphically it is still part of the bolson constructional topography and has yet to experience any significant erosion. Windblown sand sheets derived from the bolson-floor area to the west are also moving into the area. Sedimentation is not rapid, however; and detailed soil-geomorphic research by the Soil Conservation Service and the New Mexico Bureau of Mines and Mineral Resources shows that only about 25 ft of sediment have been added to piedmont slopes during the past several hundred thousand years (Gile and others, 1981).

Site 5 is on an ancient bolson floor surface at the southern end of the Tularosa Basin (fig. 6, fig. 8a). The surface is flanked by piedmont slopes extending from the Hueco Mountains on the east and the Organ Mountains on the west. This extensive alluvial and lacustrine plain was constructed by distributaries of the ancestral Rio Grande in Pliocene to early Pleistocene time. The river emptied into ancient lakes of the south-central New Mexico border region and constructed a huge delta in the southern Tularosa Basin and northern Hueco Bolson (Hawley, 1978; Seager, 1981). Deltaic and associated lake beds are primarily clay with some interbedded sand. At the southeast corner of Site 5, a 940-ft section penetrated by a water test well is entirely clay and shale (Knowles and Kennedy, 1958). No aquifer was encountered in this test well, which finished in limestone at 945 ft. Clay and sand deposits in the area are commonly gypsiferous and waters are saline (fig. 8e).

Young faults in the Site 4 and 5 region are concentrated on the western side of the Tularosa structural basin (eastern base of the San Andres-Organ range--Seager, 1980, 1981). No young faults (<500,000 yrs) have been mapped in parts of the Jornada and Tularosa basins in or adjacent to Sites 4 and 5. Work in progress in the Texas-New Mexico border area northeast of El Paso indicates that the southern part of Site 5 may have significnt geothermal resources (Henry and Gluck, 1981).

This study recommends that the lands in Sites 4 and 5 which are administered by the Department of Defense (White Sands Missile Range, McGregor-Fort Bliss-Range) be considered as viable candidates for possible low-level waste disposal sites. All of Site 5 is on DOD land, but it includes right-of-ways for U.S. Highway 54 and the Southern Pacific Railroad. About half of Site 4 is on White Sands Missile Range (table 3).

Koehler Area--figs. 7, 8f

The last area considered in this report is southwest of Raton near the town site of Koehler, a former coal-mining center in the Raton Basin. This area has many of the same hydrogeologic conditions present at Site 2. Cretaceous marine shale (Pierre Shale) is the dominant rock unit, and it is about 2000 ft thick at the Koehler locality. Land surface conditions are generally more stable than at the Prieta Site (table 4) and seismic risk appears to be low. A large body of good hydrogeologic information on the Pierre Shale has already been developed by Herkenhoff and Associates and Summers and Associates (1977). This work was done for Chem-Nuclear, Inc. as part of siting activity near Colfax (fig. 1) for a proposed low-level disposal facility. This locality is on the terraced terrain of the Vermejo river, a perennial stream 12 mi southwest of Koehler; because of present siting criteria, the Colfax area can not be considered as a viable site.

In contrast to the Chem-Nuclear site near Colfax the area near Koehler is situated at least 5 miles from floodplains of the two perennial streams, the Canadian and Vermejo Rivers. The siting criteria (table 2) also necessitated avoiding irrigated farmland (and associated canal systems) and ultimately limited the available area for a possible site to <2 mi^2. The proximity of residences, presence of the historic Santa Fe Trail route within the area, and its very small size indicate that the Koehler locality is probably not a viable site. However, in terms of geology, hydrology, and geomorphic and structural stability, the Koehler area compares quite favorably with the Prieta site (no. 2).

This case history is a good example of conflicts arising from varying interpretations of criteria guidelines (table 1 vs table 2). Many other professionals would probably rate the Koehler locality as one of the best in the state; and it is here recommended that the Raton basin not be completely eliminated from future siting considerations.

CONCLUSION

This report to the Radioactive Waste Consultation Committee of the New Mexico State Legislature conforms with provisions of the 1981 "Site Identification Act" requiring 1) identification of at least three possible sites for a disposal facility for low-level waste generated in this state and 2) a report on identified sites to the committee and to the first session of the thirty-sixth legislature.

It is hoped that the methodology developed for conducting this study will be useful to other professional workers involved in site selection. This methodology includes the criteria (table 2), matrix format for site description (tables 3 to 6), and design of hydrogeologic cross sections (fig. 8a-f).

As previously stated, this state-of-the-art effort represents an early phase of the site selection process. The wide range of factural and speculative material presented in the report should receive immediate public and professional scrutiny. Perfect natural repositories for hazardous materials do not exist, nor are there perfect engineering or scientific solutions to the diversity of disposal problems. However, feedback from all sectors of society should promote the ultimate selection of best possible areas for processing, storage, and disposal of hazardous wastes, both radioactive and nonradioactive.

REFERENCES

Anderson, G.W., Hilley, T.E., Martin, P.G., Jr., Neal, C.R., and Gomez, R.C., 1982, Soil Survey of Colfax County, New Mexico: U.S. Soil Conservation Service, 187 p.

Anderson, J.U., and Maker, J.H., 1974, Suitability of New Mexico Lands for irrigation: New Mexico State University Agricultural Experiment Station, Research Report 276, 28 p.

Bachman, G.O., and Mehnert, H.H., 1978, New K-Ar dates and late Pliocene to Holocene geomorphic history of the central Rio Grande region, New Mexico: Geological Society of America, Bull., v. 89, no. 2, p. 283-292.

Balo, K.A., Wilson, N.E., and Warren, J.L., 1982, Design and operation of a low-level solid waste disposal site at Los Alamos, in Waste Management '82, volume 2--Low Level Waste, R.G. Post, ed.: Proceedings of Symposium on Waste Management at Tucson, Arizona, Arizona Board of Regents, p. 297-309.

Baltz, E.H, 1965, Stratigraphy and History of Raton Basin and notes on San Luis Basin, Colorado-New Mexico: American Association of Petroleum Geologists, Bull., v. 49, p. 2041-2075.

______, 1967, Stratigraphy and Regional Tectonic Implications of Part of Upper Cretaceous and Tertiary rocks, east central San Juan Basin, New Mexico: U.S. Geological Survey, Prof. Paper 552, 101 p.

______, 1978, Rèsumè of Rio Grande depression in north-central New Mexico, in Guidebook to Rio Grande rift in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources, Circ. 163, p. 210-233.

Bjorklund, L.J., and Maxwell, B.W., 1961, Availability of Ground Water in the Albuquerque Area, Bernalillo and Sandoval Counties, New Mexico: New Mexico State Engineer, Technical Report 21, 117 p.

Black, B.A., and Hiss, W.L., 1974, Structure and Stratigraphy in the Vicinity of the Shell Oil Co. Santa Fe Pacific No. 1 Test Well, Southern Sandoval County, New Mexico: New Mexico Geological Society Guidebook, 25th field conference, p. 365-370.

Brimhall, R.M., 1973, Ground Water Hydrology of Tertiary Rocks of the San Juan Basin, New Mexico: Four Corners Geological Society Memoir Book, p. 197-207.

Bryan, Kirk, and McCann, F. T., 1937, The Ceja del Rio Puerco--a border feature of the Basin and Range province in New Mexico, Part I, Stratigraphy and structure: Journal of geology, v. 45, p. 801-828.

______, 1938, The Ceja del Rio Puerco--a border feature of the Basin and Range province in New Mexico, Part II, Geomorphology: Journal of Geology, v. 46, p. 1-16.

Bulloch, H.E., Jr., and Neher, R.E., 1980, Soil Survey of Doña Ana County Area, New Mexico: U.S. Soil Conservation Service, 177 p.

Craigg, S.E., 1980, Hydrology and Water Resources of the Chico Arroyo/Torreon Wash area, Sandoval and McKinley Counties, New Mexico: M.S. Thesis, New Mexico Institute of Mining and Technology, 272 p.

Derr, P., 1981, Soil Survey of Otero Area, New Mexico: Parts of Otero, Eddy, and Chaves Counties: U.S. Soil Conservation Service, 244 p.

Falconer, K.L., Hull, L.C., and Mizell, S.A., 1982, Site Selection Criteria for Shallow Land Burial of Low-Level Radioactive Waste, in Waste Management '82, volume 2--Low Level Waste, R.G. Post, ed.: Proceedings of the Symposium on Waste Management at Tucson, Arizona, Arizona Board of Regents, p. 199-214.

Fassett, J.E., and Hinds, J.S., 1971, Geology and Fuel Resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey, Professional Paper 676, 76 p.

Griggs, R.L., 1948, Geology and Ground-Water Resources of the Eastern Part of Colfax County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Ground-Water Report 1, 186 p.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and Geomorphology in the Basin and Range area of Southern New Mexico-Guidebook to the Desert Project: New Mexico Bureau of Mines and Mineral Resources, Memoir 39, 222 p.

Hacker, L.W., 1977, Soil Survey of Bernalillo County and parts of Sandoval and Valencia Counties, New Mexico: U.S. Soil Conservation Service, 101 p.

Hawley, J.W., compiler, 1978, Guidebook to Rio Grande rift in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources, Circ. 163, 241 p.

_____, 1983a, Site identification for low-level radioactive waste disposal in New Mexico--report to the Radioactive Waste Consultation Committee of the New Mexico State Legislature: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 189, 16 p.

_____, 1983b, Testimony at the U.S. Senate Environment and Public Works Committee hearing on major environmental issues in New Mexico, in Environmental issues facing the state of New Mexico--Hearing before the Committee on environmental and Public Works, United States Senate (Senate Hearing 98-279): U.S. Government Printing Office, Washington, D. C., p. 48-51, 231-331.

Hawley, J.W., Bachman, G.O., and Manley, Kim, 1976, Quaternary stratigraphy in the Basin and Range and Great Plains provinces, New Mexico and western Texas, in Quaternary stratigraphy of North America, W.C. Mahaney, ed: Stroudsburg, Pennsylvania, Dowden, Hutchinson, and Ross, Inc., p. 235-274

Hawley, J.W., Lambert, P.W., Kelley, V.C., and Woodward, L.A., 1982, Road-Log Segment III-B: Sandia Mountains at Tramway Terminal to Placitas via Alameda, Rio Rancho, Ceja del Puerco, Loma Duran, and Bernalillo: New Mexico Geological Society Guidebook, 33rd field conference, p. 80-94.

Hawley, J.W., and Love, D.W., 1981, Overview of Geology as Related to Environmental Concerns in New Mexico: New Mexico Geological Society, Special Publication no. 10, p. 1-13.

Henry, C. D., and Gluck, J. K., 1981, A preliminary assessment of the geologic setting, hydrology, and geochemistry of the

Hueco Tanks geothermal area, Texas and New Mexico: University of Texas Bureau of Economic Geology, Geological Circular 81-1, 47 p.
Herkenhoff, G., and Associates, Inc., Summers, W.K. and Associates, 1977, Geology and hydrology of a site proposed for burial of low-level solid radioactive waste, western Colfax County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Rept. 79, v. 1-3, 1035 p.
Hoidale, G.B., Smith, S.M., Blanco, A.J., and Barber, T.L., 1967, A study of atmospheric dust: Atmospheric Science Laboratories, White Sands Missile Range, New Mexico, ECOM Rept. no. 5067, 132 p.
Holzer, T.L., and Pampeyan, E.H., 1981, Earth Fissures and Localized Differential Subsidence: Water Resources Research, v. 17, no. 1, p. 223-227.
Jiracek, G. R., Gustafson, E. P., Parker, M. D., 1982, Geophysical exploration for geothermal prospects west of Albuquerque, New Mexico: New Mexico Geological Society Guidebook, 33rd field conference, p. 333-342.
Keetch, C.W., 1980, Soil Survey of San Juan County, New Mexico, Eastern Part: U.S. Soil Conservation Services, 173 p.
Kelley, V.C., 1977, Geology of Albuquerque Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 33, 60 p.
King, W.E., Hawley, J.W., Taylor, A.M., and Wilson, R.P., 1971, Geology and Ground-Water Resources of Central and Western Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Hydrologic Report 1, 64 p.
Knowles, D.B., and Kennedy, R.A., 1958, Ground-Water Resources of the Hueco Bolson Northeast of El Paso, Texas: U.S. Geological Survey, Water-Supply Paper 1426, 186 p.
Lambert, P.W., 1968, Quaternary stratigraphy of the Albuquerque area, New Mexico: Ph.D. thesis, University of New Mexico, 257 p.
Lane, L.J., and Nyhan, J.W., 1982, Use of a State of the Art Model in Generic Designs of Shallow Land Repositories for Low-Level Wastes, in Waste Management '82, volume 2 - Low Level Waste, R.G. Post, ed.: Proceedings of the Symposium on Waste Management at Tucson, Arizona, Arizona Board of Regents, p. 235-244.
Longmire, P.A., Gallaher, B., and Hawley, J.S., 1981, Geological, Geochemical and Hydrological Criteria for disposal of hazardous wastes in New Mexico: New Mexico Geological Society, Special Publication, no. 10, p. 93-102.
Machette, M.N., 1978, Dating Quaternary faults in the southwestern United States by using buried calcic paleosols: U.S. Geological Survey Journal of Research, v. 6, no. 3, p. 369-381
______, 1982, Quaternary and Pliocene Faults in the La Jencia and Southern Part of the Albuquerque-Belen Basins, New Mexico: Evidence of Fault History from Fault-Scarp Morphology and Quaternary Geology: New Mexico Geological Society Guidebook, 33rd field conference, p. 161-170.
Maker, H.J., Folks, J.J., Anderson, J.U., and Gallman, W.B., 1971a, Soil Association and Land Classification for Irrigation, Sandoval and Los Alamos Counties: New Mexico State University

Agricultural Experiment Station, Research Report 188, 45 p.
Maker, H.J., Neher, R.E., Derr, P.H., and Anderson, J.U., 1971b, Soil Associations and Land Classifications for Irrigation, Doña Ana County: New Mexico State University Agricultural Experiment Station, Research Report 183, 40 p.
Maker, H.J., Anderson, G.W., and Anderson, J.U., 1972a, Soil Associations and Land Classification for Irrigation, Colfax County: New Mexico State University Agricultural Experiment Station, Research Report 239, 47 p.
Maker, H.J., Derr, P.S., and Anderson, J.U., 1972b, Soil Associations and Land Classification for Irrigation, Otero County: New Mexico State University Agricultural Experiment Station, Research Report 238, 63 p.
Maker, H.J., Keetch, C.W., and Anderson, J.U., 1973, Soil Associations and Land Classification for Irrigation, San Juan County: New Mexico State University Agricultural Experiment Station, Research Report 257, 44 p.
Maker, H.J., Dregne, H.E., Link, V.G. and Anderson, J.U, 1974, Soils of New Mexico: New Mexico State University Agricultural Experiment Station, Research Report 285, 132 p.
Molenaar, C.M., 1974, Correlation of the Gallup Sandstone and Associated Formations, Upper Cretaceous, Eastern San Juan Basin and Acoma Basins, New Mexico: New Mexico Geological Society Guidebook, 25th field conference, p. 251-258.
Parker, J.M., Riggs, E.A., and Fisher, W.L., 1977, Oil and gas potential of the San Juan Basin: New Mexico Geological Society, Guidebook 28th field conference, p. 227-234.
Post, R.G., editor, 1982, Waste Management '82, volume 2 - Low Level Waste: Proceedings of the Symposium on Waste Management at Tucson, Arizona, Arizona Board of Regents, 655 p.
Reilinger, R.E., Brown, L.D., and Oliver, J.E., 1979, Recent Vertical Crustal Movements from Leveling Observations in the Vicinity of the Rio Grande Rift, <u>in</u> Rio Grande Rift: Tectonics and Magmatism, R.E. Reicker, ed.: American Geophysical Union, Washington, D.C., 438 p.
Reiter, M., Mansure, A.J., and Shearer, C., 1979, Geothermal Characteristics of the Rio Grand rift within the Southern Rocky Mountain Complex, <u>in</u> Rio Grande Rift: Tectonics and Magmatism, R.E. Riecker, ed.: American Geophysical Union, Washington, D.C., 438 p.
Sanford, A.R., Olsen, K.H., and Jaksha, L.H., 1981, Earthquakes in New Mexico, 1849-1977: New Mexico Bureau of Mines and Mineral Resources, Circ. 171, 20 p.
Seager, W.R., 1980, Quaternary Fault System in the Tularosa and Hueco Basins, Southern New Mexico and West Texas: New Mexico Geological Society Guidebook, 31st field conference, p. 131-136.
______, 1981, Geology of the Organ Mountains and southern San Andres Mountains, New Mexioc: New Mexico Bureau of Mines and Mineral Resources, Memoir 39, 97 p.
Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, S.A., 1983, Geologic Map of Eastern Half of Las Cruces and Northeastern Part of El Paso, $1^{o}x2^{o}$ sheets: New Mexico Bureau of Mines and Mineral Resources, GM 57, in press.
Siemers, W.T., and Austin, G.S., 1979, Active Mines and Processing

Plants in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Maps, RM-9

Slack, P.B., and Campbell, J.A., 1976, Structural Geology of the Rio Puerco Fault Zone and its Relationship to Central New Mexico Tectonics: in Tectonics and Mineral Resources of Southewestern North America: New Mexico Geological Society, Special Publication no. 6, p. 46-52.

Stephens, D.B., and Siegel, J., 1981, Fluid-Waste Movement through the Vadose Zone: New Mexico Geological Society, Special Publication no. 10, p. 103-110.

Stone, W.J., Lyford, F.P., Franzel, P.F., Mizell, N.H., and Padgett, E.T., 1982, Hydrogeology and Water Resources of San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Hydrologic Report 6, 70 p.

Summers, W.K., 1979, Hydrothermal Anomalies in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Maps, RM-1.

Titus, F.B. Jr., 1961, Ground-Water Geology of the Rio Grande Trough in North-Central New Mexico, with sections on the Jemez Caldera and the Lucero Uplift: New Mexico Geological Society Guidebook, 12th field conference, p. 186-192.

U.S. Geological Survey and New Mexico Bureau of Mines and Mineral Resources, 1981, Energy Resources map of New Mexico: U.S. Geological Survey Map I-1327.

Wells, S.G., and Rose, D.E., 1981, Application of Geomorphology to Surface Coal-Mining Reclamation, Northwestern New Mexico: New Mexico Geological Society, Special Publication no. 10, p. 69-83.

Wilson, L., 1973, Variations in Mean Annual Sediment Yield as a Function of Mean Annual Precipitation: American Journal of Science, vol. 273, p. 335-349.

______, 1981, Potential for Ground-Water Pollution in New Mexico: New Mexico Geological Society, Special Publication no. 10, p. 47-54.

Wilson, L., Anderson, S.T., Jenkins, D.N., and Cristiano, C., 1979, Program for the Statewide Monitoring of Ground-water Quality in New Mexico: unpublished final report on file in the office of New Mexico Environmental Improvement Division, Santa Fe, New Mexico, 180 p.

Wilson, C.A., White, R.R., Orr, B.R., and Roybal, R.G., 1981, Water Resources of the Rincon and Mesilla valleys and adjacent areas, New Mexico: New Mexico State Engineer, Technical Report 43, 514 p.

Winograd, I.J., 1974, Radioactive Waste Storage in the Arid Zone: EOS Transactions American Geophysical Union, v. 55, no. 10, p. 884-894.

______, 1981, Radioactive Waste Disposal in Thick Unsaturated Zones: Science, Vol. 212, no. 4502, p. 1457-1463.

Woodward, L.A., and Martinez, R., 1974, Geologic Map and Sections of Holy Ghost Spring Quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 33.

Yalcintas, M.G., compiler, 1982, Proceedings of the Symposium on Low-Level Waste Disposal-Site Characterization and Monitoring: U.S. Nuclear Regulatory Commission, Washington, D.C., 503 p.

Information: 505/835-5420
Publications: 505/835-5410

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

February 18, 1983

Representative James K. Otts, Chairman
Radioactive Waste Consultation Committee
New Mexico State Legislature
State Capitol Building
Santa Fe, New Mexico 87503

Dear Representative Otts:

Inclosed is the report of the New Mexico Bureau of Mines and Mineral Resources on "Site Identification for Low-Level Radioactive Waste Disposal in New Mexico." It has been prepared by me in accordance with provisions of the "Site Identification Act," HENRCS/House Bill 397 (1981).

The report is complete except for Appendices A to C. Appendix A on Low-Level Waste Generation in New Mexico (1979-1980) needs to be updated to include statistics for 1981 and 1982. Appendix B is a new State Geologic Map that is being published by the New Mexico Geological Society in early March. Appendix C is the latest state map showing landownership, which I still have to obtain from the U. S. Bureau of Land Management.

As you and the rest of the committee clearly understand, this has been a very tough assignment; and at the same time it has been one of the most worthwhile service requests ever made to the New Mexico Bureau of Mines. The possible sites designated in this report are "good sites" when compared with other low-level waste facilities in the nation. However, is there really such a thing as a "good" radioactive waste disposal site? To say the least this has been a humbling experience for me. One does not lightly jump into this type of work.

Dr. Kottlowski and I feel that this effort deserves public and professional attention at the earliest possible opportunity. We would therefore like the committee's and legislature's permission to release this document in our open-file-report series. It would then be available at a nominal fee for duplication costs. The document could also serve as the basis for a somewhat more elaborate formal publication at a later date.

Sincerely yours,

John W. Hawley

John W. Hawley
Senior Environmental Geologist

JWH/dh

cc: Frank E. Kottlowski

Rep. Vernon Kerr

N. MEXICO BUREAU OF MINES AND MINERAL RESOURCES

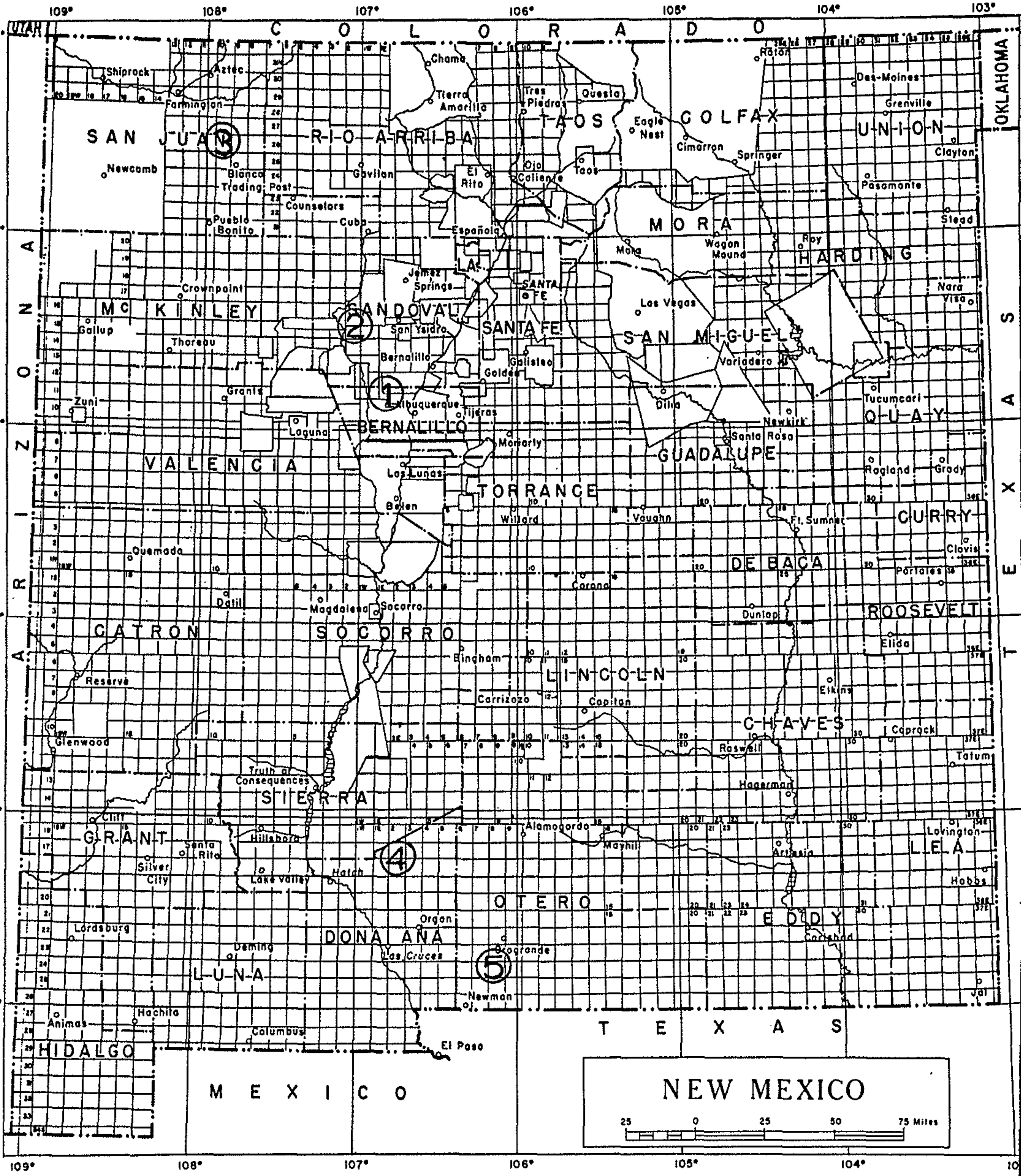


Figure 1. Five possible sites for disposal of low level radioactive wastes
1.Llano de Albuquerque 2.Prieta 3.Huerfano 4.Jornada 5.Desert

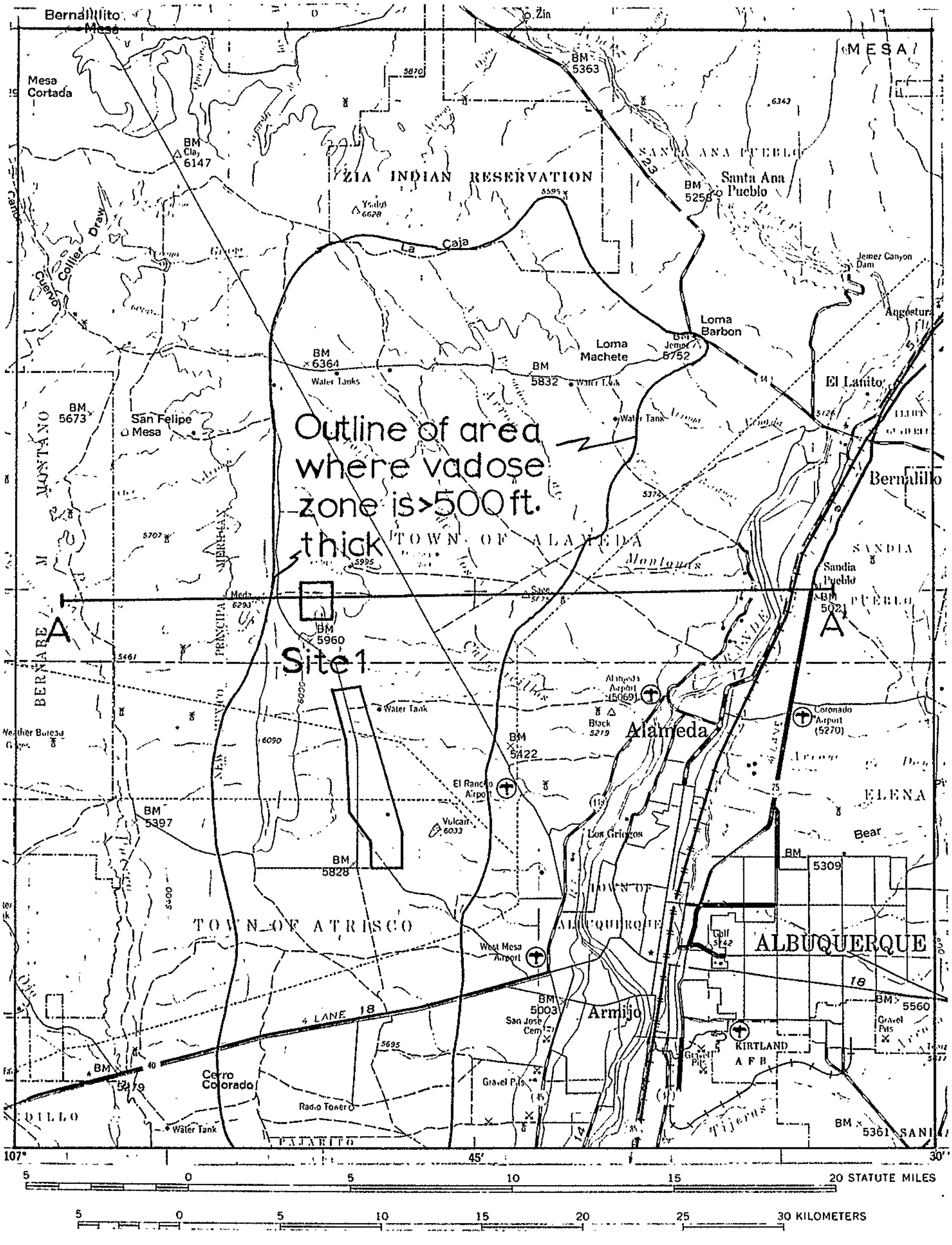


Figure 2. Index map to Site 1 area (Llano de Albuquerque) and location of section AA'

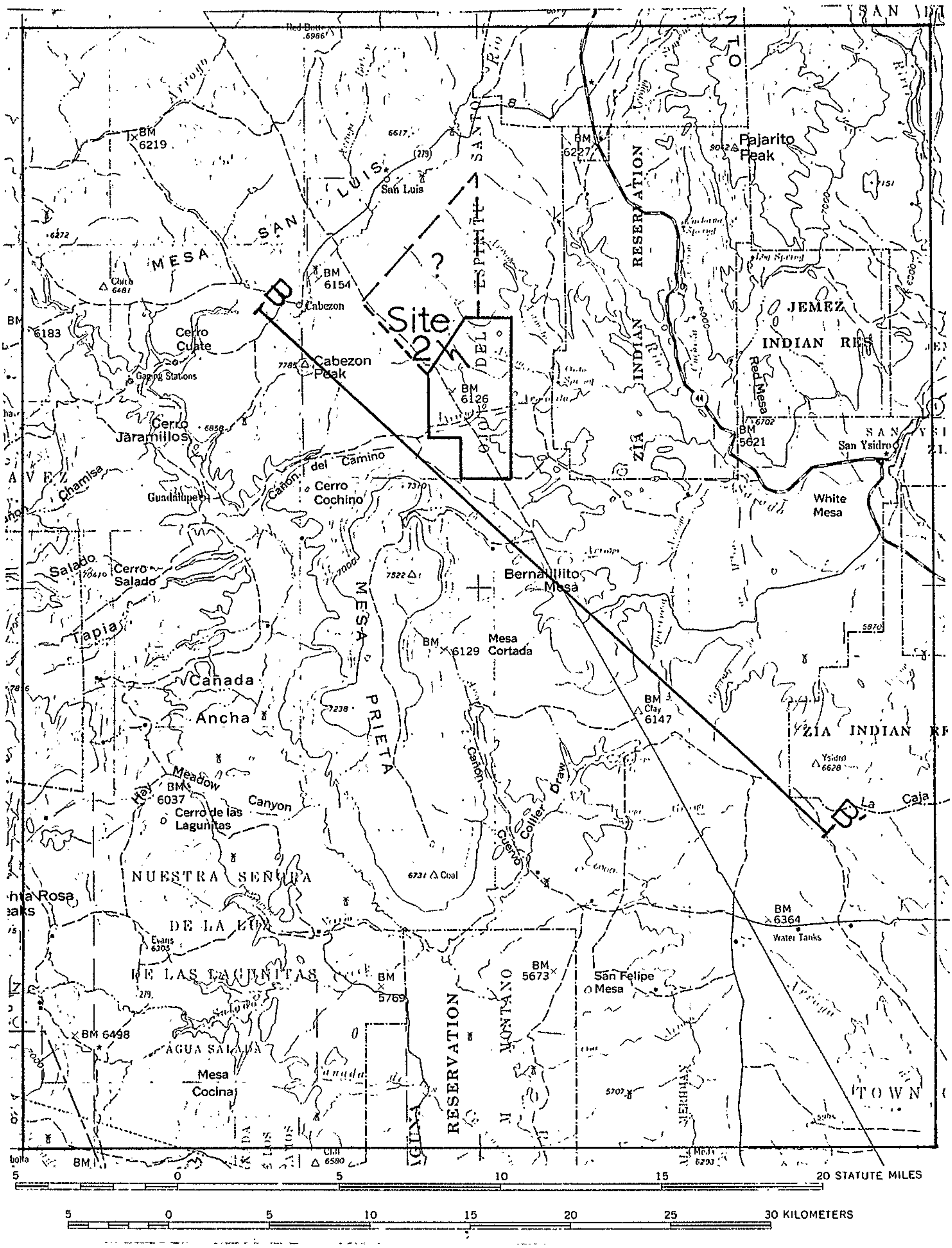


Figure 3. Index map to Site 2 area (Prieta) and location of section BB'

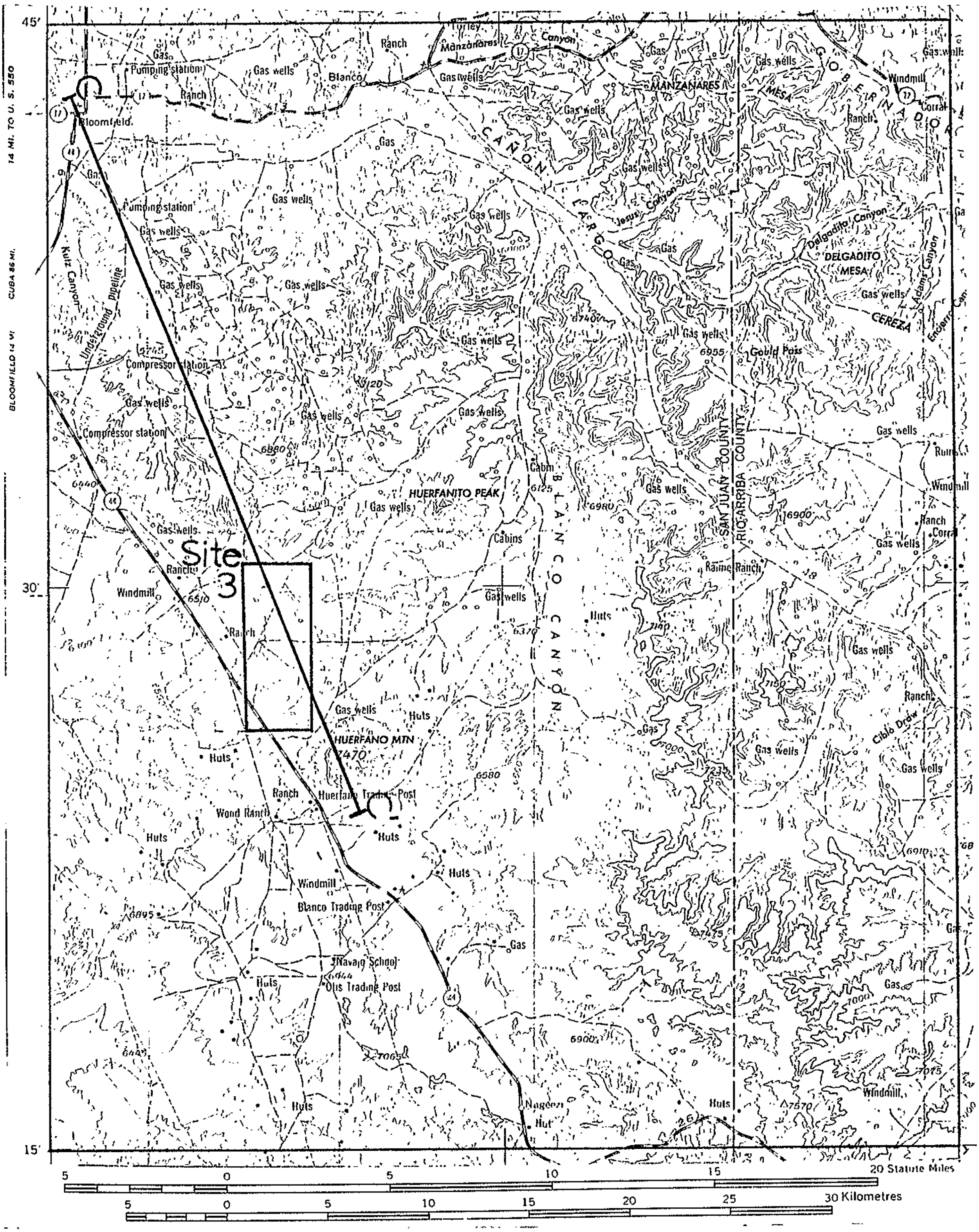


Figure 4. Index map to Site 3 area (Huerfano) and location of section CC'

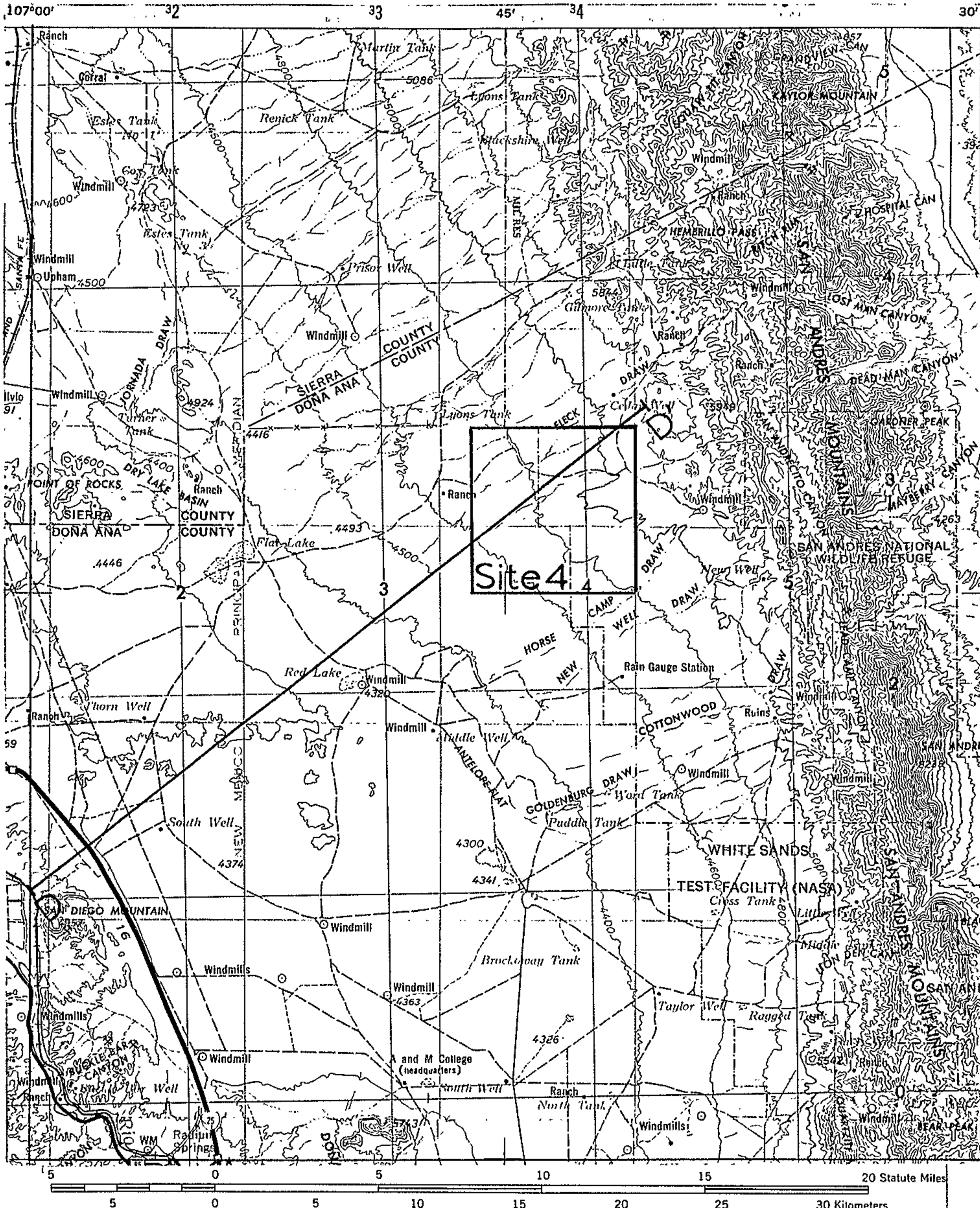


Figure 5. Index map to Site 4 area (Jornada) and location of section DD'

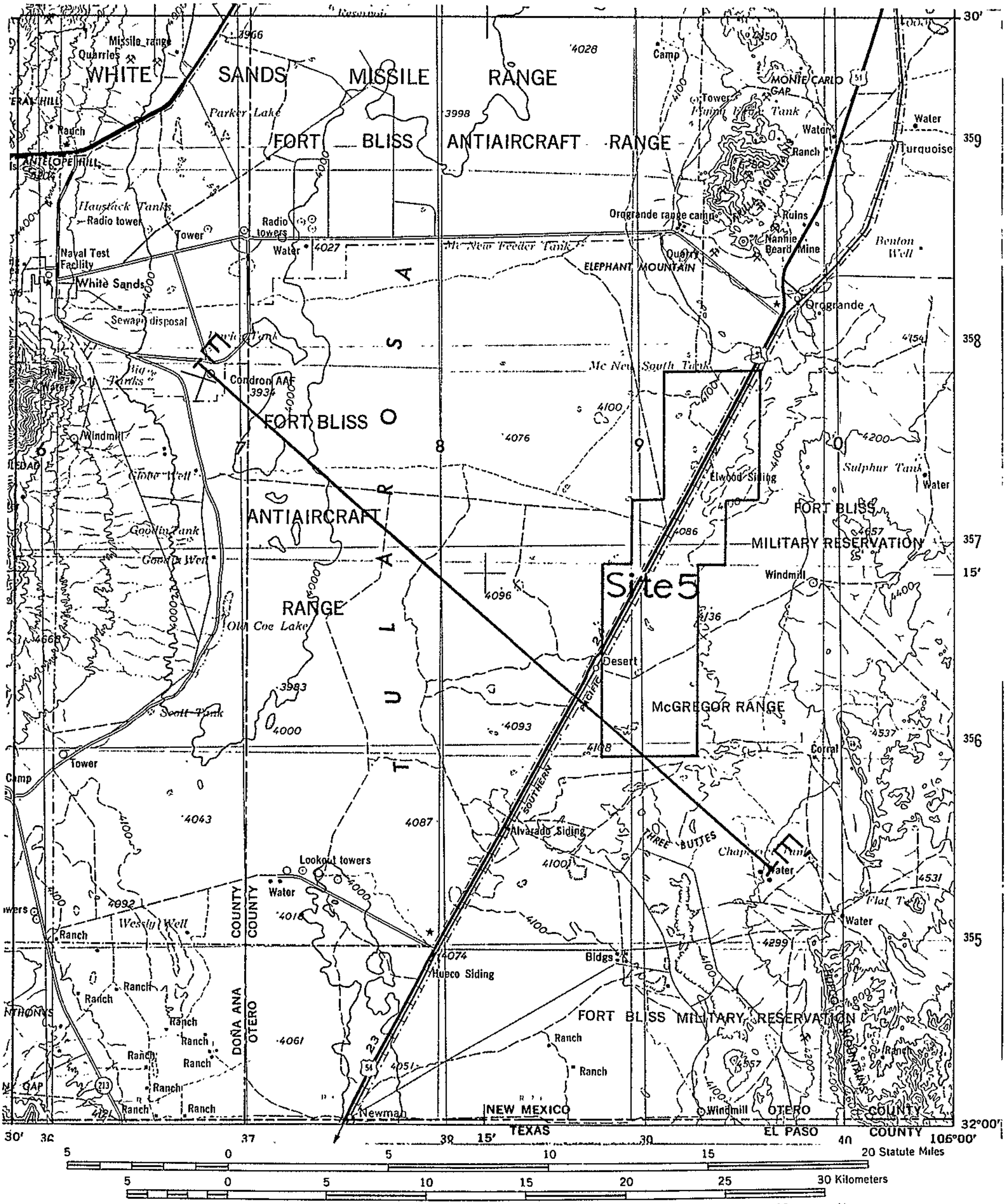


Figure 6. Index map to Site 5 area (Desert) and location of section EE'

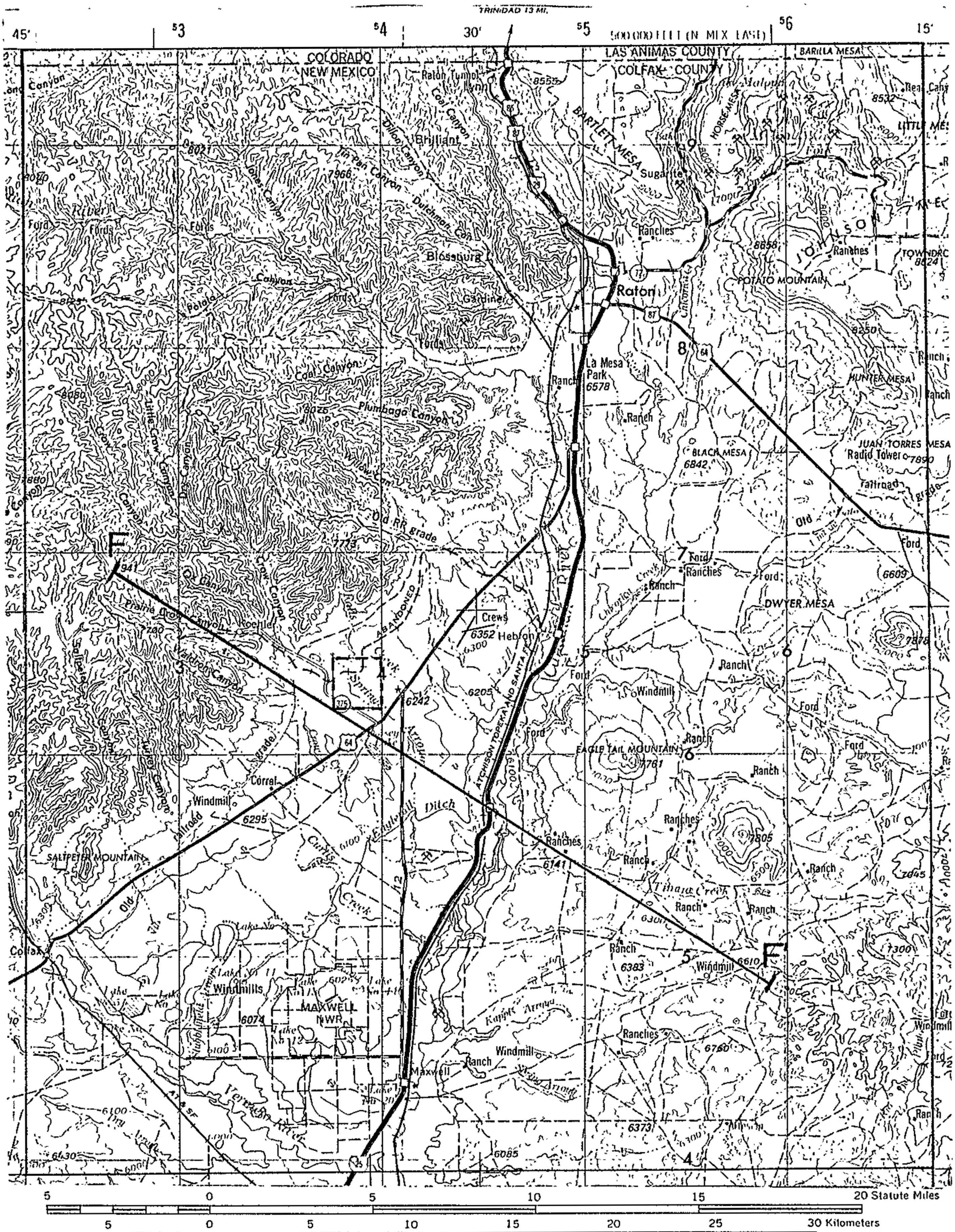
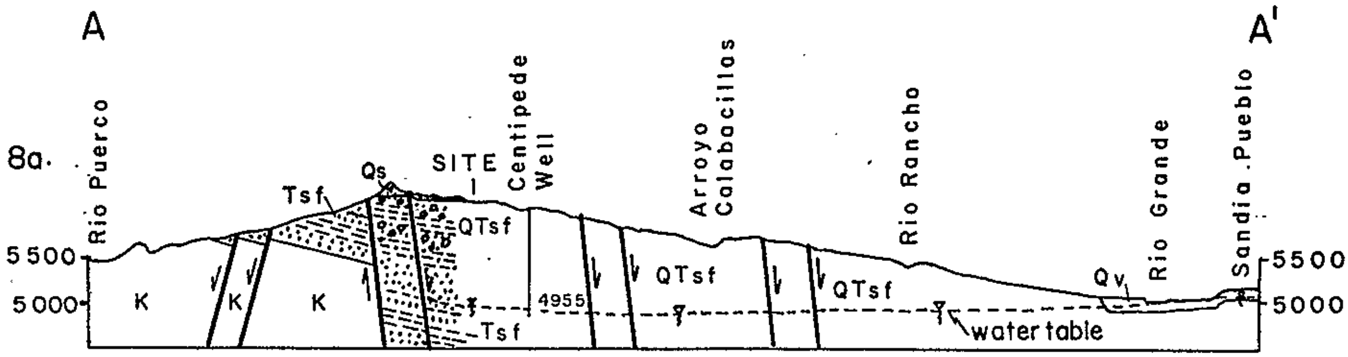
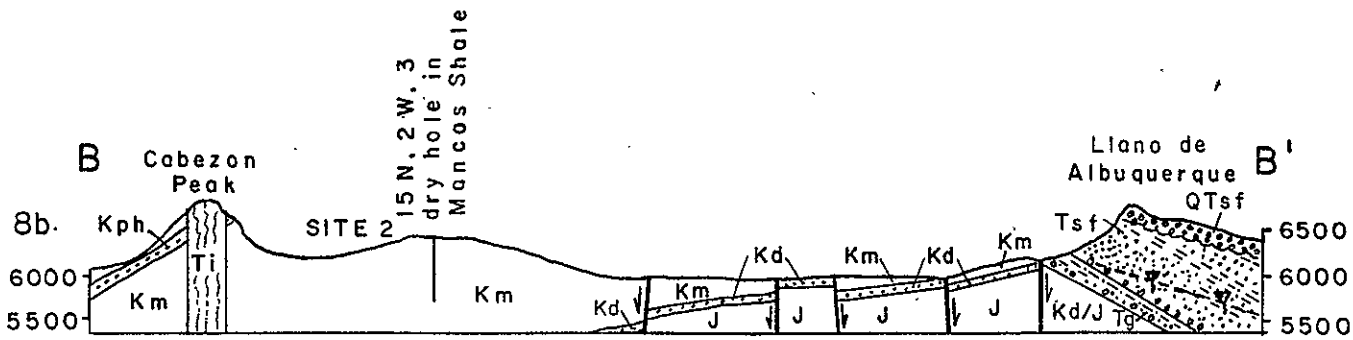


Figure 7. Index map to Site 6 area (Raton-Koehler) area and location of section FF'



Qs Windblown sand
Qv Rio Grande Valley Fill-sand, gravel, silt, clay
QTsf Upper Santa Fe Group-sand and gravel; interbedded with some clay and silt
Tsf Lower Santa Fe Group-interbedded sand, silt, and clay
K Undivided Mesozoic rocks-mostly Cretaceous shale and sandstone



QTsf	Upper Santa Fe Group-sand and gravel	KToa	Ojo Alamo Sandstone
Tsf	Lower Santa Fe Group-sand, silt, clay	Kk	Kirtland Shale
Tg	Galisteo Formation-sandstone and mudstone	Kph	Point Lookout Sandstone-Hosta Tongue
Tsj	San Jose Formation-sandstone	Km	Mancos Shale
Tn	Nacimiento Formation-shale with minor sandstone	Kd	Dakota Sandstone
		J	Jurassic mudstones and sandstones

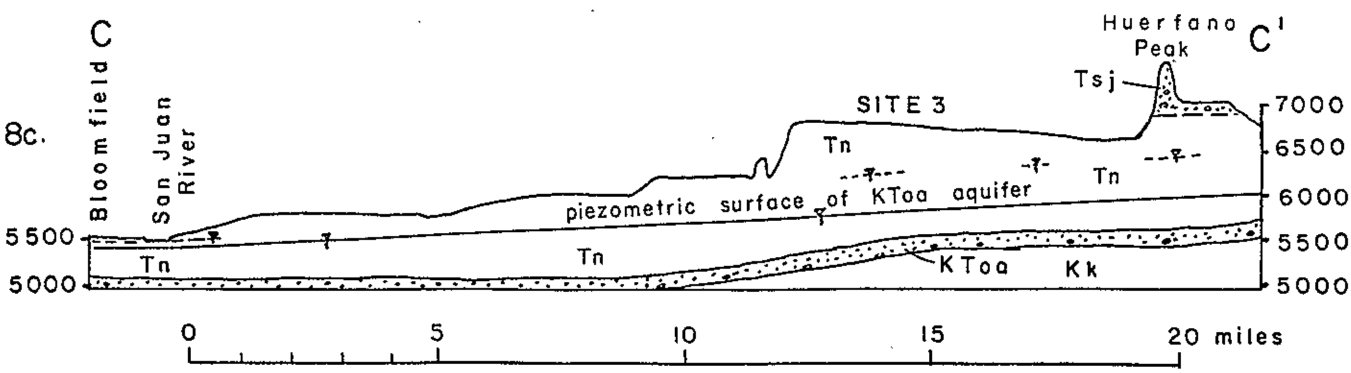
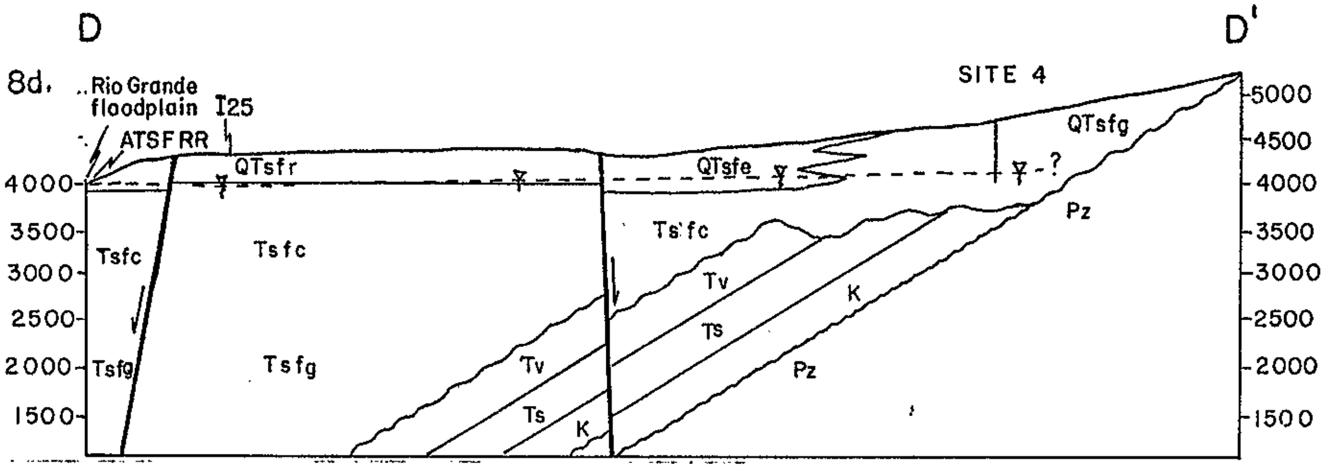
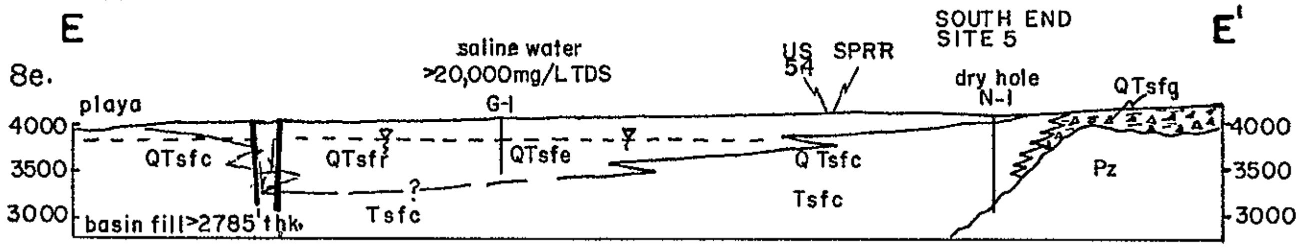


Figure 8 a-c. Hydrogeologic sections AA', BB', CC' of Site 1, 2, and 3 areas



Santa Fe Group, Upper	QTsfr	river sand and gravel
	QTsfe	sand and gypsum
	QTsfc	clay and gypsum
	QTsfg	fan gravel
Santa Fe Group, Lower	Tsfg	fanglomerate
	Tsfc	claystone and mudstone

Tv Middle Tertiary volcanics
Ts Lower Tertiary conglomerate and mudstone
K Cretaceous sandstone and shale
Pz Limestone, sandstone, and shale



TKr Raton Formation-sandstone, shale, coal
Ktv Vermejo and Trinidad Formations-sandstone, shale, coal
Kp Pierre Shale
Kn Smoky Hills Marl (shale)
Knf Fort Hays Limestone
Kc Carlisle Shale
Kgg Greenhorn Limestone and Graneros Shale

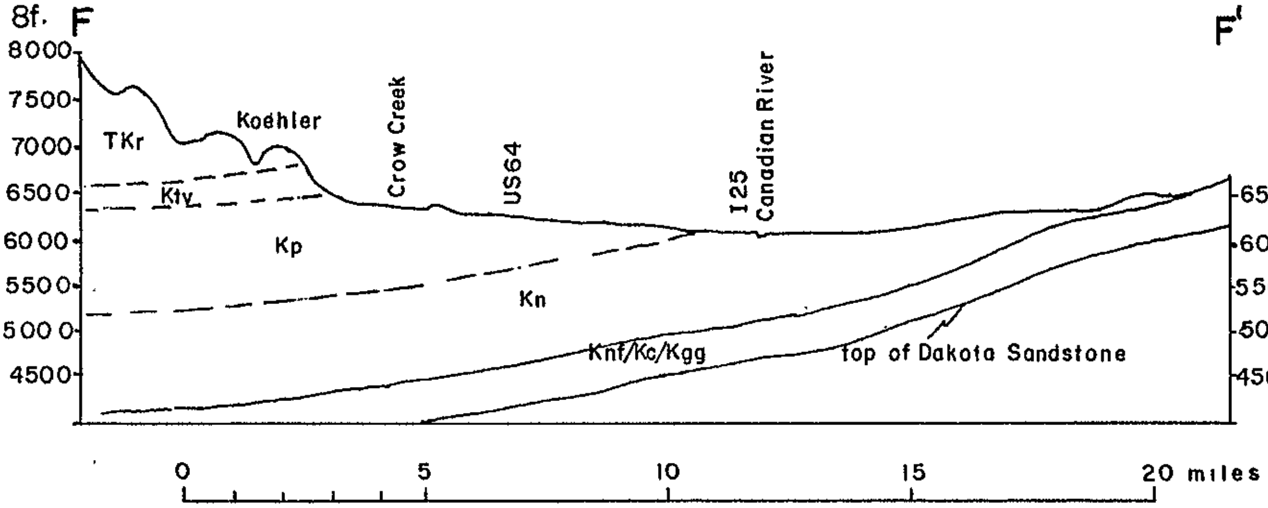


Figure 8 d-f. Hydrogeologic sections DD', EE', FF' of Site 4, 5, and Koehler areas

TABLE 1. NATIONAL AND REGIONAL SITING CRITERIA FOR SHALLOW LAND BURIAL OF LOW-LEVEL RADIOACTIVE WASTE

1a. 10CRF 61 SITE SUITABILITY CRITERIA

1. The disposal site shall be capable of being characterized, modeled, analyzed and monitored.
2. Within the region or state where the facility is to be located, a disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet performance objectives
3. Areas must be avoided having economically significant natural resources which, if exploited, would result in failure to meet the performance objectives
4. The disposal site must be generally well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year flood plain, coastal high-hazard area or wetland.
5. Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or innundate waste disposal units
6. The disposal site must provide sufficient depth to the water table that ground water intrusion, perennial or otherwise, into the waste will not occur
7. Any groundwater discharge to the surface within the disposal site must not originate within the hydrogeologic unit used for disposal
8. Areas must be avoided where tectonic processes such as faulting, folding, seismic activity, or vulcanism may occur with such frequency and extent to significantly affect the ability of the disposal site to meet performance objectives or may preclude defensible modeling and prediction of long-term impacts
9. Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering occur with such frequency and extent to significantly affect the ability of the disposal site to meet performance objectives or may preclude defensible modeling and prediction of long-term impacts
10. The disposal site must not be located where nearby facilities or activities could adversely impact the ability of the site to meet performance objectives or significantly mask the environmental monitoring program

1b. PERFORMANCE OBJECTIVES, WASTE-MANAGEMENT ASSUMPTIONS, AND RECOMMENDED SITING CRITERIA (FALCONER AND OTHERS, 1982)

<u>Performance Objectives</u>

1. The annual dose from radionuclides released from any shallow land burial site to persons outside the site boundary shall not exceed 25 mrem/yr--thyroid, 25 mrem/yr--any organ, for a performance period of 500 years.
2. Waste shall not be disposed of in a shallow land burial site that would result in an unexceptable dose to an inadvertant intruder after an institutional control period of 100 years has ended.

<u>Assumptions about Waste Management Systems</u>

1. The site will be selected, designed, operated and closed to meet performance objectives. Zero release is not achievable.
2. Performance objectives can be met by utilizing both natural and engineered barriers.
3. After the institutional control period, the site will be suitable for normal surface use but will not be designed to prevent human excavations into the waste.
4. Waste form will not jeopordize site performance.

<u>Site Selection Criteria</u>

1. The site should be of sufficient area and depth to accomodate the projected volume of waste and a three dimensional buffer zone.

   To meet site performance objectives for low-level radioactive waste disposal, the site and its operation must not limit the activity of man beyond site boundaries. A three-dimensional buffer zone will allow waste attenuation within the site boundary such that performance objectives are met. The essential information required to determine outer boundaries of the site (i.e., the buffer zone) includes the rate of change of radionuclide concentration as a function of distance from the disposal facility along all migration pathways and the concentration and quantity of radionuclides in the waste source. The depth to which the buffer zone extends depends on the hydrologic, geologic, and climatic setting of the disposal facility and whether waste is buried in unsaturated or saturated materials.

   In environments where infiltration does not reach the zone of saturation, such as areas where evapotranspiration plus runoff equal or exceed precipitation, solutes dissolved from upper soil horizons are deposited in a zone of accumulation. Material leached from the waste would be deposited in the zone of accumulation and would not reach the saturated zone. Between the zone of accumulation and the capillary fringe is a zone of low geochemical activity. The buffer zone boundary could be in this inactive zone if sufficient leaway is allowed for potential climatic changes or enhanced infiltration through the disposal trenches.

   In very arid climates, little or no water is available for leaching, and a thick zone of low geochemical activity separates buried waste from an underlying saturated zone. This environment would present a minimal probability of release by ground-water pathways, and the lower buffer zone boundary could be placed at a moderate distance below the disposal horizon.

2. The site should allow waste to be buried either completely above or below the transition zone between the unsaturated and saturated zones.

   The reliability of performance prediction may be significantly decreased by burial of waste in the transition zone and greater radionuclide release rates may result from the increased geochemical activity associated with this zone. To determine compliance with this criterion, it is necessary to examine the water table elevation, the range of both seasonal and long-term water-table fluctuations, height of the capillary fringe, thickness of excavatable material, and, if waste is buried below the transition zone, the hydraulic characteristics of earth materials in the saturated zone.

3. The site should be located where flooding will not jeopardize performance.

Where burial occurs above the water table, flood waters can transport waste material and/or saturate the waste, increasing leachate formation and accelerating subsurface water flow. Flooding can also interfere with site operations irrespective of the zone of burial. Locating burial sites outside areas that require extensive engineered protection will ensure that no increase in the probability of flooding occurs during the performance period of the site because of failure of engineered barriers.

4. The site should be located where erosion will not jeopardize performance.

During the required performance period of the site, erosion by wind and water mst not cause intrusion on the buffer zone and/or waste cover such that it (a) uncovers the waste, (b) increases surface radiation levels above regulatory limits, and/or (c) significantly shortens radionuclide release pathways. Waste that is uncovered is susceptible to transport from the site, but erosion does not have to uncover the waste to significantly shorten migration pathways. During closure, certain engineered structures, such as trench caps, will likely be emplaced to improve waste containment. Erosion of these emplaced structures could decrease the performance capabilities of the site. Allowances for predicted rates of erosion during the site performance period should be incorporated into site design, operating, and closure criteria.

Plant cover and moisture availability are the most important factors governing the rate of erosion by both wind and water. Where average annual precipitation is very low, natural vegetation may be sparse or absent, allowing high wind erosion rates and high water erosion rates whenever precipitation does occur.

5. The site should be located in areas where hydrogeologic conditions allow reliable performance prediction.

Confident characterization of the hydrogeologic system in which a waste disposal site is located enables determination of potential migration pathways, estimation of radioactive contaminant movement rates in the subsurface environment, and design of a monitor network to collect data that can be used to confirm performance predictions of radionuclide transport. Major hydrologic characteristics of the site that must be examined include: subsurface geology, hydrologic budget, direction and magnitude of groundwater flow, permeability type and diffusion and dispersion properties of the system.

6. The site should be located where geologic hazards will not jeopardize performance.

Significant land disturbances may destroy site integrity and increase the likelihood of radionuclides entering the biosphere. In addition, site hydrology may be altered to the extent that performance predictions are no longer applicable. Specific geologic events that must be considered include earth movement associated with seismic activity, mass movement, land subsidence, and volcanic activity. The results of these events in the geologic past may so complicate the hydrogeologic system that predictions of site performance cannot be confidently obtained.

7. The site should be selected with consideration given to those characteristics of earth materials and water chemistry that favor increased residence times and/or attenuation of radionuclide concentrations within site boundaries.

Leachate migrating from buried wastes may carry radionuclides and other contaminants picked up from the waste. Slowing the movement of contaminants relative to the movement of water will provide more time for radioactive decay to decrease radionuclide concentrations. Properties of earth materials and water chemistry that favor the removal of radionuclides from solution by sorption or precipitation and that favor retention on or in solid phases, will retard the movement of radionuclides. Nuclide concentration will decline more rapidly with distance from the waste if geochemical processes actively remove radionuclides from leachate than if only hydrodynamic dispersion is acting.

8. The site should be selected with consideration given to current and projected population distributions.

The minimum distance a site can be located from a population cluster must be determined by considering the size of the population and the effects of potential accidental and chronic radiation releases during operations. A site located close to population centers could interfere with their expansion, as well as increase the likelihood of human intrusion into the waste after institutional control has ended.

9. The site should be selected with consideration given to current and projected land use and resource development.

Site selection must represent a balanced choice in land use, in that siting represents a commitment in land use to future generations. Historical, current, and potential land uses at the site and the adjacent areas should be prime considerations in complying with this criterion. Land uses which represent a higher priority in comparison to low-level waste disposal should be evaluated.

10. To the extent consistent with other criteria, the site should be selected with consideration given to location of waste generation, access to all-weather highway and rail routes, and access to utilities.

A certain risk exists from the transport of radioactive waste from points of generation to final disposal. This risk is a function of the waste form, nuclide content, vehicle safety, transportation systems, and distance traveled. By considering major points of waste generation and transportation routes in site selection, this risk can be reduced. Locating a site with regard to waste generators and transporation systems also minimizes the cost of land disposal. Additional economic factors that can be controlled through site selection include access to utilities, materials for site construction, operation and closure, and public services.

11. The site should be selected consistent with federal laws and regulations.

Federal laws that a disposal site must comply with include but are not limited to: Clean Air Act (PL 95-95), Federal Water Pollution Control Act (PL 95-217), Safe Drinking Water Act (PL 93-523), National Environmental Policy Act (PL91-190).

12. The site should not be located within areas that are protected from such use by federal laws and regulations.

Federal laws which preclude, by intent, the selection of low-level waste disposal sites within the boundaries of areas protected under them include but are not limited to: Wilderness Act of 1964 (PL 88-577), Wild and Scenic Rivers Act (PL 90-542), Endangered Species Act of 1973 (PL 93-205), National Wildlife Refuge Act of 1966 (PL 89-669), Laws establishing National Parks, Historic Properties-Preservation (PL 89-665), Archeological and Historical Preservations Act of 1974 (PL 93-291).

TABLE 2. GEOLOGIC AND HYDROLOGIC SITING CRITERIA FOR LOW-LEVEL WASTE DISPOSAL IN NEW MEXICO

I. The most important goal in waste disposal is to prevent contamination of surface and ground waters and the atmosphere. Key to achieving this goal is to prevent the uncontrolled release of fluid, gaseous, and particulate wastes at a disposal facility. Meteoric water must be precluded from entering a containment facility and leachate must not be allowed to leak from the facility. The wastes must be isolated from the atmosphere and biosphere, as well as from surface and subsurface hydrologic systems. A thorough understanding of the local and regional environmental setting is needed to accomplish the desired isolation and assure long-term site stability.

II. Land, Mineral and Energy Resources.

Sites should not be located in areas where future natural resource development could adversely affect site integrity. Potential activities include irrigation agriculture, mineral extraction, and geothermal energy development (Anderson and Maker, 1974; Siemers and Austin, 1979; U.S. Geological Survey, 1981; Summers, 1979).

III. Surface Processes

Geomorphic processes that adversely affect site stability, and landforms or surficial deposits that indicate various degrees of surface stability must be thoroughly evaluated. The site should be in a physiographic position naturally resistant to water and wind erosion, flooding, mass wasting or subsidence (Hawley and Love, 1981; Nyhan and Lane, 1982; Wilson, 1973; Holzer and Pampeyan, 1981).

A. Climate-process considerations:

1. Sites should be located in arid and semiarid areas with low local relief.

2. Mean annual precipitation should not exceed 425 mm (16 in), with 24-hr storm intensities no greater than 200 mm (8 in).

3. Annual evaporation (Class A pan) should be at least 60 in .

4. Surficial materials and natural vegetation cover should inhibit wind erosion (deflation).

B. Slopes and other topographic factors associated with limited erosion-sedimentation rates:

1. Local relief should be low (elevation range of less than 300 ft in an area of less than 36 square miles)

2. Natural slopes should be $\lesssim$5%.

3. Where slopes are very low (<1%), they should not be susceptible to flooding or ponding from storm runoff. Avoid all floodplains and lake plains.

4. Avoid areas of active erosion-sedimentation, including areas of thick alluvial and eolian deposits of Holocene age (10,000 yrs).

5. Distance to very steep slopes such as rim zones of escarpments should exceed 1 mile.

6. Surficial geologic units should not contain deposits emplaced by mass wasting, such as landslide and debris-flow units.

C. Soil-geomorphic factors. Sites should be on stable geomorphic surfaces where absolute age-dating techniques and soil-profile characteristics (strong pedogenic horizons of carbonate and clay accumulation) indicate that surface ages exceed 10,000 years.

IV. Geologic Structure and Volcanic Features

The geologic structure should be simple enough to be well understood and evaluated in terms of site suitability. A thorough investigation is needed to reveal the presence of faulting, folding, and jointing in the general site area.

A. Avoid areas of major tectonic deformation (e.g. complexly folded and faulted rocks associated with rugged terrain).

B. Site should be at least 1 mile from known faults with movement during the past 500,000 years (Machette, 1982; Seager, 1980).

C. Site should be at least 1 mile from volcanic centers with known activity during the past 500,000 years.

D. Avoid areas with major historical seismic activity (local magnitude, M_L, $\gtrsim$4), or anomalous vertical crustal movements. See Sanford and others (1981), and Reilinger and others (1979).

E. Avoid areas with anomalous terrestrial heat flow. See Reiter and others, (1979).

V. Geohydrology

Ground and surface water must be protected from contamination by low-level wastes or waste byproducts (Wilson, 1979, 1981). Protection of aquifers--geologic materials that contain recoverable water of suitable quality for human consumption--is of primary importance. Aquifers are charactorized by minimum well yields in the 1 to 10 gpm range, and water quality is in the fresh (<1,000 mg/L total dissolved solids-TDS) to slightly saline (1,000-3,000 mg/L TDS) range. (Saline water exceeds 3,000 mg/L TDS.)

1. The preliminary evaluation of possible site areas should include determination of depth to water table or piezometric surfaces; direction of groundwater flow; distribution of aquifers and confining beds; and nature of major geochemical components of the flow system.

2. The site should be at least 5 miles from the maximum floodplain or lake shoreline of perennial surface waters.

3. The site should be at least 5 miles from any well or spring tapping a major aquifer (minimum yield 100 gpm of fresh water).

4. Where unconfined ground-water conditions exist, the water table should be at least 300 feet below the surface.

5. If the unsaturated zone is less than 500 ft thick, at least 150 feet of clay-rich, relatively impermeable materials should be present betweem the surface and any potential aquifer. Recommended hydraulic conductivity values for clay-rich materials should not exceed 10^{-7}cm/sec (e.g. under unit head fluids would migrate 0.1 ft/yr or less).

6. Where relatively impermeable, clay-rich materials extend from the surface (or near-surface) into the saturated zone, confined ground-water conditions usually exist; and it is often impossible to determine unconfined "water-table" configurations. Piezometric surfaces associated with underlying confined aquifers should be at least 300 feet below the land surface.

7. Major areas of the state where unsaturated zones exceed 500 ft in thickness should get special scrutiny for possible disposal sites.

8. Areas of the state with known "dry hole" water tests in thick, clay-rich units should also receive special attention.

9. Areas where ground-water flow is primarily through fractures or solution-enlarged conduits should be avoided.

VI. Hydrogeologic Settings for Waste Repositories

A. Site areas underlain by fine-grained marine rocks.
Clay-rich marine rocks (shales, claystones, mudstone) locally have good potential as host materials. Smectite-type clay minerals with large ion-adsorptive and expansive properties, are major constituents. Units are very impermeable and commonly saturated or nearly saturated with saline water. (Type I material of Longmire and others, 1981.)

Representative formations:

1. Pierre Shale and Smoky Hill Marl Mbr-Niobrara Fm (Upper Cretaceous). More than 2,000 ft thick in parts of Colfax County southwest of Raton (fig. 8f).

2. Mancos Shale (Upper Cretaceous) as much as 1200 ft thick in parts of San Juan Basin-Colorado Plateau (fig. 8b).

B. Site areas underlain by basin and valley fill.
Sand, silt, clay and gravel (unconsolidated to partly indurated); locally thousands of feet thick. Exhibits wide range in texture and geochemical properties (e.g. lake clay, dune sand, gravelly fan alluvium, and river sand and gravel). (Type II material of Longmire and others, 1981). Representative units include:

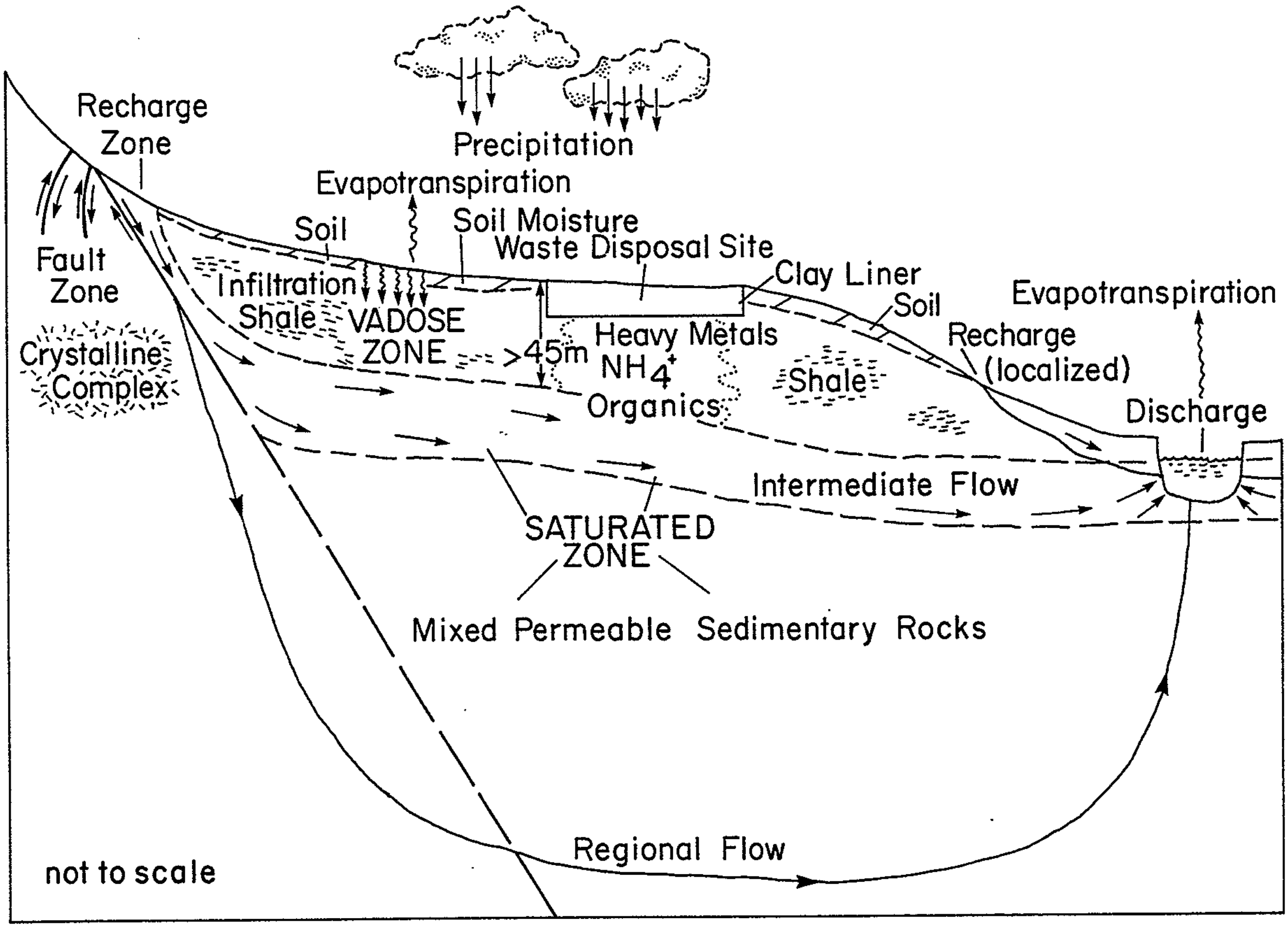
1. Ogallala Fm. Upper Miocene alluvial and eolian deposits on the High Plains. This major aquifer is unsuited for waste repositories of any type.

2. Santa Fe Group. Major fill unit of intermontane basins in central and southern New Mexico. River and stream deposits of late Miocene to middle Pleistocene age form major aquifer. Clay-rich, partly-saline and zeolitic, lake and playa deposits locally make up large part of unit in bolson-floor areas (e.g. sites 4 and 5, figs. 1 and 7). Unit ranges up to 16,000 feet thick in parts of the central Albuquerque Basin where it constitutes one of the great aquifers of the nation. Interbedded sand, silt, clay and gravel of the Santa Fe Group also underlie the extensive Llano de Albuquerque tableland situated between the Rio Grande and Puerco valleys. In that area the unsaturated zone is as much as 1,000 ft thick (site 1, figs. 1 and 7).

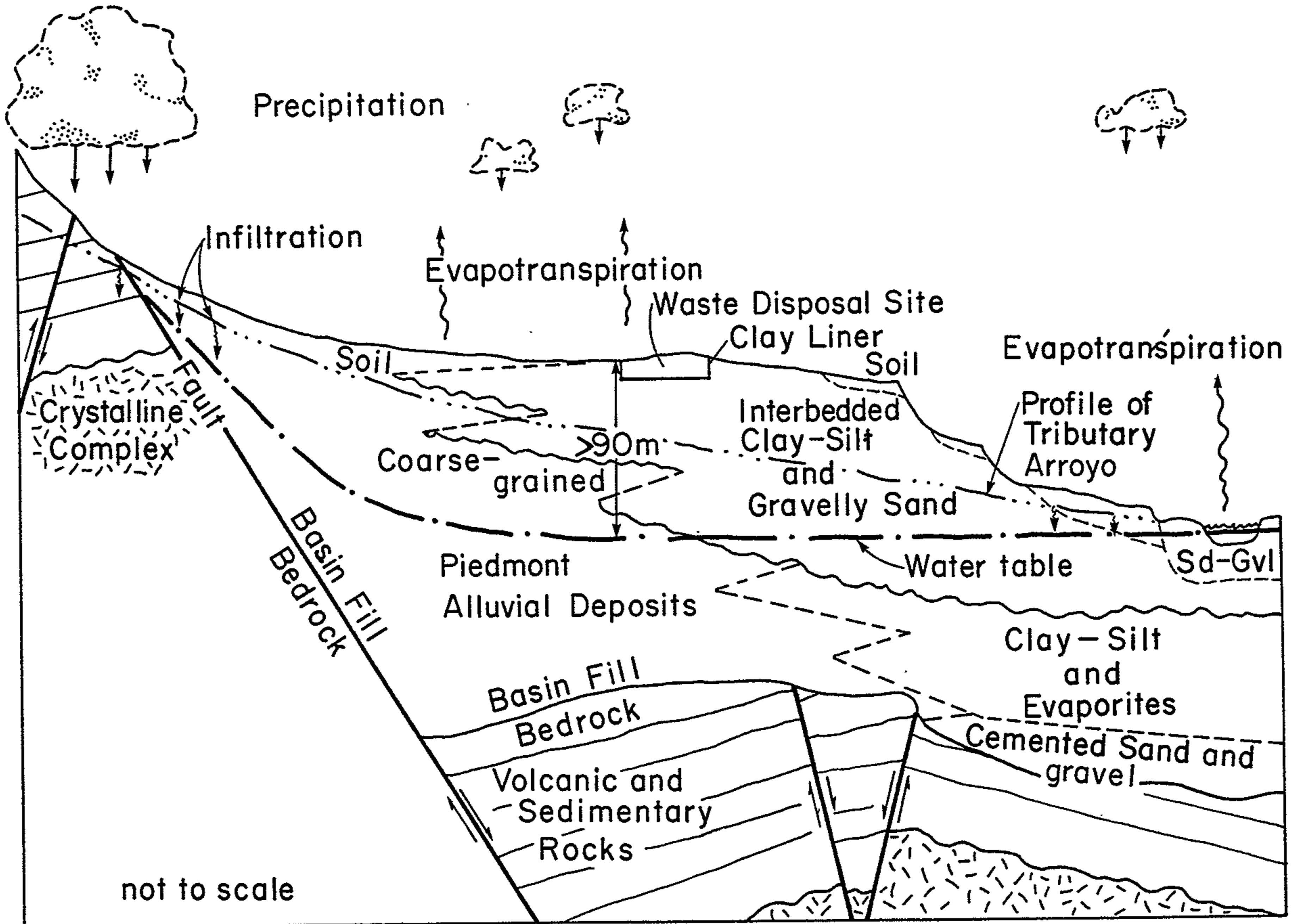
C. Site areas underlain by older continental deposits.
Shale, mudstone, siltstone and sandstone (in places poorly consolidated); locally several thousand feet thick. Unit includes stream and lake deposits of early to middle Tertiary age in the Colorado Plateau and Basin and Range Provinces. (Type III materials of Longmire and others, 1981). Representative units include:

1. Nacimiento Fm. Lower Tertiary alluvial and lacustrine unit in the San Juan Basin that is primarily shale, but which locally contains lenticular, water-bearing sandstone beds (site 3, figs. 1 and 7).

2. Clay- to sand-rich clastic deposits, commonly zeolitic; primarily conglomeratic debris-flow units and mudstones associated with middle Tertiary volcanic terranes of southwestern New Mexico (e.g. Spears, Palm Park, Rubio Peak Fms). Unit may prove to be important host rock for waste repositories.



ADDENDUM TO TABLE 2 (ฦy A) - TYPE I MATERIAL OF LONGMIRE ET AL., 1981



ADDENDUM TO TABLE 2 (fig. B) - TYPE II MATERIAL OF LONGMIRE ET AL., 1981

TABLE 3. INSTITUTIONAL AND CULTURAL FEATURES AT POSSIBLE SITES FOR LOW-LEVEL WASTE DISPOSAL

SITE NUMBER	1	2	3	4	5	Unrated
COUNTY	Bernalillo	Sandoval	San Juan	Doña Ana	Otero	Colfax
SITE NAME	Llano de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
QUADRANGLE(S)	Albuquerque 2° Volcano Ranch 7-1/2' Sky Village SE 7-1/2'	Albuquerque 2° Ojito Spring 7-1/2' Cabezon Peak 7-1/2' San Luis 7-1/2?	Aztec 2° Bloomfield 15' Huerfano Trad. Post NW Huerfano Trad. Post 7-1/2'	Las Cruces 2° Chicken Well 15' Kaylor Mtn 15'	Las Cruces 2° Elwood 7-1/2' Orogrande S 7-1/2'	Raton 2° Koehler 7-1/2'
TOWNSHIP/ RANGE/ SECTION	10N/1E/1,2 11N/1E/10,11,14,15,22, 23,25,26,35,36 12N/1E/21,22,27,28	15N/1W/6,7 15N/2W/1,12 16N/1W/18,19,30,31 16N/2W/13,14,23-26,36 17N/2W/?	26N/10W/10,11,14,15,22, 23,26,27,34,35	17S/2E/20-29,32-36 18S/2E/1-5,8-12	23S/8E/3-5,8-10, 15-17,20-22, 28-30,31-33	
LAND GRANT-LONGITUDE/ LATITUDE	Town of Alameda	Formerly part of Ojo de Espiritu Santo Grant				Maxwell 104°33-35' Long 36°42-43' Lat
SITE AREA	>10 mi², 2 parcels	10 mi² (20 mi²)	10 mi²	25 mi²	36 Mi²	<2 mi²
LAND OWNERSHIP	Private State (10/1/2,11/1/36)	Public (BLM)	Public (BLM)	DOD (WSMR) 13 mi² Public (BLM) 11 mi² State (17/2/32)	DOD (McGregor Rge Fort Bliss)	Private
MAJOR LAND USES	Grazing Land Suburban Expansion	Grazing Land Gas Pipeline	Grazing Land Gas Pipeline 4 gas/oil wells	Grazing Land WSMR (Buffer zone)	Military, Highway and RR right-of-way	Grazing Land
ESTIMATED DISTANCE TO NEAREST: Town	3-6 mi (suburban Albuquerque)	12 mi (San Ysidro)	15 mi (Bloomfield)	20 mi (Rincon)	3-15 mi (Orogrande)	12 mi (Raton, Maxwell)
Residence	Several on or near site	2 mi	1-5 mi	1-5 mi	3-15 mi	1 mi
Perennial Stream	6-11 mi (Rio Grande)	12 mi (Jemez River)	13-18 mi (San Juan River)	17-23 mi (Rio Grande)	30-42 mi (Rio Grande)	5 mi (Canadian River)
Lake or Reservoir (downstream)	20-25 mi (Rio Grande floodplain)	23 mi (Jemez Reservoir)	NA	NA	NA	8 mi (Maxwell Natl. Wildlife Refuge)
Irrigated Farm Land	6-11 mi	13 mi	5-10 mi (Navajo Irrig. Proj.)	17-23 mi	15-25 mi	5 mi
Interstate Highway	4-12 mi (I-40)	29 mi (I-25)	80 mi (I-40)	15-21 mi (I-25)	25-36 mi (I-25)	4-5 mi (I-25)
Federal/State Hwy.	4-12 mi	5 mi (NM-44,NM-279)	<4 mi (NM-44)	20 mi	0-4 mi (US-54)	1-2 mi (US-64)
Railroad	8-13 mi	29 mi	80 mi (ATSF)	15-21 mi (ATSF)	0-4 mi (SP)	4-5 mi (STSF)
ARCHEOLOGICAL(A)/ HISTORICAL(H)/ CULTURAL SITES (C)	A-on site C-Albuquerque volcanoes, 1-7 mi	A-on site C-Cabezon Peak Wilderness Study Area, 2-5 mi	A-on site	A-on site	A-on site	A-on site H-Santa Fe Trail on site; near Koehler townsite
REMARKS	Area may be expanded to north and south	Area may be expanded north into San Luis Quad (T16-17N,R2W)			Area considered because of highway and railroad right-of-ways	Area may be considered at later date
KEY REFERENCES	Bjorklund and Maxwell (1961); Black (1982); Black and Hiss (1974); Hacker (1977); Hawley et al. (1982); Kelley (1977); Lambert (1968); Machette (1978, 1982); Slack and Campbell (1976); Titus (1961)	Baltz (1978); Black and Hiss (1974); Craigg (1980); Kelley (1977);Maker et al. (1971a); Molenaar (1974); Slack and Campbell (1976); Woodward and Martinez (1974)	Baltz (1967); Brimhall (1972); Fassett and Hinds (1971); Keetch (1980); Maker et al. (1973); Parker et al. (1977); Stone et al. et al. (1983); Wells and Rose (1981)	Bulloch et al. (1980); Gile et al. (1981); King et al. (1971); Maker et al. (1971b); Seager et al. (1983); Wilson et al. (1981)	Derr (1981); Heidale et al. (1967); Knowles and Kennedy (1958); Maker et al. (1972b); Seager (1980, 1981) Seager et al. (1983)	Anderson et al (1982); Baltz (1965); Griggs (1948); Herkenhoff and Assoc. (1977); Maker et al. (1972a)

TABLE 4. PHYSIOGRAPHIC FEATURES AT POSSIBLE SITES FOR LOW-LEVEL WASTE DISPOSAL

SITE NUMBER	1	2	3	4	5	
SITE NAME	L. de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
CLIMATOLOGICAL DATA Station (elevation)	Albuquerque (5314')	Cuba (6945')	Aztec (5640')	Las Cruces (3881')	Alamogordo (4350')	Springer (5857')
Precipitation (in) Mean Annual Maximum (24-hr)	7.9 4	13.8 <3.5	9.3 —	8.4 6.5 (8/30/35)	10.1 <6.5	15.6 6-7 (9/1/42)
Temperature (°F) Mean January Mean July	35 79	26 69	29 74	42 79	42 80	28 75
Evaporation (in) Class-A Pan (estimated)	75	—	60	97	100	75
Wind Conditions	Late winter-early summer high winds (dust)	Late winter-early summer high winds (dust)	Late winter-early summer high winds (dust)	Late winter-early summer high winds (dust)	Late winter-early summer high winds (dust)	Late winter-early summer high winds (dust)
PHYSIOGRAPHIC UNIT Province	Basin and Range	Colorado Plateau	Colorado Plateau	Basin and Range	Basin and Range	Great Plains
Section	Mexican Highland	Navajo	Navajo	Mexican Highland	Mexican Highland	Raton
GEOGRAPHICAL AREA	north-central Albuquerque Basin	upper Rio Salado (Jemez Rv.) basin	central San Juan Basin	east-central Jornado del Muerto Basin	SE Tularosa Valley N. Hueco Bolson	upper Canadian River Valley
ELEVATION RANGE (ft)	5000-6100	5800-6400	6550-6815	4500-5100	4060-4110	6300-6450
LANDFORMS Major	Summit of high tableland (mesa) flanked by river valleys	upland; SE slope of Rio Puerco-Salado drainage divide	summit of high tableland (mesa) flanked by stream valleys	piedmont slope grading from San Andres Mtns to floor of Jornada del Muerto basin, a closed intermontane basin (bolson)	bolson floor, river and lake plains not yet integrated with Rio Grande Valley System	pediment, grading from Park Plateau escarpment to Canadian River Valley
Minor	shallow arroyo valleys, small closed depressions eolian sand sheets	shallow arroyo valleys, broad shale and narrow sandstone ridges	shallow arroyo valleys, eolian sand sheets, and low dune ridges	coalescent alluvial fans, shallow arroyo valleys	shallow deflation depressions, eolian sand sheets and dunes	shallow arroyo valleys, local shale ridges
LOCAL RELIEF (ft)	50-100	100-200	50-200	100	<25	50-150
SLOPE CHARACTER Range (major)	mostly <5% Locally up to 15%	mostly <10% Locally up to 25%	most <5% very locally up to 15%	mostly 2-3% very locally up to 15%	<1% except for coppice dunes	mostly 1-5% Locally up to 25%
Distribution	broad smooth upland, with fringing shallow valleys	gently sloping and undulating uplands with shallow valleys	broad undulating upland, with shallow valleys	uniform, broad piedmont slope, with shallow arroyos	irregular, many small steep dunes	gently-sloping footslope
Steep Terrain	narrow strips near arroyos	narrow strips near arroyos, cuesto scarps	narrow strips near arroyos	none	none	narrow strips near arroyos, cuesta scarps
DRAINAGE NETWORK Pattern	discontinuous, subparallel, few closed structural depressions	subparallel, irregular, bedrock control	disrupted by eolian deposits, subparallel	subparallel	essentially absent, many small deflation depressions	irregular, bedrock control
Density	low	moderate to high; low on divides	very low	low	extremely low	low to moderate; high on small cuestas

TABLE 4 (continued)

SITE NUMBER	1	2	3	4	5	
SITE NAME	L. de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
SURFICIAL MATERIALS Genetic Classes	eolian/fluvial (deposits of major tributaries to ancestrial Rio Grande)	colluvial/alluvial (stream deposits on ancient erosion surface, and young valley fill)	eolian/alluvial (stream deposits on ancient erosion surface)	eolian/alluvial (coalescent alluvial-fan piedmont deposits)	eolian/fluvial and lacustrine (deposits of deltaic distributaries of ancestrial Rio Grande)	alluvial/colluvial (pediment veneer)
Lithologic Character	loam-sand (thin) with calcic soils; over sand and gravel	loam-silty clay (thin); over shale	clay loam-sand, locally pebbly, (<50'), over shale	loamy sand to pebbly loam	sand-loam with calcic soils, over clay or sand	silty clay-loam and sand (<10') over shale
Stratigraphic Units (age)	Late Quaternary sediments/upper Santa Fe Gp (Middle Pleistocene and older)	Late Quaternary sediments/ Cretaceous	Late Quaternary sediments/ Paleocene	Late Quaternary sediments/upper Santa Fe Gp (Middle Pleistocene and older	Late Quaternary sediments/upper Santa Fe Gp	Late Quaternary sediments/ Cretaceous
MAJOR SOILS Taxonomic Classes	haplargids, calciorthids, psamments	camborthids, orthents	haplargids, psamments	haplargids, psamments	haplargids, psamments	argiustolls, orthents, orthids
Association	Madurez-Wink	Las Lucas-Litle-Persayo	Doak-Sheppard-Shiprock	Onite-Pintura	Pintura-Dona Ana	Swastika, Mion-Litle
Engineering Classes (unified)	SC-SM, SM, CL	CL, ML	ML, CL, SP-SM	SM, SP-SM, SM-MC	SM-MC, SP-SM	CL, CH
Irrigation Potential	low to unsuited for cultivation	low to unsuited for cultivation	moderate	low to moderate	low to moderate	high, low
MAJOR VEGETATION	grasses and shrubs	grasses and shrubs	grass	shrubs and grass	shrubs-barren	grass
EROSION Water-erosion Hazards	slight to moderate	high to moderate	slight to moderate	moderate	low	moderate to high
Wind-erosion Hazards	moderate to severe	low to moderate	moderate to severe	high to severe	high to severe	moderate to low
STABILITY OF MAJOR GEOMORPHIC SURFACE	very stable; no significant soil loss for 100,000 to 300,000 yrs	unstable to moderately stable; many areas with erosion-sedimentation in past 10,000 yrs	stable; no significant soil loss for 100,000 yrs, extensive wind reworking of surface layers	constructional; minor deposition and no significant soil loss for 100,000 years	very stable; no significant soil loss for 500,000 years; extensive wind reworking of surface layers	moderately stable; large area stable for <25,000 years; local erosion-sedimentation in past 10,000 years in shale outcrop areas

TABLE 5. GEOLOGIC STRUCTURE AND HAZARDS, AND ENERGY AND MINERAL RESOURCES AT POSSIBLE SITES FOR LOW-LEVEL WASTE DISPOSAL

SITE NUMBER	1	2	3	4	5	
SITE NAME	L. de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
STRUCTURE Major Tectonic Features	Rio Grande rift; intermontane basins; slightly tilted fault blocks	E. San Juan Basin; W. of Nacimiento fault zone; NW of Puerco fault zone	Central San Juan Basin	Rio Grande rift; intermontane basin; slightly tilted fault blocks	Rio Grande rift, intermontane basin; slightly tilted fault blocks	Central Raton Basin
Known Faults and Folds	High-angle normal faults	Broad folds, NW dipping homocline	Very gentle ENE dipping homocline	High-angle normal faults	High-angle normal faults	Very gentle NW dipping homocline
Distribution	Common, local	regional	regional	widely spaced	widely spaced	regional
Age	Pliocene-Holocene	Cenozoic		Pliocene-Pleistocene	Pliocene-Pleistocene	Cenozoic
Fault with Displacement in Past 500,000 Years	documented (Machette, 1982)	none noted	none	nearby areas to west and east	nearby areas to west and south	none
Distribution	Common 2-5 mi spacing			widely spaced	widely spaced	
Minimum Distance	1-2 mi			5-12 mi	6-12 mi	
Seismic Activity/Risk	$\geq$ moderate	moderate to high	moderate	$\geq$ moderate	$\geq$ moderate	moderate
Terrestrial Heat Flow	moderate to high	high to moderate	moderate	moderate to high	moderate	moderate
Volcanic Activity	Albuquerque Volcanoes basalt center 0.2 m.y. (1-6 mi)	Cabezon Neck, basaltic center 2.5 m.y. (4-5 mi)	none	none	none	Eagle Tail Mtn. basaltic center 2-4 m.y. (9 mi)
HAZARDS Distance to escarpments	>1 mi	>1 mi	>1 mi	>8 mi	>5 mi	1 mi
Mass Wasting	none	Noted on slopes of Mesa Prieta (>1 mi)	Noted on slopes of Huerfano Peak (>1 mi)	none	none	Noted on slopes of Park Plateau escarpment >1 mi
Land Subsidence	none	none	none	none	none	none
Earth Fissures	none	none	none	none	none	none
MINERAL AND ENERGY RESOURCES						
Oil and Gas	no producers nearby	no producers nearby	present	no producers nearby	no producers nearby	no producers nearby
Wells	recent tests	early tests	4 producers	recent tests	early tests	early tests
Resource Potential	probable	possible	excellent	possible	possible?	possible?
Coal	none	none	none	none	none	mining at Koehler (3 mi)
Uranium	none	possible	none	none	none	none
Geothermal Energy	possible?	possible	none?	possible?	probable	none
Metals	none	none	none	none	none	none
Industrial Minerals	?	clay (shale)	none	none	clay	clay (shale, marl)
Aggregate Materials	sand and gravel	none?	none?	none?	sand and gravel	none?

TABLE 6. HYDROGEOLOGIC FEATURES AT POSSIBLE SITES FOR LOW-LEVEL WASTE DISPOSAL

SITE NUMBER	1	2	3	4	5	
SITE NAME	L. de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
GENERAL SUBSURFACE CONDITIONS	"Type II" unit: unconfined basin-fill aquifer below very thick vadose zone; few deep wells	"Type I" unit: thick marine shale; no major aquifer, "Dry hole" near Site (15/2/3.43).	"Type III" unit: fine-grained continental rocks over deep, confined sandstone aquifer no well	"Type II" unit: thin unconfined basin-fill aquifer below thick vadose zone; 1 well	"Type II" unit: no known aquifer below thick clay-rich vadose zone "Dry hole" near Site (25/8/6.22).	"Type I" unit: thick marine shale, no major aquifer present; no well on site
UNSATURATED ZONE (VADOSE ZONE)	area >200 mi^2	partly-saturated shale	area >50 mi^2	area ~25 mi^2	area >100 mi^2	partly-saturated shale
Thickness Range (ft)	800-1000	thin?	300-500	500-700	~300	thin?
Stratigraphic Units	Santa Fe Group	thin valley-fill alluvium/Mancos Shale	thin eolian and alluvial deposits/ Nacimiento Fm.	Santa Fe Group, with thin alluvial and eolian veneer	Santa Fe Group (upper), with thin eolian veneer	thin pediment and valley-fill alluvium/ Pierre Shale
Lithologic Character	interbedded sand, clay, and silt; with some gravel in upper 200 ft	shale, with siltstone, mudstone, and thin sandstone, sand and clay	shale, with lenticular sandstone beds, and thin loamy sand deposits	interbedded sand, silt, and clay; with gravelley zones in upper 300 ft	clay, with some interbedded sand	shale, with marl, limestone and siltstone, and thin sand and clay
Geochemical Properties	montmorillonitic clay, zeolitic? silt and sand	montmorillonitic shale, locally saline	montmorillonitic shale	montmorillonitic and zeolitic clay and silt; gypsiferous sand-clay	montmorillonitic and zeolitic clay and silt; gypsiferous clay-sand	montmorillonitic shale, locally saline
Hydrology						
Soil moisture	permantly deficient at depth in most areas; evapotranspiration high	as at Site 1	as at Site 1, local and transitory saturation zones below sand dune tracts	as at Site 1	as at Site 1	as at Site 1
Recharge	small size, limited to arroyos and playa basins	small size, limited to arroyos	small size, limited to arroyos and deep sand areas	small size, limited to arroyos	small size, limited to deeper deflation basins	small size, limited to arroyos
"Perched" Water tables	not noted	occur locally in basal valley fills and weathered shale zones	occur locally in sandstone lenses and basal alluvial fills	no noted	not noted	occur locally in basal valley fills and weathered shale zones
SATURATED ZONE-UNCONFINED AQUIFERS	major aquifer at great depth east of site	thick shale interval (see above)	limited to sandstone lenses below 300 ft	minor aquifer, thin, locally saline	minor aquifer at depth SW of site	thick shale interval (see above)
Stratigraphic Unit	Santa Fe Group		Nacimiento Fm.	Santa Fe Group	Upper Santa Fe	
Lithologic Character	interbedded sand, silt, clay and minor basalt	———	fine-grained sandstone	interbedded sand and clay	interbedded sand and clay	———
Geochemical Properties	fresh to slightly saline water; minerals as in vadose zone	———	fresh to slightly saline water	slightly saline water; minerals as in vadose zone	slightly saline to saline water; as in vadose zone	———
Water Table Depth (ft)	700-1000 slightly below Rio Grande level, rises steeply to west	———	discontinuous ~300	500-700	~300	———
Flow Dynamics	long southward flow path (subparallel to Rio Grande Valley)—25-50 mi to river	———	long northward flow path to San Juan River Valley—13-18 mi to river	long westward flow path to Rio Grande Valley—30-25 mi to river	long southward flow path to Rio Grande Valley—30-50 mi to river	———

TABLE 6 (continued)

SITE NUMBER	1	2	3	4	5	
SITE NAME	L. de Albuquerque	Prieta	Huerfano	Jornada	Desert	Koehler
SATURATED ZONE-CONFINED AQUIFERS Stratigraphic Unit	———	———	Important regional aquifer Ojo Alamo Ss	———	———	———
Lithologic Character	———	———	sandstone, with some siltstone and shale	———	———	———
Geochemistry	———	———	fresh water	———	———	———
Confining Beds	———	———	Nacimiento Fm	———	———	———
Piezometric Surface	———	———	400-500 ft depth	———	———	———
Flow Dynamics	———	———	northward to San Juan Valley	———	———	———

NEW MEXICO

LLW Generation

Facility	1979 Ft^3/Yr	1979 Mci/Yr	1979 Percentage (Volume)	1980 Ft^3/Yr	1980 Mci/Yr	1980 Percentage (Volume)
Medical	190	9	6.8	105	4.6	0
University	2,302.5	467.3	82.5	1,252.5*	12,784*	100
Industrial	300	83	10.7	0*	0*	0
TOTAL	2,792.5	559.3	100	1,357.5	12,788.6	100

* Does not include waste currently stored for future disposal.

Waste Forms, Radioisotopes

Licensee	Radioisotopes	Form	1980 Ft^3/Yr	1979 Ft^3/Yr
University of New Mexico	Xe-133, Ga-67, Se-75, In-111, Ni-63 I-131, I-125, H-3, C-14, Tl-201 I-123, S-35, Cr-51, Co-57, P-32, Ca-45, K-42, Tc-99, Fe-59, Co-60, Eu-152, Ra-226, Mo-99, Se-75, Rb-86	Solid or adsorbed liquid.	1,252.5	1,522.5
Interstate Industrial Laundry	Pu-238, Pu-239, Mixed fission products	Solid	0*	150
Eberline Instrument Corp.	Am-241, Sr-90, Co-60, Pu-238, Pu-239, Cr-137, Ba-133	Solids or adsorbed liquids in very small quantities	0	150
Presbyterian Hospital	I-125, Co-57, Cr-51, H-3	Solids or adsorbed liquids	105	190
TERA (Terminal Effects Research & Analysis Group, NMIMT)	Depleted Uranium	Solid	0*	780

* Does not include waste currently stored for future disposal.

NEW MEXICO

LLW Generation

Facility	1981 Ft^3/Yr	1981 Mci/Yr	1981 Percentage (Volume)	1982 Ft^3/Yr	1982 Mci/Yr	1982 Percent (Volum
Medical	0	0	0	0	0	0
University	1414.5	554.73	70	1313.9	460.17	70
Industrial	599.0	129.0	30	572.5	70.87	30
TOTAL	2013.5	683.73	100	1885.4	530.97	100

* Does not include waste currently stored for future disposal.

Waste Forms, Radioisotopes

Licensee	Radioisotopes	Form	1981 Ft^3/Yr	1982 Ft^3/Yr
University of New Mexico	Xe-133, Ga-67, Se-75, In-111, Ni-63 I-131, I-125, H-3, C-14, Tl-201 I-123, S-35, Cr-51, Co-57, P-32, Ca-45, K-42, Tc-99, Fe-59, Co-60, Eu-152, Ra-226, Mo-99, Se-75, Rb-86	Solid or adsorbed liquid.	1414.5	1313.9
Interstate Industrial Laundry	Pu-238, Pu-239, Mixed fission products	Solid	599	572.5
Eberline Instrument Corp.	Am-241, Sr-90, Co-60, Pu-238, Pu-239, Cr-137, Ba-133	Solids or adsorbed liquids in very small quantities		0*
Presbyterian Hospital	I-125, Co-57, Cr-51, H-3	Solids or adsorbed liquids	0	0*
TERA (Terminal Effects Research & Analysis Group, NMIMT)	Depleted Uranium	Solid	0	0*

● Does not include waste currently stored for future disposal.