San Juan Basin Action Plan

PALEONTOLOGY TECHNICAL REPORT

for the
Environmental Impact Statement on Public Service Company of New Mexico's Proposed New Mexico Generating Station and Possible New Town

United States
Department
of the Interior

Bureau of Land Management
New Mexico State Office
Santa Fe, New Mexico

October 1982

Report 9 of 22

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
NEW MEXICO STATE OFFICE
P.O. BOX 1449
SANTA FE, NEW MEXICO 87501

IN REPLY REFER TO
NM30840EIS
1792.73(934A)

October 1982

Dear Interested Citizen:

Attached is one of twenty-two technical reports developed as a basis for writing the Environmental Impact Statement on Public Service Company of New Mexico's Proposed New Mexico Generating Station and Possible New Town (NMGS EIS). (A list of the technical reports is attached.)

These technical reports provide detailed information on the existing environment, methods used for the impact analysis, and related data supportive of the analysis and conclusions presented in the EIS. These reports should be retained for use with the Draft and Final EIS and other documents related to BLM's San Juan Basin Action Plan (SJBAP).

The Draft NMGS EIS will be filed with the Environmental Protection Agency and released for public review on November 30, 1982. Comments on the Draft EIS will be due by close of business February 7, 1983, at the BLM New Mexico State Office. Because of the large volume of material presented in the technical reports, the BLM is distributing these reports in advance of the Draft EIS to provide sufficient time for public review. The technical reports will be available for public review at the places indicated on the attached list. Copies will also be available from the BLM New Mexico State Office, U.S. Post Office and Federal Building, Santa Fe, for a copy fee.

Informational public meetings are scheduled for December 1982 to provide a public forum to clarify questions and concerns about the SJBAP proposals and the related environmental documents, which will all have been issued by that time. The meetings are scheduled as follows:

- December 14, Civic Center, Farmington, 3 to 9 PM
- December 14, Convention Center, Albuquerque, 3 to 9 PM
- December 15, Chapter House, Crownpoint, 3 to 9 PM
- December 16, Holiday Inn, Gallup, 3 to 9 PM
- December 16, Kachina Lodge, Taos, 3 to 9 PM

In addition, formal public hearings will be held in January 1983 to solicit public comments on the SJBAP Proposals. These meetings are scheduled as follows:

- January 10, Chapter House, Crownpoint, beginning at 1:00 PM
- January 12, Civic Center, Farmington, beginning at 9:00 AM
- January 14 (and 15th if necessary because of the number of registrants), Four Seasons Motor Lodge, Albuquerque, I-40 and Carlisle Blvd., beginning at 9:00 AM (each day)

Questions on the public meetings, hearings, and the technical reports themselves should be directed to:

Leslie M. Cone
NMGS Project Manager
BLM, New Mexico State Office
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6184 FTS 476-6184

Sincerely yours,

Charles W. Luscher
State Director, New Mexico

List of Technical Reports

1. Purpose and Need
2. Project Description
3. Alternatives to the Project
4. Site Alternatives
5. Permit Reconnaissance
6. Air Quality
7. Geologic Setting
8. Mineral Resources
9. Paleontology
10. Soils, Prime and Unique Farmlands
11. Hydrology
12. Water Quality
13. Vegetation
14. Wildlife and Aquatic Biology
15. Threatened and Endangered Species
16. Cultural Resources
17. Visual Resources
18. Recreation Resources
19. Wilderness Values
20. Transportation
21. Social and Economic Conditions
22. Land Use Controls and Constraints

Availability of Technical Reports for Public Review

Individual copies of the technical reports can be obtained for a copy fee. Inquiries should be directed to:

Bureau of Land Management, New Mexico State Office
Title Records and Public Assistance Section (943B)
U.S. Post Office and Federal Building
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6107 FTS 476-6107

Copies of the reports are available for public review at the locations listed below. [Formal and informal cooperating agencies are denoted by an asterisk (*).]

BUREAU OF LAND MANAGEMENT OFFICES

New Mexico State Office

NMGS Project Staff (934A)
Room 122, Federal Building
Cathedral Place
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6184 FTS 476-6184

San Juan Energy Projects Staff (911)
Room 129, Federal Building
Cathedral Place
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6226 FTS 476-6226

Public Affairs Staff (912)
Room 2016
U.S. Post Office and Federal Building
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6316 FTS 476-6316

Division of Resources(930)
509 Camino de los Marquez, Suite 3
P.O. Box 1449
Santa Fe, NM 87501
(505) 988-6212 FTS 476-6212

Albuquerque District Office
3550 Pan American Freeway NE
P.O. Box 6770
Albuquerque, NM 87107
(505) 766-2455 FTS 474-2455

Farmington Resource Area Headquarters
900 La Plata Road
P.O. Box 568
Farmington, NM 87401
(505) 325-3581

Taos Resource Area Office
Montevideo Plaza
P.O. Box 1045
Taos, NM 87571
(505) 758-8851

Socorro District Office
198 Neel Avenue
P.O. Box 1219
Socorro, NM 87801
(505) 835-0412 FTS 476-6280

Las Cruces District Office
1705 N. Valley Drive
P.O. Box 1420
Las Cruces, NM 88001
(505) 524-8551 FTS 571-8312

Roswell District Office
1717 W. Second Street
P.O. Box 1397
Roswell, NM 88201
(505) 622-7670 FTS 476-9251

Carlsbad Resource Area Headquarters
114 S. Halagueno Street
P.O. Box 506
Carlsbad, NM 88220
(505) 887-6544

USDI, Bureau of Land Management
Division of Rights-of-Way (330)
18th and C Streets, NW
Washington, D.C. 20240
(202) 343-5441 FTS 343-5441

USDI, Bureau of Land Management
Denver Service Center (D-460)
Technical Publications Library
Denver Federal Center, Bldg. 50
Denver, CO 80225
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NEW MEXICO STATE AGENCIES

New Mexico State Environmental Improvement Division*
725 St. Michaels Drive
P.O. Box 968
Santa Fe, NM 87503
(505) 827-5217, ext. 2416

New Mexico Energy and Minerals Department*
525 Camino de los Marquez
P.O. Box 2770
Santa Fe, NM 87503
(505) 827-3326

New Mexico Historic Preservation Bureau*
State Historic Preservation Officer
505 Don Gasper Avenue
Santa Fe, NM 87503
(505) 827-2108

New Mexico Natural Resource Department*
Villagra Building
Santa Fe, NM 87503
(505) 827-5531

New Mexico Public Service Commission*
Bataan Memorial Building
Santa Fe, NM 827-3361
(505) 827-3361

New Mexico State Engineer's Office*
Bataan Memorial Building
Santa Fe, NM 87503
(505) 827-2423

New Mexico State Planning Office*
505 Don Gasper Avenue
Santa Fe, NM 87503
(505) 827-5191

OTHER ORGANIZATIONS

Public Service Company of New Mexico
Alvarado Square
P.O. Box 2268
Albuquerque, NM 87158
(505) 848-2700

Woodward-Clyde Consultants, Inc.
3 Embarcadero Center, Suite 700
San Francisco, California 94111
(415) 956-7070

PUBLIC AND UNIVERSITY LIBRARIES

Reading copies of the NMGS EIS and associated technical reports will be available at the following public and university libraries:

State and Public Libraries

Albuquerque Public Library
501 Copper Avenue NW
Albuquerque, NM 87102

Aztec Public Library
201 W. Chaco
Aztec, NM 87401

Crownpoint Community Library
c/o Lioness Club, P.O. Box 731
Crownpoint, NM 87313

Cuba Public Library
Box 5, La Jara
Cuba, NM 87027

Farmington Public Library
302 N. Orchard
Farmington, NM 87401

Gallup Public Library
115 W. Hill Avenue
Gallup, NM 87301

Mother Whiteside Memorial Library (Public)
525 W. High Street
P.O. Box 96
Grants, NM 87020

New Mexico State Library
325 Don Gaspar Avenue
Santa Fe, NM 87503

OTHER DEPARTMENT OF THE INTERIOR AGENCIES

Bureau of Indian Affairs*
Albuquerque Area Office
123 4th Street
P.O. Box 2088
Albuquerque, NM 87198
(505) 766-3374 FTS 474-3374

Bureau of Indian Affairs*
Eastern Navajo Agency
P.O. Box 328
Crownpoint, NM 87313
(505) 786-5228

Bureau of Indian Affairs*
Navajo Area Office
Box M - Mail Code 305
Window Rock, AZ 86515
(602) 871-5151 FTS 479-5314

Bureau of Reclamation*
Upper Colorado Regional Office
125 S. State Street
P.O. Box 11568
Salt Lake City, UT 84147
(801) 524-5463 FTS 588-5463

Minerals Management Service*
South Central Region
505 Marquette Avenue NW, Suite 815
Albuquerque, NM 87102
(505) 766-1173 FTS 474-1173

Minerals Management Service*
Resource Evaluation Office
411 N. Auburn
Farmington, NM 87401
(505) 327-7397 FTS 572-6254

National Park Service*
Southwest Regional Office
1100 Old Santa Fe Trail
Santa Fe, NM 87501
(505) 988-6375 FTS 476-6375

National Park Service*
Environmental Coordination Office
Pinon Building, 1220 St. Francis Drive
P.O. Box 728
Santa Fe, NM 87501
(505) 988-6681 FTS 476-6681

U.S. Fish and Wildlife Service*
Field Supervisor, Ecological Services
3530 Pan American Highway, Suite C
Albuquerque, NM 87107
(505) 766-3966 FTS 479-3966

U.S. Geological Survey (WRD)*
505 Marquette Avenue, Room 720
Albuquerque, NM 87101
(505) 766-2810 FTS 474-2817

OTHER FEDERAL AGENCIES AND ORGANIZATIONS

Environmental Protection Agency*
Region VI
1201 Elm Street
Dallas, TX 75270
(214) 767-2716 FTS 729-2716

Navajo Tribe*
c/o Division of Resources
P.O. Box 308
Window Rock, AZ 86515
(602) 871-6592

Pueblo of Zia*
General Delivery
San Ysidro, NM 87053
(505) 867-3304

Soil Conservation Service*
424 N. Mesa Verde
Aztec, NM 87410
(505) 334-9437

U.S. Corps of Engineers*
P.O. Box 1580
Albuquerque, NM 87103
(505) 766-2657 FTS 474-2657

USDA, Forest Service*
717 Gold Avenue
Albuquerque, NM 87102
(505) 474-1676 FTS 474-1676

USDA, Forest Service*
District Ranger
Mt. Taylor Ranger District
201 Roosevelt Avenue
Grants, NM 87020
(505) 287-8833

Harwood Foundation Library
(Public)
25 LeDoux
P.O. Box 766
Taos, NM 87571

University/College Libraries

University of New Mexico
General Library
Albuquerque, NM 87131

Navajo Community College Library
Shiprock Branch
P.O. Box 580
Shiprock, AZ 87420

Northern New Mexico Community College
P.O. Box 250
Espanola, NM 87532

New Mexico State University
San Juan Campus
4601 College Blvd.
Farmington, NM 87401

University of New Mexico, Gallup Campus
Learning Resources Center
200 College Road
Gallup, NM 87301

New Mexico State University/Grants
1500 Third Street
Grants, NM 87020

New Mexico Highlands University
Donnelly Library
National Avenue
Las Vegas, NM 87701

College of Santa Fe
Fogelson Memorial Library
St. Michaels Drive
Santa Fe, NM 87501

PALEONTOLOGY TECHNICAL REPORT

for the

Environmental Impact Statement on Public Service Company of New Mexico's Proposed New Mexico Generating Station and Possible New Town

Prepared by

Woodward-Clyde Consultants

for the

U.S. Department of the Interior Bureau of Land Management

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MAPS AND FIGURES

NEW MEXICO GENERATING STATION

SUMMARY

Public Service Company of New Mexico proposes the development of a power plant, transmission lines, and cooling-water pipelines in northwestern New Mexico. A study was undertaken to assess the potential effects this project may have on the paleontological resources of the general area.

The proposed development lies in the midst of a region known for 120 years to be rich in significant paleontological materials. Intensive study of this region is currently underway by paleontologists from across the United States. Large numbers of significant fossils have been collected from this area in the past, and more are expected to be recovered in the future.

In parts of the study area adverse disturbances to paleontological resources can be expected to result from the proposed development. As an aid to development planning, the study area was classified into zones of high, moderate, or low sensitivity of paleontological resources to adverse effects from the proposed development. Both direct and indirect impacts are expected to occur in areas designated to be of high and moderate sensitivity. Most impacts could be adequately mitigated. However, mitigation measures may not be adequate to alleviate impacts expected to result from construction and operation of transmission line corridor T1 and pipeline corridor P3, and substantial losses of significant paleontological data may result from these proposed project elements.

1.0
INTRODUCTION

BACKGROUND

Included in the recent Council on Environmental Quality Regulations (1979) are several important objectives to reduce excessive paperwork in the preparation of environmental impact statements (EISs):

- Discuss only briefly issues other than significant ones.
- Emphasize the portions of the EIS that are useful to decision makers and the public and reduce emphasis on background material.
- Prepare analytic rather than encyclopedic EISs.

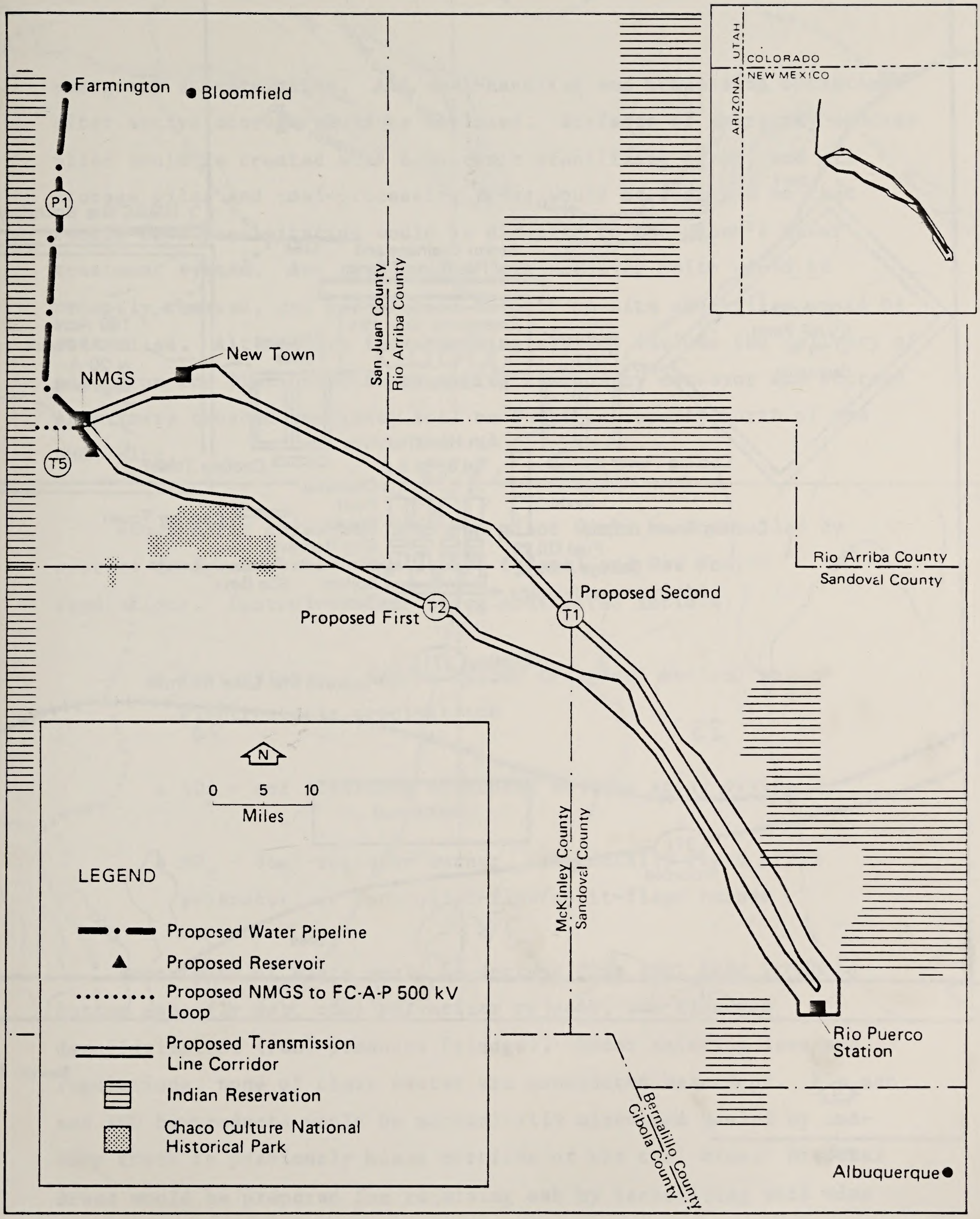
In order to accomplish these objectives and still provide the depth and background required for an analytic impact statement, this technical report has been prepared for the New Mexico Generating Station (NMGS) project. In this report, impacts that were not identified as significant but which are still considered important by the public or technical specialists are analyzed. Background material is provided for those issues and impacts that were considered necessary for the comparison of alternatives. Impacts that were not identified as significant or important by the public and by technical preparers are summarized, and reasons for their elimination from detailed analysis are discussed.

SUMMARY DESCRIPTION OF PROJECT COMPONENTS

Public Service Company of New Mexico (PNM) proposes to construct a 2000-megawatt (MW) coal-fired electric generation plant approximately 35 miles south of Farmington, New Mexico, in San Juan County (Map 1-1). The proposed NMGS, at ultimate development, would have four 500-MW generating units. Each generating unit would include a turbine generator area, coal pulverizer area, boiler area, particulate removal system, SO_2 removal system, and chimney stack. The proposed arrangement of these and other power plant components is shown in Figure 1-1. For the environmental analysis, it was assumed that commercial operation of the first 500-MW unit would begin in 1990 and that other units would start operating during the 1990s.

Coal for NMGS would be acquired through long-term contracts with Sunbelt Mining and Arch Minerals (Proposed Action) or other producers in the San Juan Basin (alternative coal supply). Coal acquired from a joint venture of Sunbelt and Arch Minerals would be supplied from surface mines (referred to as the Bisti mine in this analysis) in the immediate vicinity of the proposed plant site. Coal acquired from other producers in the San Juan Basin would be hauled from mines located as much as 30 miles from the proposed plant site. Coal required for NMGS would average 7.5 million tons per year, or a total of 300 million tons over the 40-year project life.

The proposed fuel-handling system would involve hauling coal from the Bisti mine (or other mine locations) by truck to a receiving facility located adjacent to the NMGS site. Coal would then be transferred via conveyor belt from the receiving station to active or



Note: For more information, see the location maps in Appendix G of the EIS.

Source: BLM 1982.

Map 1-1. GENERAL LOCATION OF PROPOSED ACTION

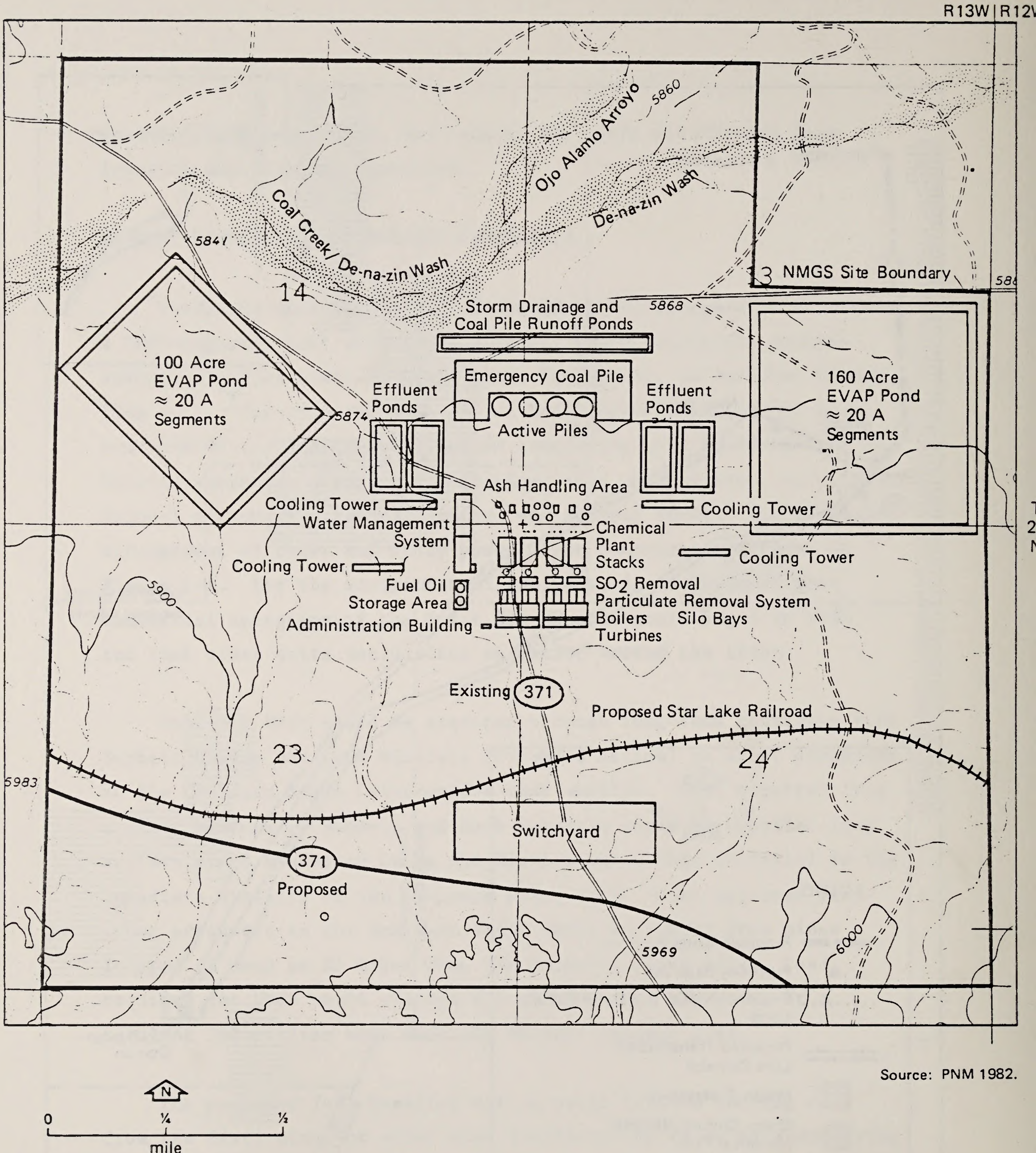


Figure 1-1. STATION LAYOUT

emergency storage piles. All coal-handling and processing operations after active storage would be enclosed. Surfaces of emergency storage piles would be treated with a nontoxic stabilizing agent, and all storage piles and coal-processing areas would be designed so that runoff from precipitation would be diverted to the plant's water treatment system. Any coal spills from conveyor belts would be promptly removed, and percolation beneath on-site stockpiles would be controlled. Alternative fuel-handling systems include the delivery of coal from the Bisti mine to receiving station by conveyor and storage of primary crushed emergency coal on Sunbelt property north of the NMGS site.

Atmospheric emissions from the plant would be controlled by systems designed to meet applicable federal and New Mexico regulations. Control systems being considered include:

- Particulates - fabric filter (Proposed Action) and electrostatic precipitator

- SO_2 - wet limestone scrubbing or lime spray drying

- NO_x - dual-register burner, tangentially fired steam generator, or controlled-flow/split-flame burner

Four types of waste would be derived from coal used in NMGS: bottom ash, fly ash, coal pulverizer rejects, and flue gas desulfurization (FGD) products (sludge). Under existing laws and regulations, none of these wastes are considered hazardous. Fly ash and FGD by-products would be mechanically mixed and hauled by end-dump truck to previously mined portions of the coal mine. Disposal areas would be prepared for receiving ash by backfilling with mine overburden. Ash would then be dumped and spread in layers over the mine overburden. After the ash was placed and spread, it would be covered with layers of overburden and surface soil or topsoil and then a vegetative cover would be established. Bottom ash and pulverizer rejects would be collected for disposal in dewatering bins and then hauled by end-dump trucks for disposal into previously mined portions of the coal mine. Procedures for disposal would be the same as for fly ash.

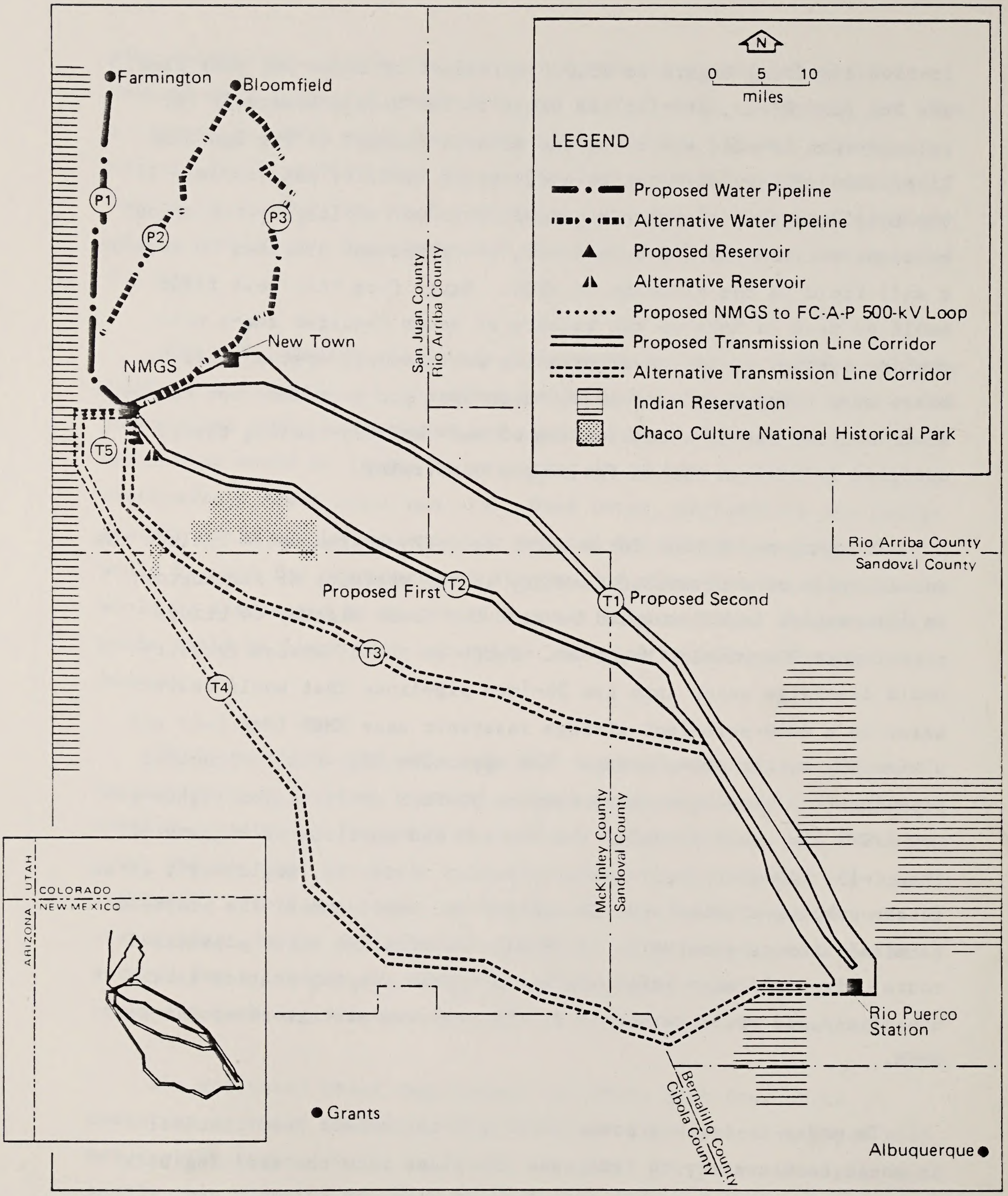
The water management system would contain all equipment necessary to treat and supply all the plant makeup water and potable water. The power plant would be designed and operated as a zero-discharge plant; wastewater would be reused by cascading it to uses requiring successively lower water quality. Used water, degraded to the extent that it could not be economically treated for further in-plant use, would be used for transport and disposal of plant-generated wastes or would be discharged to evaporation ponds (Figure 1-1). Evaporation ponds would be lined with impervious material to limit seepage losses.

Water supplies available for NMGS are believed to be sufficient to construct an all-wet heat-rejection system, based on evaporative cooling, and to use forced-draft cooling towers (Figure 1-1). Cooling-tower makeup water would be drawn from the nearby raw-water storage reservoir. The makeup water would replace the tower losses from evaporation, drift, and blowdown. If sufficient water could not be secured for a totally evaporative system, a water-cooling system employing both dry and conventional wet towers might be required.

The estimated water requirement for NMGS, with four units operating at rated capacity and a heat-rejection system equipped with wet-cooling towers, would be 35,000 acre-feet per year. In order to supply this quantity of water to NMGS, the Proposed Action would involve acquiring rights to 35,000 acre-feet of water per year from the San Juan River, storing the water in the Navajo Reservoir for release upon demand, and using the natural channel of the San Juan River for delivery of water to a diversion facility downstream. If the total quantity of water required for a wet-cooling system cannot be acquired from the San Juan River, the applicant proposes to develop a well field in the vicinity of NMGS. Water from this well field would be used to make up the balance of water required for a wet-cooling system. A second alternative water supply system would be based on a total supply of 20,000 acre-feet per year from the San Juan River and the use of a combination of wet- and dry-cooling towers designed to perform within the supply constraint.

The Proposed Action for a water delivery system would include the construction of a diversion facility in the vicinity of Farmington; an alternative location would be near the State Highway 44 bridge crossing at Bloomfield (Map 1-2). Pumps at the diversion facility would discharge water into two 36-inch pipelines that would deliver water to a 4000-acre-foot storage reservoir near NMGS (Map 1-1) and ultimately to the power plant. The approximately 40-mile proposed pipeline (P1) would generally require 90-foot construction rights-of-way (ROW) and would parallel the new and old portions of Highway 371 (Map 1-1). An alternative water pipeline route, P2, would begin at an intake pumping station near Bloomfield and would end at the proposed terminal storage reservoir. A 49-mile alternative water pipeline route, P3, would also originate at an intake pumping station near Bloomfield and would terminate at the proposed storage reservoir near NMGS.

In order to deliver power from NMGS to various load centers, it would be necessary to integrate the plant into the existing bulk



Note: For more information, see the location maps in Appendix G of the EIS.

Source: BLM 1982.

Map 1-2. GENERAL LOCATION OF ALTERNATIVES INCLUDING THE PROPOSED ACTION transmission systems of PNM and neighboring utilities. Thus the proposed transmission system would consist of a 500-kilovolt (kV) loop linking NMGS with PNM's approved 500-kV Four Corners-Ambrosia-Pajarito (FC-A-P) line, located approximately 5 miles west of NMGS, and two 500-kV lines linking NMGS with the Albuquerque distribution and load center at the proposed Rio Puerco Station (Map 1-1). The NMGS-Albuquerque system would be installed in phases: the 500-kV loop in 1990 with commencement of commercial operation of Unit 1, the first 500-kV line with Unit 2 in 1993, and the second 500-kV line with Unit 4 in 1998.

Four routes are considered technically and economically feasible for construction of the 500-kV transmission system. Route T2 is proposed for the first 500-kV line and route T1 is proposed for the second 500-kV line; routes T3 and T4 are alternatives to the Proposed Action. The total distance traversed would be similar for the two proposed and two alternative corridors: 101 miles (T2), 107 miles (T1), 105 miles (T3), and 126 miles (T4). With the exception of tower sites, the proposed 200-foot ROW could support other compatible land uses, such as grazing. PNM would keep the transmission line ROW closed and would patrol the line by helicopter each month. Lands disturbed by heavy equipment and temporary access roads would be restored to their original condition.

Table 1-1 displays construction work force estimates over time. Construction employment for station facilities would reach peaks of 1515 employees in 1987 and 1530 employees in 1992. Operations employment at station facilities would increase steadily, from 30 employees in 1989 to 900 employees in 1999 when all four units are expected to be on-line.

Table 1-1. NMGS CONSTRUCTION AND OPERATION EMPLOYMENT

			NMGS											
			Construction					Operation						
Year	Intake Pipeline and Reservoir	500-kV Transmission Line	Unit 1	Unit 2	Unit 3	Unit 4	Total	Unit 1	Unit 2	Unit 3	Unit 4	Total	Total Employment	Annual Change
1985	—	—	85	—	—	—	85	—	—	—	—	—	85	+85
1986	—	—	800	—	—	—	800	—	—	—	—	—	800	+715
1987	115	—	1515	—	—	—	1630	—	—	—	—	—	1630	+830
1988	295	104	1180	30	—	—	1505	—	—	—	—	—	1505	-125
1989	—	—	360	450	—	—	914	30	—	—	—	30	944	-560
1990	—	—	100	940	40	—	1080	200	—	—	—	200	1280	+336
1991	—	—	—	750	570	—	1320	250	—	—	—	250	1570	+290
1992	—	—	—	270	1260	—	1530	250	24	—	—	274	1804	+234
1993	—	—	—	105	955	30	1090	250	160	—	—	410	1500	-304
1994	—	78	—	—	325	435	838	250	200	30	—	480	1318	-182
1995	—	—	—	—	90	940	1030	250	200	200	—	650	1680	+362
1996	—	—	—	—	—	775	775	250	200	250	—	700	1475	-205
1997	—	—	—	—	—	255	255	250	200	250	24	724	979	-496
1998	—	—	—	—	—	95	95	250	200	250	160	860	955	-24
1999	—	—	—	—	—	—	0	250	200	250	200	900	900	-55

Source: PNM 1980, unpublished data.

According to PNM (unpublished data, 1980), estimated construction employment skill requirements would be as follows:

Skill	Percent of Total Construction Work Force
Boilermakers	9.4
Pipefitters	14.2
Electricians	14.4
Carpenters	5.6
Ironworkers	10.0
Operators	10.0
Laborers	9.0
Teamsters	4.1
Cement masons	0.8
Millwrights	3.3
Insulators	4.0
Sheetmetal workers	1.1
Painters	1.2
Others	0.5
Supervision	12.4

The above estimates are averaged for construction of all four units.

SAN JUAN BASIN ACTION PLAN OVERVIEW AND RELATIONSHIP OF THE NMGS EIS TO ACTIONS INCLUDED IN THE PLAN

The proposed site for the NMGS is located in the San Juan Basin of northwestern New Mexico. The Bureau of Land Management (BLM) is responsible for the management of much of the land and mineral resources in this area, and currently has six separate but interrelated proposals under consideration within the basin. In order to respond to these, the BLM has developed a San Juan Basin Action Plan (SJBAP). This plan provides for the organizational arrangements whereby the environmental analyses and decision making can be implemented in a timely and efficient manner. The plan describes the process for preparation of three site-specific EISs (including the NMGS EIS) and three Environmental Assessments (EAs):

- Coal Preference Right Lease Applications (EA)
- San Juan River Regional Coal Leasing (EIS)
- Wilderness Study Areas (WSAs) (EIS)
- New Mexico Generating Station (EIS)
- Ute Mountain Land Exchange (EA)
- Bisti Coal Lease Exchange (EA)

In addition to these documents, the action plan provides for the preparation of a Cumulative Overview (CO). The CO is intended to focus on the cumulative impacts that would result from the proposed actions analyzed in the EISs and EAs listed above and therefore to facilitate public review and decision making. As a result of this organization, the impact analysis in the NMGS EIS and technical background reports concentrates on the impacts expected to result from the specific NMGS components proposed. The cumulative impacts expected to result from the proposed NMGS, in addition to the cumulative impacts of other proposals to be developed in the same time period, are described in the CO.

BASELINE CONDITIONS ASSUMED FOR THE NMGS TECHNICAL REPORT IMPACT ANALYSES

The site-specific impact analysis for this technical report was based on the affected environment and available resources that would be existing at the time of construction and operation of the NMGS facility. Since construction at the NMGS facility would not begin until 1985, certain assumptions regarding project development in the San Juan Basin were necessary. Two levels of project development were considered, along with criteria for each, in developing a status for the various non-SJBAP actions proposed for the San Juan Basin area.

- Baseline 1 - The projects considered in this level of development are those that have approval and are to be built or under construction in 1985. This level represents the projected existing environment without the proposals included in the SJBAP.

- Baseline 2 - The projects considered in this level are in some phase of the application stage. In this level, Baseline 1 projects are added to any projects in Baseline 2 along with any revision in resource production or uses (e.g., coal).

Where differences in Baselines 1 and 2 affect the results of impact analyses, discussion is provided. If no differences are identified, it should be assumed that consideration of the two different baselines did not alter the impact analyses.

A complete list of projects and comprehensive location maps for Baselines 1 and 2 are provided in Appendix C of the NMGS EIS.

ORGANIZATION OF THE REPORT

Section 2.0 of this technical report describes the assumptions and methodological approach used in the assessment of potential impacts of the Proposed Action on the affected environment. In addition, Section 2.0 contains a definition of the study area and identification of data sources.

Section 3.0, Affected Environment, contains baseline data on existing conditions in the study area, as well as projections of future conditions without the Proposed Action. Information on historical trends is presented where it is useful in providing a basis for predicting most likely future trends. The description of projected future trends takes into consideration the changes in the environment that are expected to occur as a result of the projects identified in Baseline 1. This provides a reasonable estimate of the future existing environment against which the potential impacts of the Proposed Action and alternatives can be assessed.

Section 4.0 describes the potential effects of implementing the Proposed Action and alternatives. Impacts identified are measured against indicators of significance in order to estimate the importance of the impact to the affected human environment. (Potential impacts associated with alternatives to the Proposed Action are compared in Section 9.0.)

In Section 5.0, mitigation measures are suggested. These measures would help to alleviate the potentially significant adverse impacts or enhance the beneficial impacts identified in the Section 4.0 analysis. Those potentially adverse impacts for which no appropriate mitigation measures have been suggested are discussed in Section 6.0 as "unavoidable adverse impacts."

BACKGROUND AND OVERVIEW FOR PALEONTOLOGICAL RESOURCES

The proposed development is centered in the midst of a region that has been known for more than 120 years to contain rich deposits of highly important paleontological resources (e.g., Simpson 1981). Aspects of the paleontology of this region are currently the subject of intensive research by professional paleontologists from across the United States (Lucas, Rigby, and Kues 1981). The results of their investigations have had, and promise to continue to have, major impact on paleontological research around the world.

In order to assess the potential effects that the proposed development may have on the paleontological resources of the region, a paleontological review study, reported here, was commissioned. The purposes of this study were:

- To document the occurrence of fossils in the study area by gathering, summarizing, and evaluating pertinent data collected by other paleontologists
- To determine the importance of the study area to ongoing paleontological research
- To evaluate the reliability of previous work and fill any major data gaps by conducting a limited field survey
- To identify potential disturbances to the identified paleontological resources that could result from the proposed development
- To develop recommendations and approximate procedures to mitigate the identified disturbances

- To prepare a report summarizing the results of this study, which would serve as an aid in development planning

Preliminary research for this study was carried out in February and March 1981. Fieldwork and preparation of this report were carried out between November 15, 1981, and January 15, 1982.

PERSONNEL

This study was directed by Mr. Timothy Rowe. Mr. Rowe is a professional paleontological consultant who has been supervising predevelopment paleontological assessment studies in northwestern New Mexico and other parts of the western United States since 1974. Mr. Rowe has an A.B. degree (Geology/Biology) from Occidental College and an M.S. degree (Anatomy/Paleontology) from the University of Chicago, and has published a number of scholarly research papers on fossils, including several concerning the paleontology of northwestern New Mexico. Mr. Rowe was assisted in this study by Dr. E. Bruce Lander and Ms. Roseanne C. Perman. Dr. Lander has a B.S. degree (Geology) from the University of California, Los Angeles, and M.A. and Ph.D. degrees (both in Paleontology) from the University of California, Berkeley. Dr. Lander has published a number of scholarly research papers on aspects of paleontology and has been involved in two previous predevelopment paleontological assessment studies. Ms. Perman has two A.B. degrees (Geography and Earth Sciences) from the University of California, Berkeley. She is currently a Senior Staff Geologist with Woodward-Clyde Consultants of San Francisco and a graduate student in the Department of Paleontology, University of California, Berkeley. Ms. Perman has been involved in two previous predevelopment paleontological assessment studies. Dr. Ruthann Knudson, Senior Project Scientist with Woodward-Clyde Consultants, served as Paleontology Task Leader. Dr. Knudson has B.A., M.A., and

Ph.D. degrees in anthropology, with emphasis in prehistoric archaeology and Quaternary studies (geology, soils, ecology) and has been involved in previous paleontological impact assessments.

NATURE AND OCCURRENCE OF PALEONTOLOGICAL RESOURCES

Paleontological resources consist of the fossilized remains and evidence of ancient life forms. Fossils include the mineralized remains of organic tissues such as bone, shell, wood, and plant materials. Fossils also include impressions left by organisms in rock. These impressions, known as "trace fossils," include footprints, worm trails, and other indirect evidence of ancient organisms.

Fossils are formed after organic materials or their traces are buried by sediments. As the sediments harden and turn to rock, the organic material is replaced by minerals and becomes fossilized. Fossils are generally discovered when some part becomes exposed at the surface of the earth, usually by natural erosion, and can thus be seen by a person walking in their general vicinity. With the exception of gathering pollen samples, only in unusual circumstances are fossils deliberately recovered by digging into ground whose surface is free of fossils. Such digging is usually initiated on account of predictions made from known fossil occurrences in adjacent regions.

Fossils may occur in any type of sedimentary rock, that is, in any rock formed by the natural accumulation of solid fragmental material, chemical precipitation from solution, or secretion by organisms. Only in extremely unusual circumstances do fossils occur in other types of rock.

Within sedimentary rocks the occurrence of fossils is highly variable. Their presence depends on historical events such as the life and death of organisms, burial, fossilization, and natural erosion that exposes fossils for possible discovery. Relevant variables include the abundance of organisms in life, the climatic environment in which they lived, the chemical and sedimentary environment in which they were buried, and the precise nature of the erosion that exposed the fossil. Thus, although the depositional environment in which a rock was formed contained abundant life before and during sedimentation, later events determine whether the rock will contain abundant and well-preserved fossils or be barren of fossils. Fossils are rarely distributed homogeneously throughout an entire geologic formation. Instead, they tend to occur in restricted layers, lenses, or as isolated specimens separated from one another by expanses of barren rock.

In prospecting for fossils in the field, one must carefully examine exposures of sedimentary bedrock. Fossils found in place in bedrock have the highest potential scientific value because they are generally far more complete and less damaged than fossils that have weathered out onto alluvial plains or into stream channels. Most fossils are extremely fragile. Weathering and any subsequent transport tend to cause them to fracture into small unidentifiable fragments. In addition, fossils that have been transported from their original place of burial and fossilization have generally lost all information concerning their geologic and paleoecological (ancient ecological) context. Fossils found in place in bedrock can be examined relative to the local geologic setting and to other fossil animals and plants from the same geologic horizon, permitting their paleoecology to be reconstructed. Therefore, while fossils are occasionally found in areas other than bedrock, such finds are generally of little or no scientific value.

A basic goal of all paleontologists is to develop a thorough understanding of the evolutionary history of life. However, collecting techniques and methods of study vary considerably among paleontologists, depending on the particular group of organisms under study. Three major disciplines are generally recognized, each requiring somewhat different techniques. These are vertebrate paleontology, invertebrate paleontology, and paleobotany (including paleopalynology, the study of fossil pollen and spores).

Vertebrate paleontologists study the fossilized remains of animals with backbones (fish, amphibians, reptiles, birds, mammals). They can recover valuable information from most identifiable specimens assignable to their group of interest or that occur in their geographic area of interest. This does not mean, however, that every vertebrate specimen will prove scientifically valuable. Unidentifiable scraps, specimens lacking locality data, and poorly preserved specimens are generally of little or no research use. Furthermore, in certain abundantly preserved and well-studied groups additional specimens may offer little information that cannot be obtained from specimens in existing museum collections. Nevertheless, vertebrate fossils are comparatively rare, their occurrences restricted, and, in general, each vertebrate specimen should be considered as having potential scientific value until a contrary opinion is voiced by a trained paleontologist.

A variety of techniques for recovering vertebrate fossils are necessary to accommodate the wide size range of the fossils and their highly varied occurrence in the field. At one extreme, screen washing of large quantities of raw rock matrix (e.g., McKenna 1965) is used to recover very small fossils. Teeth smaller than the head of a pin have been recovered in abundance in this way. At the other extreme, large-scale quarrying with heavy machinery is required for the recovery of large fossils such as dinosaurs. A pertinent example is the recovery of a skull and partial skeleton of the dinosaur Pentaceratops by the

Museum of Northern Arizona in 1977 (Rowe, Colbert, and Nations 1981) from the Fruitland Formation, just a few miles from the present study area. The skull alone measured about 6 feet in length and weighed more than 5000 pounds. Excavation required more than 80 workdays and the use of a crane. Further discussions of techniques and costs of collecting vertebrate fossils in northwestern New Mexico are presented by Miller, Tidwell, and Petersen (1979).

Invertebrate paleontologists study organisms that produce hard shells (e.g., snails, clams, corals). The majority of these organisms are aquatic, living in oceans and fresh-water bodies, and they tend to exist in relatively high abundance. In favorable environments their remains are fossilized in great abundance and often occur over wide geographic areas. The size range of invertebrate organisms is small compared to that of vertebrates, and they rarely require the elaborate and time-consuming techniques necessary for collecting vertebrate fossils. Most single invertebrate specimens can be collected with less than an hour or two of labor. Many studies of invertebrates involve the recovery of only a small percentage of the potentially recoverable fossils in a given area, in contrast to the typical situation faced by the vertebrate paleontologist to whom nearly every specimen may prove important. Although invertebrate paleontologists could cite exceptions to these generalizations, they do describe the typical situation encountered in the study area. Miller, Tidwell, and Petersen (1979) present further discussion of costs and techniques related to collecting invertebrate fossils in the general vicinity of the study area.

Studies of ancient plant life are based on two more or less distinct lines of evidence. The first comes from plant megafossils, which include leaf and stem impressions and petrified wood. Collecting large petrified wood specimens can be difficult and time consuming, but studies of this material usually involve extensive field observation and collection of only small samples for laboratory examination. Leaf and stem impressions are generally less than 1 square meter in size. At some localities large quarries have been opened to recover adequate samples, but more often specimens can be recovered with little expenditure of time and relatively unspecialized collecting tools (see Miller, Tidwell, and Petersen [1979] for further discussion).

Fossil pollen and spores (plant microfossils) are the second major line of evidence used in studying fossil plants. In non-oxidizing environments they occur in great abundance over wide areas. Samples are obtained by processing small quantities of rock, usually less than 1 kilogram per sample, from accurately measured sections. Samples may be taken from field exposures of bedrock or from drilling cores.

In general, sedimentary rocks deposited by rivers and streams (i.e., continental sediments) have the highest potential for yielding vertebrates, plant mega- and microfossils, and locally abundant invertebrate fossils. Marine sediments generally contain invertebrates, often in great abundance, plant microfossils, and relatively rare vertebrate fossils.

[illegible]

[illegible] the study area.

Studies [illegible] based on the [illegible] [illegible] which [illegible] Polluting large [illegible]

2.0

FRAMEWORK FOR ANALYSIS

GEOGRAPHIC AREA OF INFLUENCE

Direct and indirect disturbances, or impacts, to paleontological resources are expected to result from the proposed development. Direct impacts, as used here, consist of any disturbances to fossils resulting from actual construction activities and that occur more-or-less instantaneously at the time of construction. Most direct impacts, for example, will result from bedrock disturbances by heavy machinery during construction. Direct impacts can affect fossils located at the surface and below the surface to the depth of bedrock disturbance. Direct impacts would occur in areas where direct ground-disturbing impacts take place, including construction zones for the plant facilities, for the water supply and transmission systems, and for the long-term operation and maintenance of the new facilities (including access roads).

Indirect impacts are defined as secondary disturbances to fossils that occur after construction. Typically these occur as a result of increased human access and activity, or from routine operation of the new development. They may occur intermittently or continuously over a long period of time. Off-road vehicle traffic and fossil collecting by amateurs are probably the most common types of indirect impact. The geographic area of influence defined for indirect impacts is the area considered to be the recreation resource base, or those activity areas considered to be a reasonable day's drive (50-100 miles one way) from the major communities of residence.

Not all impacts are necessarily detrimental. Bedrock disturbance can lead to the creation of new exposures that, in turn, can lead to the recovery of specimens that would not otherwise have been discovered. This is especially true for the recovery of leaf fossils, where damage to specimens is occasionally more than offset by the amount of fresh, unweathered material that may subsequently be recovered (Rigby 1981; Wolberg 1981; Miller, Tidwell, and Petersen 1979). Large vertebrate fossils, however, tend to suffer badly from mechanical disturbances to bedrock. Although it is true that occasional large bones and relatively more abundant small bones and teeth have been recovered from overburden stripped from surface mining operations, there is reason to believe that the resulting sample is strongly biased and of diminished scientific value (Miller, Tidwell, and Petersen 1979). The success of attempts to recover material during construction depends on the nature of the paleontological resources, type of construction, and adequacy of the monitoring program. Although high recovery rates are theoretically possible, in practice these programs have met with little success.

INDICATORS OF IMPACT SIGNIFICANCE

At present there is no widely accepted definition of "significance" for paleontological resources. It is therefore necessary to define the criteria used to evaluate the paleontological resources that occur in the study area. In this study a fossil was considered significant if it fulfilled any of the following criteria (cf. Bureau of Land Management 1978:1-2).

1. It provides important information on the evolutionary trends

in organisms, relating living inhabitants of the earth to extinct organisms or clarifying relationships among extinct organisms.

2. It provides important information regarding development of biological communities, or interaction between botanical and zoological biotas.

3. It demonstrates unusual or spectacular circumstances in the history of life.

4. It is in short supply and in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and is not found in other geographic locations.

Not all fossils are scientifically, educationally, or culturally significant. The previously listed criteria must be applied with the understanding that fossils without significance:

- Are of a species that occurs in large numbers throughout a large geographic area

- Do not provide additional scientific data not found in other specimens of the same species

- Are invertebrates or paleobotanical fossils that do not fulfill any of requirements 1 thru 4 listed above.

As an aid to development planning, particularly with regard to evaluating and selecting among the proposed PNM pipeline and transmission line corridor alternatives, the study area was classified into zones reflecting the relative sensitivities of paleontological resources to disturbance by the proposed development. It is important to note that this classification takes into account the specific type of development proposed for each part of the study area and not strictly the abundance and significance of fossils in a given geographic area. Thus an area that contains rich and important paleontological resources is given a relatively low sensitivity classification if the specific type of development proposed for that area entails little or no appreciable disturbance of bedrock.

The classification consists of three zones or categories of sensitivity: high, moderate, and low.

- High Sensitivity: Regions where abundant significant (as defined in Section 1.0) fossil assemblages or individual fossils have been recovered; where high potential exists for natural erosion to expose more significant material; or where the proposed development is likely cause direct disturbance to material exposed at the surface or interfere with the future recovery of potentially significant fossils.

- Moderate Sensitivity: Regions where significant fossils are known to occur in low abundance; where a realistic probability exists for natural erosion to expose more significant material but in low abundance; or where development is likely to result in limited direct disturbances to material exposed at the surface or interfere with future recovery of significant fossils

- Low Sensitivity: Regions where no fossils or only insignificant fossils are known to occur; where there does not appear to be a realistic probability that natural erosion will expose new material; and/or where the scheduled development will result in no appreciable disturbance to bedrock.

METHODS FOR DATA COLLECTION

Published and unpublished literature pertaining to the study area was reviewed to determine the paleontological resources that had been reported in this general region. Locality archives of institutions that have sponsored research in the western San Juan Basin were examined to determine as precisely as possible the nature and locations of fossil materials recovered from this area. This review provided a basis for predictions regarding the nature and locations of paleontological resources that could be encountered during the proposed development. In addition, a number of professional paleontologists currently engaged in research in this region were contacted in an effort to gather the most up-to-date information pertaining to the study area. Institutions and individuals that were contacted are listed in the Consultation and Coordination section of this report.

Locality data provided by the above individuals and institutions were plotted on project-related U.S. Geological Survey 7.5-minute topographic maps. Careful attention was paid to identify geologic horizons that are rich in fossils, with the goal of identifying regions in the study area that are highly likely to contain significant, presently unexposed paleontological resources. Where developments are scheduled to proceed over areas now covered by Quaternary alluvial deposits, an effort was made to obtain data from immedidately adjacent areas to provide a reliable basis for estimates of subsurface paleontological resources.

To confirm the accuracy of previous reports of fossil occurrences and to gather new data, seven workdays in December 1981 were spent in the field examining the proposed plant site, the new town site, and selected portions of the proposed cooling-water pipeline corridors and transmission line corridors. No fossils were collected during this field survey. The proposed transmission line and pipeline corridors were visually examined during a helicopter flight on December 22, 1981.

A major source of data for this study is a report by Kues et al. (1977). This report was criticized in an unpublished report by Krishtalka et al. (1979). However, data that pertain to our study area collected during the Kues study were rechecked during our field survey and were found to be accurate. This conclusion of reliability was further substantiated by Dr. J. Keith Rigby, Jr. (1981).

In order to predict more accurately the precise nature of disturbances to paleontological resources that may result from the proposed development, details of the development were reviewed and discussed with personnel at Woodward-Clyde Consultants and professional paleontologists (listed above) who are familiar with long-term consequences of development on fossils. Various aspects of possible mitigation alternatives were also discussed, and the comments presented in Section 4.0 reflect opinions shared by a number of paleontologists now engaged in research in the general vicinity of the study area (e.g., Kues 1981; Wolberg 1981; Rigby 1981; O'Neil 1982; Miller, Tidwell, and Petersen 1979; Kues et al. 1977). We gratefully acknowledge the assistance provided by these colleagues but must point out that uniform agreement does not exist on all points discussed in this report. We take full responsibility for all data and conclusions presented herein.

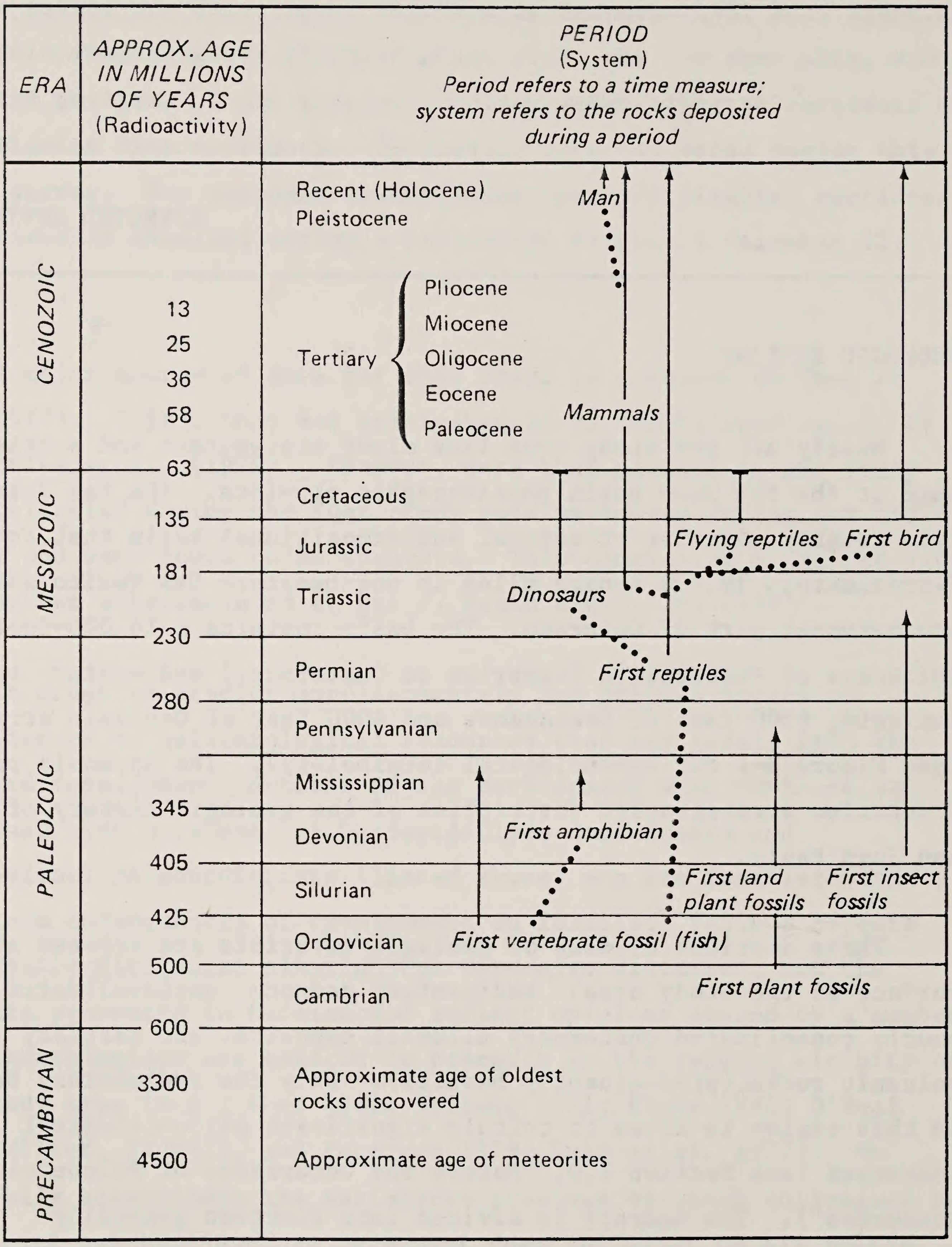
3.0

AFFECTED ENVIRONMENT

GEOLOGIC SETTING

Nearly all the study area lies along the western and southern edge of the San Juan Basin physiographic province. The San Juan Basin is a roughly circular structural and depositional basin that occupies approximately 30,000 square miles in northwestern New Mexico and the southernmost part of Colorado. The basin contains a 14,000-foot thickness of Phanerozoic (Cambrian to Quaternary) sedimentary rocks, including 6500 feet of Cretaceous and 4000 feet of Cenozoic strata (see Figure 3-1 for chronological terminology). The Appendix presents a detailed stratigraphic description of the geologic history of the San Juan Basin.

Three distinct classes of geologic materials are exposed at the surface of the study area: sedimentary bedrock, unconsolidated or poorly consolidated Quaternary alluvial deposits, and Tertiary volcanic rocks (predominantly basalts). Only the sedimentary bedrock in this region is known to contain significant paleontological resources (see Section 1.0, "Nature and Occurrence of Paleontological Resources"). The bedrock is divided into fourteen generally recognized geologic formations. These are, from youngest to oldest:



Source: Foster (1971), p. 144.
This simplified diagram does not include many types of invertebrates (e.g., clams, brachiopods, corals, sponges, snails) that have occurred from the Cambrian or Ordovician to the present.

Figure 3-1. GEOLOGIC TIME SCALE

1. Nacimiento Formation
2. Ojo Alamo Sandstone
3. Kirtland Formation
4. Fruitland Formation
5. Pictured Cliffs Sandstone
6. Lewis Shale
7. Cliff House Sandstone
8. Menefee Formation
9. Point Lookout Sandstone
10. Crevasse Canyon Formation
11. Gallup Sandstone
12. Mancos Shale
13. Dakota Sandstone
14. Morrison Formation

Table 3-1 summarizes the ages, depositional environments, and known paleontological resources of each of these formations. Summary descriptions of the geology and references to publications that contain listings of the fossils reported from each formation are presented in the Appendix. These lists are important in that they form much of the basis for determining the relative paleontological sensitivities of the study area to the proposed development.

Over most of the study area the formations listed above are oriented such that they strike generally in a northwesterly direction and have a regional dip of between 2° and 10° to the northeast. Thus the oldest formations are exposed along the southern and western edges of the San Juan Basin, and progressively younger formations lie to the northeast. Along the southern edge of the study area, complex structural deformation has complicated the orientations and relationships of many of these formations (Map 3-2).

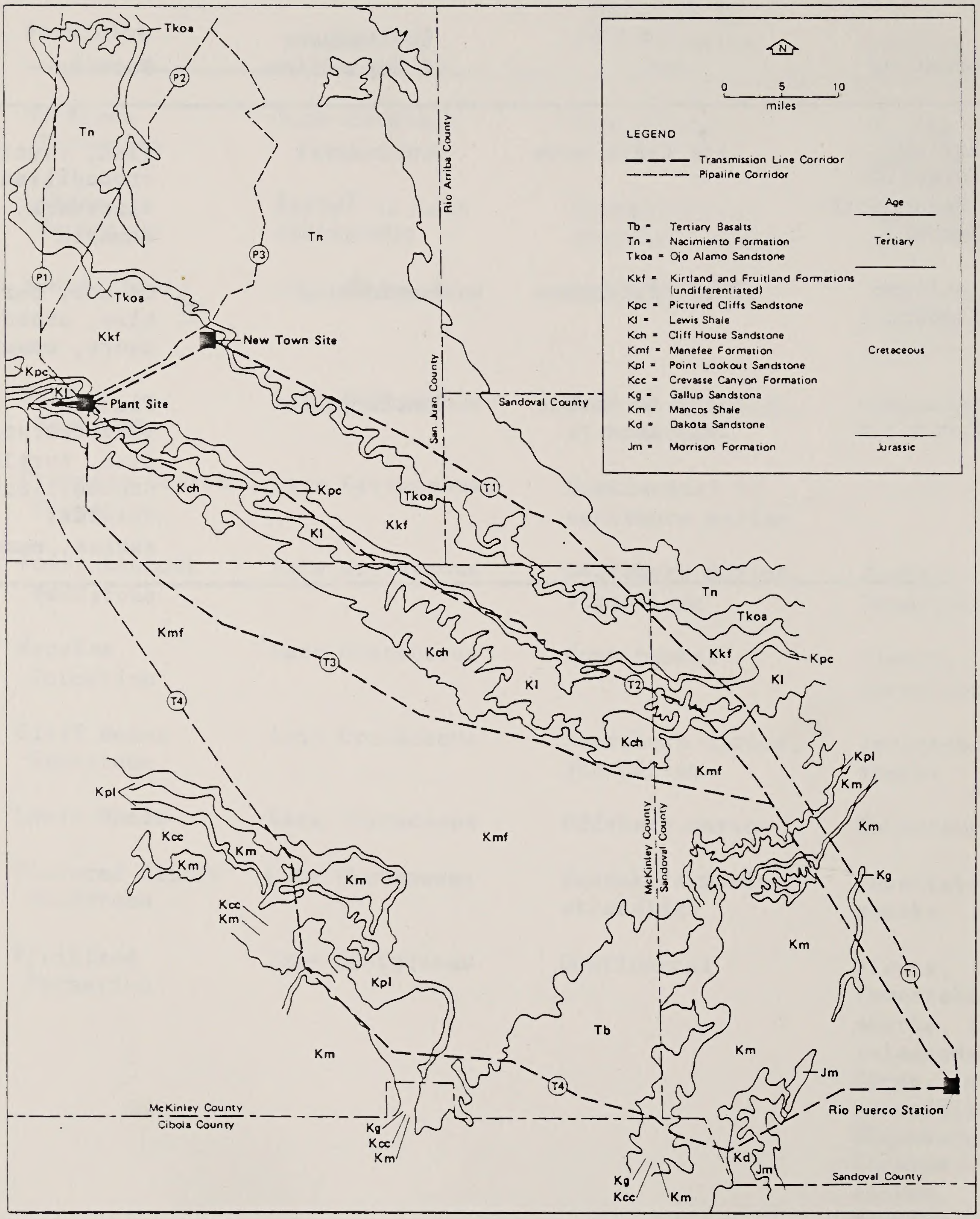
The fossils found in these formations include marine invertebrates, plant mega- and microfossils, and vertebrates. The vertebrate fossils range in size from tiny teeth of mouse-sized animals to fragmentary remains of dinosaur skeletons.

Table 3-1. SUMMARY OF GEOLOGY AND PALEONTOLOGY OF STUDY AREA

Formation	Age	Environment of Deposition	Fossils
Morrison Formation	Late Jurassic	Continental	Dinosaurs, mammals
Dakota Sandstone	Early? to Late Cretaceous	Continental to nearshore marine	Plants, invertebrates
Mancos Shale	Late Cretaceous	Offshore marine	Microfossils, invertebrates, plesiosaurs
Gallup Sandstone	Late Cretaceous	Nearshore marine, strandline	Invertebrates
Crevasse Canyon Formation	Late Cretaceous	Continental to nearshore marine	Plants
Point Lookout Sandstone	Late Cretaceous	Nearshore marine, strandline	Plants, invertebrates
Menefee Formation	Late Cretaceous	Continental	Plants, invertebrates
Cliff House Sandstone	Late Cretaceous	Nearshore marine, strandline	Invertebrates, sharks
Lewis Shale	Late Cretaceous	Offshore marine	Invertebrates
Pictured Cliffs Sandstone	Late Cretaceous	Nearshore marine, strandline	Invertebrates, sharks
Fruitland Formation	Late Cretaceous	Continental	Plants, invertebrates, sharks, fish, salamanders, frogs, turtles, crocodilians, dinosaurs, lizards, snakes, mammals
Kirtland Formation (exclusive of Naashoibito Member)	Late Cretaceous	Continental	Plants, invertebrates, sharks, fish, turtles, crocodiles, dinosaurs, mammals

Table 3-1. SUMMARY OF GEOLOGY AND PALEONTOLOGY OF STUDY AREA (concluded)

Formation	Age	Environment of Deposition	Fossils
Kirtland Formation (Naashoibito Member)	Late Cretaceous	Continental	Fish, turtles, crocodilians, dinosaurs, mammals
Ojo Alamo Sandstone	Early Paleocene	Continental	Plants, turtles, archosaurs, mammals
Nacimiento Formation	Early to Middle Paleozoic	Continental	Plants, invertebrates, fish, turtles, crocodilians, lizards, snakes, mammals



(Modified after Dane and Bachman, 1965: Geologic Map of New Mexico)

Map 3-2. GEOLOGY OF THE STUDY AREA

HISTORY OF RESEARCH AND SIGNIFICANCE OF THE STUDY AREA

The western edge of the San Juan Basin has for more than 120 years been the subject of paleontological research of great importance and far-reaching implications. Despite its long history of intensive study this area continues to have significant bearing on major current paleontological issues and is the subject of ongoing research by paleontologists across the United States and from other parts of the world. The rock exposures within a 15-mile radius of the proposed PNM plant site and the new town site are among the paleontologically richest in the entire San Juan Basin. This is especially true for the Cretaceous and Paleocene continental deposits. Most research has centered on these exposures, and a large literature now exists on the paleontology of this area (e.g., Kues and Northrop 1981). Fossils recovered from this region are currently displayed in museums across the United States and in Europe (Rowe, Cifelli, and Kues n.d.).

The first trained geologist to explore this area was J.S. Newberry, who accompanied a party of U.S. Army Engineers into the San Juan Basin in 1859 (Simpson 1981) and discovered plant fossils near the study area. By the late 1870s the greatest American paleontologists of the time, Edward Drinker Cope and O.C. Marsh, had begun research on the wealth of vertebrate fossils that had been discovered in the western San Juan Basin since Newberry's expedition. By the end of the nineteenth century, Henry Fairfield Osborn involved the American Museum of Natural History in a major collecting campaign that has continued intermittently to the present, in the western San Juan Basin. Under Osborn's direction some of the most eminent paleontologists of the day worked in the basin, including J.L. Wortman, O.A. Peterson, Walter Granger, Barnum Brown, W.D. Matthew, and W.J. Sinclair. In 1908-1909 and 1915-1916 the U.S. Geological Survey sent major expeditions into the area. At about that time J.W.

Gidley, O.P. Hay, and Charles Gilmore of the United States National Museum began research that was to continue intermittently for the next 30 years. During the first three-quarters of this century many other institutions became involved in research and collecting in the western San Juan Basin, including the Museum of Paleontology, University of California, Berkeley; University of Kansas; University of Arizona; Museum of Northern Arizona; Harvard University; and University of Mexico. The results of the last century of research have led to thousands of published pages. Kues and Northrop (1981) offer a comprehensive bibliography of New Mexico paleontology that lists more than 2000 published research papers, nearly half of which deal specifically with the western half of the San Juan Basin.

Among the most significant results of past research is the formulation of a standard definition for a worldwide Paleocene epoch through work centered a few miles from the study area. Most previous work focused on the vertebrate fossils. Although numerous studies touch on the invertebrates, little systematic work on this group in this area has been published since Stanton (1916). Fossil plants have been largely neglected since Knowlton (1916), although Tidwell, Ash, Robison, and others are currently working to remedy this situation (e.g., Tidwell, Burderson, and Parker 1980; Tidwell, Ash, and Parker 1981; Zavada 1976; Robison, Wolberg, and Hunt 1981a, 1981b).

That current research is this area is progressing at an intensive pace is well demonstrated by the recent publication of Advances in San Juan Basin Paleontology, a 393-page anthology (Lucas, Rigby, and Kues 1981). This volume includes 15 articles by 20 authors, and 14 of the papers treat fossils discovered in geologic formations crossed by the proposed construction features. New discoveries are still being made around the study area, and they often necessitate reexamination of old localities and data gathered by past workers. Dr. J. Keith

Rigby, Jr. (1981) reports that his work over the last four years in the "Fossil Forest," which lies roughly between the proposed plant site and the possible new town site, has led to the discovery of approximately 20 new vertebrate species. Preliminary reports of research that include new discoveries and reinterpretation of previous data collected in or near the Fossil Forest are presented by Rigby and Wolberg (1980); Hutchinson (1981); Robison, Wolberg, and Hunt (1981a, 1981b); Wolberg et al. (1981); Wolberg and Rigby (1981); Wolberg and Kotlowski (1980); and Wolberg (1980). These paleontologists and a number of others intend to continue intensive work in and near the study area in the future.

Among the most important topics now being addressed by research in the vicinity of the study area is the extinction of the dinosaurs and many other groups at the close of the Cretaceous period, approximately 65 million years ago. Geologic formations crossed by the study area contain fossil dinosaur-mammal communities that survived until or almost until the time of the complete dinosaur extinction. The mammals found in these communities include forms ancestral to many of the major groups of Tertiary and modern mammals. This area also preserves the earliest known mammal communities to evolve immediately following the dinosaur extinction, giving us our first glimpse of life after one of the greatest extinctions in history. For example, Kutz Canyon, which is crossed by the proposed transmission line corridor T3, contains one of these early mammal communities and includes some of the earliest known primates. Much current research focuses on the dinosaur-mammal communities in an effort to detect climatic change and changes in community structure that may have influenced the demise of the dinosaurs. Other researchers are trying to precisely date these communities using paleomagnetic and radiometric dating techniques together with the fossils to give an important measure of the rate of extinction of the dinosaurs. This, in turn, will offer a test of the plausibility of recently expressed views on possible extraterrestrial causes for their extinction (Alvarez and others 1980). Additional work by Kues, Wolberg, Robison, and others concerns some of the more basic research problems that remain to be solved in this area.

Great public interest and support for protection of the fossils of New Mexico in general and of the western San Juan Basin in particular were expressed in 1980 when New Mexico Governor Bruce King signed Bill 19 (Laws of 1980, Chapter 128) to provide public funding for the development and operation of a New Mexico Museum of Natural History. Motivation for this measure came largely from governmental and public recognition of the importance of fossils located in close association with economically important mineral deposits in the western San Juan Basin, and the possible destruction of fossils coincident with mineral development (Rowe, Cifelli, and Kues 1980, n.d.).

In summary, the study area lies in the midst of an intensely studied paleontological area, one that promises to remain of substantial scientific and educational significance.

4.0
ENVIRONMENTAL CONSEQUENCES

Paleontological sensitivities of areas that would be affected by each of the project components, and the environmental consequences expected in these areas, are described below. Table 4-1 provides a summary of these sensitivities, and Map 4-1 illustrates them for each of the project components.

PROPOSED PLANT SITE

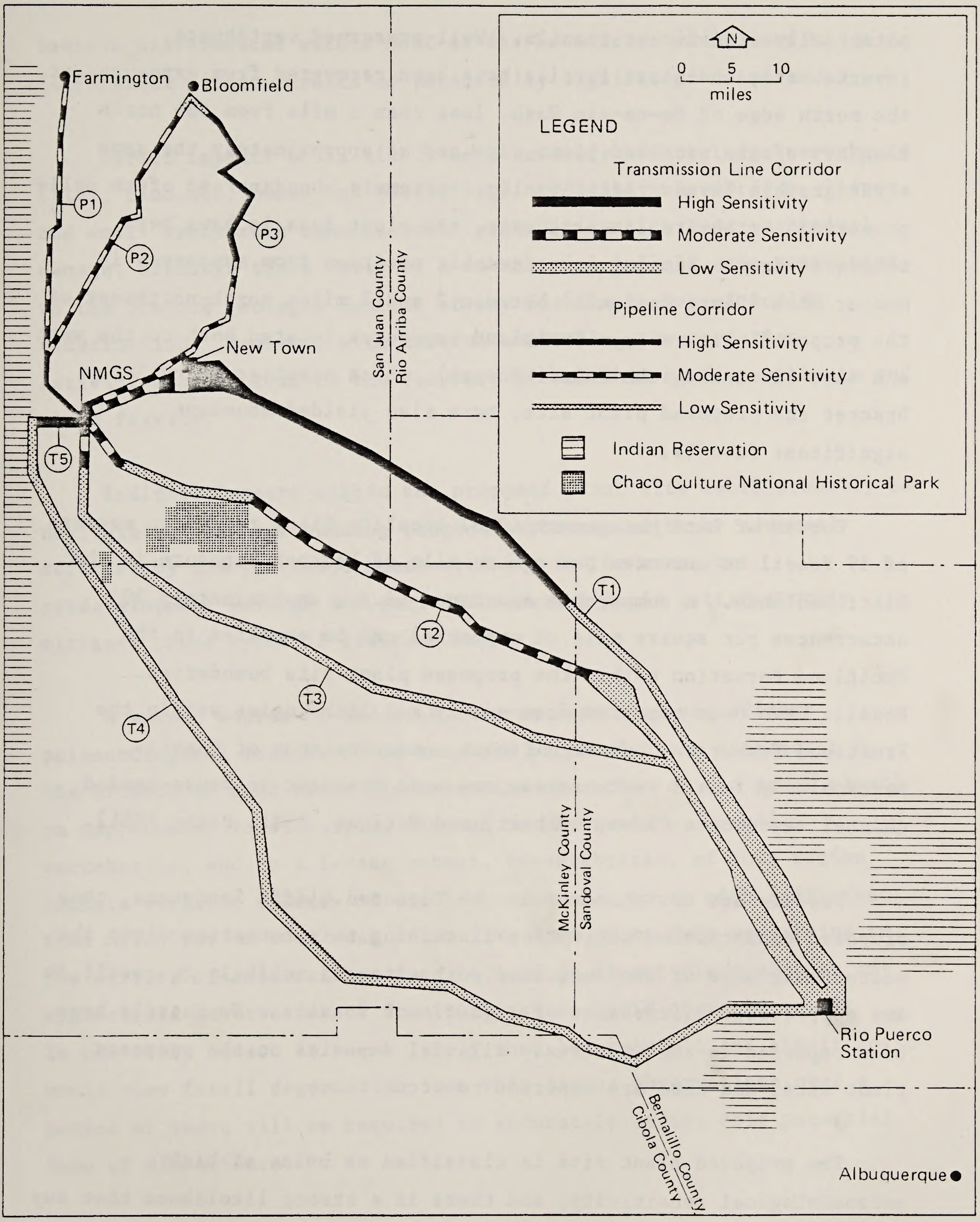
Most of the proposed plant site lies on the Fruitland Formation, while a small portion of its western edge overlies the Pictured Cliffs Sandstone. Only about 10 percent of the site has bedrock exposures, the remaining 90 percent being covered by a thin veneer of Quaternary alluvium. Construction of the plant would involve scraping away the alluvial cover and enough bedrock disturbance to provide a level bedrock surface for the plant foundations.

Three occurrences of fossils have been reported from the proposed plant site area (Table 4-1), all three occurring in Fruitland Formation bedrock exposed along its southern edge. None of these occurrences included significant fossils. However, the reported distribution of fossils in adjacent areas strongly suggests that this small number of reported occurrences reflects the relatively small area of bedrock exposure on the plant site itself. The bedrock below the thin surficial Quaternary deposits is expected to be quite rich in

Table 4-1. PALEONTOLOGICAL SENSITIVITIES OF PROJECT COMPONENTS

Formation	NMGS Plant Site	Water Pipelines P1	P2	P3	Transmission Corridors T1	T2	T3	T4	T5
Nacimiento Formation	-	M	M	H	H	-	-	-	-
Ojo Alamo Sandstone	-	M	M	M	M	-	-	-	-
Kirtland Formation	-	M	M	M	M	-	-	-	-
Fruitland Formation	H	H	H	M	M	M	M	H	H
Pictured Cliffs Sandtone	L	-	-	-	L	L	L	L	L
Lewis Shale	-	-	-	-	L	L	L	L	L
Cliff House Sandstone	-	-	-	-	L	L	L	L	L
Menefee Formation	-	-	-	-	L	L	L	L	-
Point Lookout Sandstone	-	-	-	-	L	L	-	L	-
Crevasse Canyon Formation	-	-	-	-	-	-	-	L	-
Gallup Sandstone	-	-	-	-	L	-	-	L	-
Mancos Shale	-	-	-	-	-	-	-	L	-
Dakota Sandstone	-	-	-	-	-	-	-	L	-
Morrison Formation	-	-	-	-	-	-	-	L	-
Tertiary Basalts	-	-	-	-	-	-	-	L	-

H = High sensitivity
M = Medium sensitivity
L = Low sensitivity



Source: BLM 1982.

Map 4-1. RELATIVE PALEONTOLOGICAL SENSITIVITIES WITHIN THE STUDY AREA potentially significant fossils. Well-preserved vertebrate, invertebrate, and plant fossils have been recovered from exposures at the north edge of De-na-zin Wash, less than 1 mile from the north boundary of the proposed plant site and at approximately the same stratigraphic level. Additionally, extremely abundant and often well-preserved vertebrate, invertebrate, and plant fossils have been recovered from a similar stratigraphic position from exposures in Hunter Wash (Bisti Badlands) between 2 and 5 miles north-northwest of the proposed plant site. Fruitland exposures located both to the west and east (including the Fossil Forest), which stratigraphically bracket the proposed plant site, have also yielded abundant significant fossils.

Bureau of Land Management (BLM) locality files record an average of 39 fossil occurrences per square mile of bedrock exposure in the Bisti Badlands. A comparable abundance (i.e., approximately 39 occurrences per square mile of exposure) can be expected in the Fruitland Formation within the proposed plant site boundaries. Fossils have been reported from nearly all lithologies within the Fruitland Formation, but significant concentrations of fossils, particularly fossil vertebrates, are most frequent in cross-bedded channel sandstones (Rowe, Colbert, and Nations, 1981; Rigby 1981).

Fossils are not abundant in the Pictured Cliffs Sandstone, thus proposed construction activities disturbing this formation along the westernmost edge of the suggested work site are unlikely to result in any appreciable disturbance of significant fossils. No fossils have been reported in the Quaternary alluvial deposits on the proposed plant site, and none are expected to occur there.

The proposed plant site is classified as being of high paleontological sensitivity, and there is a strong likelihood that any bedrock disturbances within most of its boundaries would lead to detrimental direct impacts to potentially significant fossils.

Direct impacts would likely most severely affect large vertebrate (i.e., dinosaur) bones and fossil logs. Fossil invertebrates, leaves, and small vertebrate remains would probably receive less mechanical damage, although there could be a substantial loss of data pertaining to the precise geologic context of any fossils recovered during construction. However, with careful monitoring, construction activities could lead to the recovery of valuable small vertebrate and plant fossils.

Indirect impacts within the proposed plant site would probably be negligible. The surrounding bedrock exposures might be adversely affected by the increased human activity in the area, but predevelopment salvage and periodic resurvey could satisfactorily mitigate these types of indirect impact.

A second source of indirect adverse impact to significant paleontological fossils on or near the proposed plant site might be the effects of acid rains (from routine operation of the power plant) on unprotected fossils lying exposed on the surface. Fossil vertebrates, and to a lesser extent, invertebrates, of this region contain variable amounts of calcium carbonate, which with sufficient time dissolves in even weak acids. We know of no data pertaining to the effects of acid rain on fossils, and it is not clear whether any appreciable adverse impact from such action could or would result in the study area. It seems likely that low rainfall and alkali soils would slow fossil degradation from this cause; observations over a period of years will be required to accurately assess this potential form of disturbance.

WATER PIPELINES

The three proposed cooling-water pipeline corridors each cross the Nacimiento, Ojo Alamo, Kirtland, and Fruitland formations (Map 4-1). Construction of any of these proposed pipelines would involve localized bedrock disturbance along the entire length of the corridor. This would probably result in local high direct and indirect impacts, especially the proposed P3 pipeline work in Kutz Canyon, but most of the pipeline construction will have no more than moderate impact on significant paleontological values. Because of the uneven distributions of fossils and the very localized nature of the actual disturbances, meaningful quantitative impacts are not possible. However, qualitative estimates of projected impacts are possible and are discussed below.

Corridors P1 and P2

Proposed corridor alternatives P1 and P2 cross paleontologically sensitive formations along their entire lengths but are generally located well away from (5 to 15 miles) important scientific fossil localities. The only exception occurs where the two proposed corridors share a route for about 2 miles near the Bisti Trading Post, in T24N, R13W, sections 31 and 32; and T23N, R13W, section 5 (mileposts 31 to 33 along P1, and MP 33.5 to 35.5 along P2). In this area 17 occurrences of fossils, including some significant specimens, have been reported (Table 4-2). All these occurrences are in the Fruitland Formation. Thus, adverse but localized direct impacts to potentially significant paleontological resources are likely to result from construction in this area, and it has been classified as being of high paleontological sensitivity. Only direct impacts of the proposed construction are likely to occur here, primarily disturbances to large and small vertebrates, plants, and invertebrates in the Fruitland Formation bedrock. Since the area is currently readily accessible to

Table 4-2. SENSITIVE SITES NEAR PROPOSED PROJECT COMPONENTS

Project Component	Quadrangle Sheet	Location: Town-ship	Location: Range	Location: Sec-tion	Location: 1/4 (if available)	Occurrence Number*	Materials Found	Significance	Sensi-tivity Rating	Comments
Plant Site										
	Tanner Lake	23N	13W	23	SW 1/4	BLM 629	Dinosaur bone, wood.	Individual sites not significant, but indicate local high significance potential.	High.	Data from adjacent areas indicate high potential for occurrences of significant fossils in abundance.
	Tanner Lake	23N	13W	24	SW 1/4	BLM 26	Fern impressions.			
	Tanner Lake	23N	13W	24	SE 1/4	BLM 100	Ophiomorpha sp.; wood.			
Pipeline Corridors										
P1 and P2	Bisti Trading Post	24N	13W	31	SW 1/4	BLM 44	Dinosaur vertebra.	Nonsignificant.	High.	Identifications very generalized but abundance and diversity of bone indicate high probability of abundant significant fossils.
		24N	13W	31	SE 1/4	BLM 173	Invertebrates.	Nonsignificant.		
		24N	13W	32	SW 1/4	BLM 19	Not recorded.	--		
		24N	13W	32	NW 1/4	BLM 28	Not recorded.	--		
		24N	13W	32	SW 1/4	BLM 45	Dinosaur; microvertebrate bone.	Significant.		
		24N	13W	32	SW 1/4	BLM 61	Turtle carapace.	Significant.		
		24N	13W	32	SW 1/4	BLM 92	Carnosaur teeth, microvertebrates.	Significant.		
		24N	13W	32	NW 1/4	BLM 156	Dinosaur bone; microvertebrates invertebrates.	Significant.		
		24N	13W	32	SW 1/4	BLM 174	Dinosaur bone.	Nonsignificant.		
		24N	13W	32	SW 1/4	BLM 175	Partial turtle carapace.	Nonsignificant.		
		24N	13W	32	SW 1/4	BLM 181	Dinosaur bone, teeth; turtle carapace.	Nonsignificant.		
P3	Bloomfield	28N	11W	11	The cumulative list of fossils from this area (Kutz Canyon) consists of numerous specimens representing the following mammal groups (data from Taylor 1981): • Multituberculates: 3 families, 3 genera • Insectivores: 4 families, 8 genera • Primates: 1 family, 4 genera • Taeniodonts: 1 family, 3 genera • Condylarths: 5 families, 21 genera • Carnivores: 1 family, 1 genus			Significant.	High.	This area (Kutz Canyon) has been carefully studied (e.g., Taylor 1981; Conroy 1981), and intensive research is currently in progress. General locality data are presented in Taylor (1981). Excellent detailed data have been collected but are largely held confidential, pending full analysis.
		28N	11W	12						
		28N	11W	13						
		28N	10W	18						
		28N	10W	19						
		28N	10W	20						
		28N	10W	29						
		28N	10W	32						
		28N	10W	33						
		27N	10W	4						
		27N	10W	5						
		27N	10W	7						
		27N	10W	8						
		27N	10W	17						
		27N	10W	18						
		27N	10W	20						
		27N	10W	21						
		27N	10W	27						
		27N	10W	28						
		27N	10W	34						

Table 4-2. SENSITIVE SITES NEAR PROPOSED PROJECT COMPONENTS (continued)

Project Component	Quadrangle Sheet	Location: Township	Location: Range	Location: Section	Location: 1/4 (if available)	Occurrence Number*	Materials Found	Significance	Sensitivity Rating	Comments
Transmission Line Corridor T1 (continued)	Kimbeto (continued)	23N	9W	18	NW 1/4	BLM 232		Significant.	High.	Mammalon Hill locality (continued).
		23N	9W	18	NE 1/4	BLM 238				
		23N	9W	19	NE 1/4	BLM 218				
		23N	9W	19	NE 1/4	UA 76129				
		23N	9W	19	—	Gilmore (1919)				
		23N	9W	21	NW,NE, SE 3/4	UCMP v.2811	See UCMP v.2811 above.			
		23N	9W	22	NW,NE,SW,SE	UCMP v.2811	See UCMP v.2811 above.			
		23N	9W	22	--	Gilmore (1919)				
		23N	9W	23	NW,SW,2/4	UCMP v.2811	See UCMP v.2811 above.			
		23N	9W	26	SW 1/4	BLM 215				
		23N	9W	26	SE 1/4	BLM 216				
		23N	9W	27	NW,NE 1/2	UCMP v.2811				
		23N	9W	27	SW 1/4	MCZ 5/78				
		23N	9W	27	SW 1/4	MCZ 7/78				
		23N	9W	--	Sinclair and Granger (1914)	6				
		23N	9W	--	Sinclair and Granger (1914)	7				
	Ojo Encino Mesa	20N	5W	26	SE 1/4	BLM 897	Vertebrata.	Significant.	High.	Most, but not all, of these occurrences are significant. The nature of the paleontological resources and abundance indicates a high sensitivity rating for the whole area.
		20N	5W	35	NW 1/4	BLM 898	Vertebrata.			
		20N	5W	23-24	--	UCMP v.1301	6 species of mammals.			
		20N	4W	32	SE 1/4	BLM 891	Dinosaur vertebrae.			
		20N	4W	32	SE 1/4	BLM 895	Abundant turtles, microvertebrates.			
		19N	4W	5	NE 1/4	BLM 889	Dinosaur, turtle fragments.			
		19N	4W	5	NE 1/4	BLM 890	Dinosaur, turtle fragments.			
		19N	4W	5	NE 1/4	BLM 892	Dinosaur bones.			
		19N	4W	5	NE 1/4	BLM 893	Dinosaur bones.			
		19N	4W	5	NE 1/4	BLM 894	Vertebrata.			
	Ojito Spring	15N	1W	21	SW 1/4	BLM 1708	Mollusks.	Nonsignificant.	Low.	
		16N	1W	29	NE 1/4	BLM 1700	12 mollusk species.	Nonsignificant.		
	Lybrook SE	22N	7W	1	SE 1/4	BLM 850	<u>Periptychus</u> (mammal).	Significant.	High.	Low abundance, but little exploration in this area.
Transmission Line Corridor T2	Fire Rock Well	21N	8W	29	NE 1/4	BLM 857	Dinosaur bone.	Significant.	Moderate.	Low abundance, poor preservation.
		21N	8W	34	SW 1/4	BLM 1318	Turtles, plants.	Nonsignificant.	Moderate.	
		21N	8W	34	NE 1/4	BLM 1317	Turtles, plants.	Nonsignificant.	Moderate.	
		21N	8W	34	SE 1/4	BLM Unnumbered		Nonsignificant.	Low.	

Table 4-2. SENSITIVE SITES NEAR PROPOSED PROJECT COMPONENTS (continued)

Project Component	Quadrangle Sheet	Location: Township	Location: Range	Location: Section	Location: 1/4 (if available)	Occurrence Number*	Materials Found	Significance	Sensitivity Rating	Comments
Transmission Line Corridor T1	Kimbeto	23N	10W	12	NE 1/4	BLM 230	Only summary data for these occurrences were collected for this study. Present among these sites are abundant, well-preserved fragmentary mammals, turtles, crocodilians, champsosaurs, fish, and plants.	Significant.	High.	This area has received considerable attention, and its fossils have become the subject of numerous paleontological studies and technical publications (e.g., Sinclair and Granger 1914; Rowe and Sundberg 1980; Lindsay, Butler, and Johnson 1981).
		23N	10W	12	NE 1/4	BLM 231				
		23N	10W	12	SE 1/4	UA 660				
		23N	10W	12	SE 1/4	UA 661				
		23N	10W	12	SE 1/4	UA 662				
		23N	10W	12	SE 1/4	UA 663				
		23N	10W	14	SW 1/4	BLM 228				
		23N	10W	14	SE 1/4	BLM 229				
		23N	10W	14	NE 1/4	UA 654				
		23N	10W	14	NE 1/4	UA 655				
		23N	10W	14	NE 1/4	UA 656				
		23N	10W	14	NE 1/4	UA 657				
		23N	10W	14	SW 1/4	UA 76108				
		23N	10W	11	SW 1/4	UA 688				
		23N	9W	11	SW 1/4	UA 689				
		23N	9W	7	SW 1/4	BLM 233				
		23N	9W	7	SW 1/4	BLM 234				
		23N	9W	7	SW 1/4	BLM 235				
		23N	9W	7	NW 1/4	BLM 236				
		23N	9W	7	NW 1/4	BLM 237				
		23N	9W	7	SE 1/4	BLM 239				
		23N	9W	7	SE 1/4	BLM 240				
		23N	9W	7	SE 1/4	BLM 241				
		23N	9W	7	SE 1/4	BLM 242				
		23N	9W	7	SE 1/4	BLM 243				
		23N	9W	7	NW 1/4	UA 665				
		23N	9W	7	SW 1/4	UA 7784				
		23N	9W	7	SW 1/4	UA 77113				
		23N	9W	7	SW 1/4	UA 77114				
		23N	9W	15	SW 1/4	BLM 222	Turtle.	Nonsignificant.	High.	Mammalon Hill locality.
		23N	9W	15	SW 1/4	BLM 223	Vertebrata.	Nonsignificant.		
		23N	9W	15	SW 1/4	UCMP v.2811	16 species of fish, reptiles, & mammals.	Significant.		
		23N	9W	15	SW 1/4	MCZ 1/78	Mammal bones.	Significant.		
		23N	9W	15	—	UNM v. 49	Turtle carapace & fragments.	Significant.		
		23N	9W	16	NE 1/4	BLM 219	Turtle shell.	Nonsignificant.		
		23N	9W	16	SE 1/4	BLM 220	Reptile bone fragments; plants.	Significant.		
		23N	9W	16	SE 1/4	BLM 221	Gar scales; microvertebrates.	Significant.		
		23N	9W	16	NE,SE,SW 3/4	UCMP v.2811	See UCMP v.2811 above.	Significant.		

Table 4-2. SENSITIVE SITES NEAR PROPOSED PROJECT COMPONENTS (continued)

Project Component	Quadrangle Sheet	Location: Township	Location: Range	Location: Section	Location: 1/4 (if available)	Occurrence Number*	Materials Found	Significance	Sensitivity Rating	Comments
Transmis-	Pueblo Alto	20N	7W	8	SW 1/4	BLM 1284	Vertebrata.	Nonsignificant.	Low.	
sion Line	T.P.	20N	7W	8	SW 1/4	BLM 1285	Vertebrata.	Nonsignificant.	Low.	
Corridor		20N	7W	23	SW 1/4	BLM unnumbered	Vertebrata.			
T2		20N	7W	23	NE 1/4	BLM unnumbered	Vertebrata.	Significant-	Moderate.	Data generally
(continued)		20N	7W	23	NE 1/4	BLM unnumbered	Vertebrata.	nonsignificant.		poor. Little
		20N	7W	36	SE 1/4	BLM unnumbered	Vertebrata.			exploration has
		20N	6W	31	SW 1/4	BLM 1245	Vertebrata.			been conducted.
		19N	6W	6	N 1/2 7	BLM unnumbered	Vertebrata.			
		19N	6W	5	NW 1/4	BLM unnumbered	Vertebrata.			
	Pueblo Pintado	20N	8W	1	SE 1/4	BLM 1294	Abundant vertebrata.	Significant.		Data generally
		20N	8W	1	SE 1/4	BLM unnumbered	Vertebrata.	Nonsignificant.	Moderate.	poor, little
		20N	8W	12	NW 1/4	BLM unnumbered	Vertebrata.	Nonsignificant.		exploration has
										been conducted.
	Star Lake	20N	6W	32	SE 1/4	BLM unnumbered				
		20N	6W	33	SW,SE 2/4	BLM unnumbered				
		19N	6W	5	SW 1/4	BLM unnumbered				
		19N	6W	4	S 1/2	BLM unnumbered				
		19N	6W	4	SE 1/4	BLM 1273				
		19N	6W	2	SW 1/4	BLM 1232	Dinosaurs and	Significant-		Data generally
		19N	6W	8	SE 1/4	BLM 1234	other vertebrates,	nonsignificant.		poor, reliability
		19N	6W	8	SE 1/4	BLM 1235	invertebrates,			questionable.
		19N	6W	8	SE 1/4	BLM 1236	plants. Abundance		Moderate	This area needs
		19N	6W	9	NW 1/4	BLM unnumbered	generally low, but			further work to
		19N	6W	9	SW 1/4	BLM unnumbered	high locally.			accurately deter-
		19N	6W	10	SW 1/4	BLM unnumbered				mine significance
		19N	6W	11	NW 1/4	BLM unnumbered				of individual
		19N	6W	11	NE 1/4	BLM unnumbered				localities, al-
		19N	6W	11	SE 1/4	BLM 1237				though there are
		19N	6W	11	SE 1/4	BLM 1238				some apparently
		19N	6W	12	SW 1/4	BLM 1239				reliable indica-
		19N	6W	12	SW 1/4	BLM 1240				tions of rare sig-
		19N	6W	12	NE 1/4	BLM 1241				nificant fossils.
Transmis-	Tanner Lake	23N	13W	25	NW 1/4	BLM 630	Plant impressions.	Nonsignificant.	High.	Data from adjacent
sion Line		23N	13W	25	SE 1/4	BLM 631				regions indicate
Corridor										high potential for
T3										abundant signifi-
										cant fossils here.

Table 4-2. SENSITIVE SITES NEAR PROPOSED PROJECT COMPONENTS (concluded)

Project Component	Quadrangle Sheet	Location: Township	Location: Range	Location: Section	Location: 1/4 (if available)	Occurrence Number*	Materials Found	Significance	Sensitivity Rating	Comments
Transmission Line Corridors T4 and T5	Tanner Lake	23N	13W	22	SW 1/4	BLM 625	Vertebrata.	Significant-nonsignificant.	High.	Not every locality is significant, but abundance and diversity of fossils present in this area indicate high sensitivity rating.
		23N	13W	22	SW 1/4	BLM 626	Dinosaur bones, turtles.			
		23N	13W	22	SW 1/4	BLM 627	Fish vertebra.			
		23N	13W	22	SW 1/4	BLM 628	Invertebrates.			
		23N	13W	21	SW 1/4	BLM 620	Turtles, invertebrates.			
		23N	13W	21	SE 1/4	BLM 621	Dinosaur bone.			
		23N	13W	21	SE 1/4	BLM 622	Invertebrata.			
		23N	13W	21	SE 1/4	BLM 623	Vertebrata, invertebrates.			
		23N	13W	21	SE 1/4	BLM 624	Vertebrata, invertebrates.			
		23N	13W	20	SE 1/4	BLM 616	Several species invertebrates.			
		23N	13W	20	SE 1/4	BLM 617	Gastropods, trace fossils.			
		23N	13W	20	SE 1/4	BLM 618	Turtle, invertebrates.			
		23N	13W	20	SE 1/4	BLM 619	Plant impressions.			

*Occurrence abbreviations:

BLM = Bureau of Land Management, Albuquerque, New Mexico.

BLM Unnumbered = Reported occurrences of fossils recorded on fossil locality archive maps housed in the Bureau of Land Management, Albuquerque, which are without official BLM locality numbers. Accompanying data and technical descriptions for these localities are of variable, but in most cases poor, quality.

UA = Laboratory of Paleontology, University of Arizona, Tuscon.

UCMP = Museum of Paleontology, University of California, Berkeley.

MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

motor vehicles, indirect impacts should not increase as a direct result of the proposed development.

Pipeline Corridor P3

This proposed corridor crosses exposures of the Nacimiento Formation in Kutz Canyon (MP 3 to 16: T28N, R11W; T28N, R10W; T27N, R10W; T26N, R11W), which have yielded a rich assemblage of significant fossils including some of the earliest known primates (Taylor 1981; Conroy 1981). The area is classified as having high paleontological sensitivity. Kutz Canyon is currently a focal point of important paleontological research that could be adversely affected by the proposed pipeline construction, even if the physical disturbances were minor. Thus, both direct and indirect adverse impacts to the paleontological resources of this area may result from the proposed pipeline construction. Kutz Canyon currently has only limited accessibility, but access is likely to increase following the proposed development in the area. This is expected to lead to increased fossil-collecting activities by amateurs and may have major adverse consequences for ongoing research.

The remainder of this corridor crosses areas of moderate paleontological sensitivity.

A review of the paleontological resources associated with the three proposed water pipeline corridors yields the following results: completion of water pipeline P3 would probably have the most adverse impacts to significant paleontological resources of the San Juan Basin; completion of either pipeline P1 or P2 would have minimal adverse affect on the known or projected fossil resource base.

TRANSMISSION LINES

Each of the transmission line corridor alternatives would cross a number of geologic formations (Tables 4-1 and 4-2), including several paleontologically sensitive areas (Map 4-1). Direct adverse impacts of the construction and maintenance of these lines would probably be localized and restricted to actual construction sites and access routes. Indirect adverse impacts could result from increased human accessibility to the area if new access roads are constructed. As with the pipeline corridors, the uneven distribution of fossils and localized nature of land disturbance by construction preclude meaningful quantitative estimates of impacts. Qualitative projections of impacts are presented below.

Because much of the area crossed by the proposed transmission line corridors has been only minimally explored for fossils, the study area evaluated here includes lands within 1 mile to either side of the entire length of the proposed corridor rights-of-way boundaries shown in Map 4-1.

Transmission Line Corridor T1

Proposed corridor T1 crosses approximately 50 miles (MP 13 to 65) of intermittent exposure of the Nacimiento Formation (Map 3-2). These exposures have been the subject of paleontological study for nearly 70 years, are of current research interest, and have yielded large numbers of significant fossils. The corridor passes directly across or within 1 mile of a number of important localities, including the famous "Mammalon Hill" and Kimbeto sites (Table 4-2).

Significant direct and indirect adverse impacts to scientific paleontological values could occur in this area, especially to vertebrate materials. The direct effects would be caused by bedrock disturbances associated with construction sites and access routes. The increased accessibility to this area that could result from proposed transmission line construction could increase nonprofessional fossil collection. While significant fossils are relatively abundant, each fossil form may be represented in only one of a few instances. Thus, even limited collecting by nonprofessionals may have major adverse effects on current or future research.

Transmission Line Corridor T2

Proposed corridor T2 lies southwest of corridor T1, roughly paralleling it along its entire length (Map 3-1). The northwestern half of proposed corridor T2 lies very near the irregularly shaped lower boundary of the Fruitland Formation, where it intermittently crosses Fruitland exposures (Map 3-2). Near the proposed plant site it crosses about 1 mile of Fruitland Formation where no fossil occurrences have been reported, but where adjacent distributions indicate that such occurrences are somewhat likely. Approximately 30 miles of proposed corridor T2 cross more or less continuously over the Fruitland Formation, from the Sargent Ranch USGS topographic sheet quadrangle into the Star Lake USGS sheet (MP 20 to 50). A number of occurrences have been reported in or within 1 mile of this proposed corridor (Table 3), although they include few significant fossils. Over the rest of its length, corridor T2 passes over areas of low paleontological sensitivity.

Local direct and indirect adverse impacts to scientific paleontological values may occur where the proposed corridor crosses exposures of the Fruitland Formation. Table 3 lists sections along this route that are classified as being of moderate paleontological sensitivity. This classification is based on the assessment that although significant fossils have been recovered from these areas, their abundance is low relative to the total number of reported occurrences. Increased accessibility to the area may lead to increased fossil collecting by amateurs, but because of the relatively low abundance of significant specimens, this activity is unlikely to have major adverse effects.

Transmission Line Corridor T3

Proposed corridor T3 crosses about 1 mile of the Fruitland Formation immediately south of the suggested plant site (MP 0 to 1). Two nonsignificant fossil occurrences have been reported there (Table 4-2), and thus moderate direct and indirect adverse impacts may result from the proposed line construction. The remainder of this proposed corridor crosses regions of low paleontological sensitivity, where no appreciable disturbance of significant paleontological resources is likely.

Transmission Line Corridor T4

Proposed corridor T4 crosses about 4 miles of the Fruitland Formation immediately west of the suggested plant site (MP 0 to 4). Thirteen occurrences of fossils have been reported along the southern corridor edge here (Table 4-2), and major but localized direct adverse impacts to the scientific paleontological resource could result from this proposed line construction. The remainder of the proposed corridor crosses areas of low paleontological sensitivity (Map 4-1).

Transmission Line Corridor T5

Proposed corridor T5 crosses about 3 miles of the Fruitland Formation immediately west of the suggested plant site (MP 0 to 3). Thirteen occurrences of fossils have been reported along the southern corridor edge here (Table 4-2), and major but localized direct adverse impacts to the scientific paleontological resource could result from this proposed line construction. The remainder of the proposed corridor crosses areas of low paleontological sensitivity (Map 4-1).

5.0
SUGGESTED MITIGATION

Paleontological resources are nonrenewable and therefore are less amenable to mitigative protection than are some other environmental elements. Mitigation of adverse effects on paleontological materials usually involves data recovery, that is, the scientifically controlled excavation, analysis, and curation of a sample of the affected resource base. Such scientific research is labor-intensive and hence relatively costly, and definitions of its mitigative "adequacy" are difficult to outline. However, in lieu of avoidance of direct or indirect impacts to the affected resources, some data recovery could provide minimal to adequate mitigation of those adverse impacts. Such a recovery program might appropriately be developed for areas classified as being of high to moderate paleontological sensitivity within the proposed project areas.

Major elements of an adequate data recovery mitigation program might include:

- Intensive inventory of proposed project areas preliminarily identified as being of high or moderate paleontological sensitivity, to identify any surface-exposed fossils and evaluate their significance.

- Development of a predictive model of significant fossil localities affected by the proposed project, to be used as a basis for designing an adequate research strategy and possible construction monitoring program.

- Implementation of a data recovery program. Based on the research strategy, this may involve various levels of recovery intensity (e.g., surface collection, excavation, and collection of units of varying size) keyed to areas of varying predicted distributions of significant fossil remains. This program would include field investigations, laboratory analysis and reporting, and curation.

- Implementation of a construction monitoring and emergency recovery program in areas of predicted occurrence of significant fossil resources. The recovery program could be designed in a manner similar to that followed under nonemergency circumstances.

Mitigative data recovery programs are most effective in offsetting the direct ground-disturbing impacts of a project such as that proposed by PNM. Thus they might provide adequate protection of the scientific information value of the fossil materials in areas of high sensitivity, such as along proposed transmission line corridor T1, at the lower end of the pipeline corridors P1 and P2 as well as perhaps P3 (which is highly sensitive), and in the areas of the plant site and possible new town. Data recovery in areas of predicted moderate paleontological sensitivity (transmission line corridors T2, T3, and T4 around the plant site, and major areas of alternative transmission line corridor T2 and pipelines P1 and P2) might be most effectively (and still adequately) conducted during a construction monitoring and emergency discovery project stage.

Mitigation of adverse effects caused by indirect impacts of the proposed project, such as by the influx of people into a possible new town, is difficult. Development of community education projects to enlist local support to protect the fossils in place, complemented by more rigorous enforcement of restrictions on off-road vehicle use in areas of rich paleontological deposits, might provide some protection of scientific values that would otherwise be lost to amateur collectors. Private (perhaps PNM) support for an ongoing paleontological research program in the general project area might also offset the losses that might occur through uncontrolled collection and/or fossil destruction through surface exposure and erosion. A long-range program of project area surface/exposure monitoring and selective data recovery of significant fossils might also provide some resource protection or a compensatory data base. All these alternatives may need to be evaluated and, if selected, woven into a well-designed long-term mitigation program if predicted adverse effects on the paleontological resource are to be minimized.

6.0

UNAVOIDABLE ADVERSE IMPACTS

Subsurface fossils may be destroyed or damaged during construction activities.

7.0
RELATIONSHIP BETWEEN THE SHORT-TERM USE OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

Data obtained from paleontological resource inventories would result in both long- and short-term benefits. In those areas where data recovery efforts are not implemented or are inadequate, an unknown volume of paleontological resources would be permanently lost and unavailable for future investigation.

8.0

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Significant fossils may be permanently damaged or destroyed during construction, maintenance, or repair.

9.0 COMPARISON OF ALTERNATIVES

Highly sensitive paleontological areas would be affected on each of the three alternative water pipelines. Impacts would be most significant on P3 and approximately equal on P1 and P2. Transmission line T1 would significantly affect important resources, while T2, T3, and T4 would not cause significant impacts.

POSSIBLE NEW TOWN

1.0

AFFECTED ENVIRONMENT

The possible new town site lies on the upper part of the Naashoibito Member of the Kirtland Formation and the lower part of the Ojo Alamo Sandstone. There is virtually no bedrock exposure within the site boundaries, the entire area being covered by a thin layer of surficial Quaternary alluvium.

Petrified wood, including large sections of logs and abundant small fragments, was found over much of the site during our 1981 field survey. This material appears to have been derived as a lag deposit during the development of the present soil profile and alluvial cover. None of this material constitutes a significant paleontological resource, although it suggests the possibility that significant plant fossils may be encountered during bedrock disturbances in the possible new town site.

There are no previous reports of fossils from the suggested new town site, but occurrences reported from adjacent areas (Kues et al. 1977; Rowe and Sundberg 1980) indicate a strong probability that significant vertebrate fossils occur in the immediately subsurface bedrock of this area. BLM, University of Arizona, University of California, and Museum of Northern Arizona locality archives record numerous localities in nearby stratigraphically equivalent areas. Numerous significant specimens have been recovered from these localities. The distribution of fossils in adjacent areas projects an estimate of 10 significant paleontological occurrences per square mile of bedrock at the possible new town site.

The possible development of a new town would result in direct impacts to significant paleontological resources within the site boundaries. These would be primarily from bedrock disturbances during construction. Since the entire site is covered by alluvium, it is not possible to predict the exact locations of the fossils expected to exist in the underlying bedrock. However, adjacent fossil distributions can be used to project disturbance frequencies of approximately 10 sites per square mile of bedrock disturbance. Based on comparative data, the possible new town site is classified as being of high paleontological sensitivity.

2.0
ENVIRONMENTAL CONSEQUENCES

The possible new town site lies in the midst of some of the richest and most extensive exposures of fossiliferous bedrock found in northwestern New Mexico. Most notable are the Bisti Badlands, the Fossil Forest, and De-na-zin Wash. These exposures are the subject of a large portion of the previous research on the western San Juan Basin, they are being intensively studied now, and their prime importance in paleontological research promises to continue well into the future. Because the possible development of a new town would be accompanied by a large influx of permanent residents to the area, the potential indirect impact of this possible population influx on the paleontological resources must be assessed.

In general, the scientific values of fossil beds close to population centers suffer badly from fossil collecting by amateurs or "rock hounds." Miller, Tidwell, and Petersen (1979) discuss this problem as it applies specifically to the exposures surrounding the study area, and they present photographs (Plates 12a-d, 13a-d) of fossils used in residential landscaping. Similar activities have been observed by the authors of this report and many other professional paleontologists (e.g., Rigby 1981; Kues 1981). Whether the collections are made for resale in local rock shops or for strictly private use is of no scientific consequence, since few of these specimens ever reach qualified scientific personnel. Fewer still are accompanied by the necessary locality and geologic context data.

Furthermore, the delicate nature of most fossils requires difficult and specialized collecting techniques that are rarely employed by nonprofessionals, generally causing severe damage to the fossils and their depositional environments.

Thus, it is likely that the population of the possible new town would adversely affect scientific paleontological values in the general area of the proposed community. Nonprofessional fossil collection could be expected to occur along the Hunter Wash, Alamo Arroyo, De-na-zin Wash, Ah-shi-sle-pah Wash, and Barrel Springs Arroyo drainage exposures. Limited collection could extend well beyond these areas.

Appendix

SUMMARY OF SAN JUAN BASIN GEOLOGY

The San Juan Basin is a roughly circular structural depression situated primarily in northwestern New Mexico, but also extending into southwestern Colorado. In the area under investigation, the southwestern quarter of the basin, regional dips of a few degrees are mostly to the east and northeast. The basin includes as much as 14,000 feet of Phanerozoic (Cambrian to Quaternary) strata, including 6500 feet of Cretaceous and 4000 feet of Cenozoic strata (see Figure 2 for chronologic terminology).

The Late Jurassic to early Tertiary (Paleocene) section in the San Juan Basin records a series of three major transgressive-regressive cycles along the western margin of the epicontinental sea that covered this part of the continent during the Late Cretaceous (Figure 3). Fluctuations in the position of the strandline resulted in time-transgressive rock units and a complex interfingering of marine and nonmarine Late Cretaceous strata, continental strata grade laterally to the northeast into correlative marine strata (Figures 2 and 3). The transgressions became less pronounced and the regressions more pronounced during the Late Cretaceous.

In ascending order, the first transgressive sequence is represented by the Late Jurassic Morrison Formation (continental), Early to Late Cretaceous Dakota Sandstone (continental to nearshore marine), and the lowermost part of the Late Cretaceous Mancos Shale (offshore marine); the first regressive phase, by the upper part of the lower Mancos Shale (offshore marine), Gallup Sandstone (nearshore marine to strandline), and the lowermost part of the Crevasse Canyon Formation (continental). The lower part of the Crevasse Canyon Formation (continental nearshore marine) and the lower part of the upper Mancos Shale (offshore marine) represent the second transgression; the uppermost Mancos Shale (offshore marine), Point Lookout Sandstone (nearshore marine to strandline), and the lower part of the Menefee Formation (continental), represent the second regression. The upper part of the Menefee Formation (continental), Cliff House Sandstone (strandline to nearshore marine), and the lower part of the Lewis Shale (offshore marine) comprise the last transgression recorded in the San Juan Basin, while the upper part of the Lewis Shale (offshore marine), Pictured Cliffs Sandstone (nearshore marine to strandline), Fruitland Formation (continental), and the Late Cretaceous Kirtland Shale (continental) represent the last regression. All post-Cretaceous strata in the San Juan Basin, including the Paleocene Ojo Alamo Sandstone and the Nacimiento Formation, are entirely continental in origin.

All of the Mesozoic and Cenozoic formations mentioned above are fossiliferous. Of particular research concern are the continental vertebrate-bearing units, which have been the object of intense investigation for over a century. The Morrison and Fruitland formations and the Kirtland Shale have all produced dinosaurs and primitive mammals. The Ojo Alamo Sandstone and the Nacimiento Formation have also produced primitive mammals. The San Juan Basin is one of the primary areas for the study of Late Cretaceous dinosaur extinctions and the explosive Paleocene mammal radiation. This is because the basin is one of the areas in the world where dinosaur and mammal-bearing strata are overlain with little or no apparent break in deposition by strata containing mammals, but not dinosaurs.

In addition to its diverse vertebrate fauna, the Fruitland Formation also contains economically significant coal deposits, as do the Crevasse Canyon and Menefee formations.

A brief description of each formation and references to publications that contain lists of taxa found in the formation are provided below.

MORRISON FORMATION

Exposures of the late Jurassic Morrison Formation extend from Montana to western South Dakota in the north to Arizona to western Oklahoma in the south. The formation, at least 500 feet thick, is continental in origin and includes fluvial sandstone; gray and variegated red, maroon, and green mudstone and siltstone; and lacustrine limestone. The Morrison Formation overlies the Jurassic San Rafael Group and disconformably underlies the Dakota Sandstone. The formation represents a continental facies deposited subsequent to the final Jurassic marine transgression, but prior to the beginning of the first major Cretaceous transgression recorded in the San Juan Basin.

The Morrison Formation has produced pollen, invertebrates, numerous dinosaur specimens, and remains of nearly 50 species of mammals, including the earliest and most primitive mammals known. Of the vertebrate taxa, only Camarasaurus is currently known from the San Juan Basin in New Mexico. Baker, Dane, and Reeside (1936); Clemens and others (1979); and Dodson, Behrensmeyer, and Bakker (1980) present lists of taxa.

DAKOTA SANDSTONE

The early (?) to late Cretaceous Dakota Sandstone extends from southeastern Montana to Minnesota in the north and from northeastern

Arizona to western Oklahoma in the south. The formation is roughly 50 to 200 feet thick. Locally, the lower part of the formation (orange fluvial sandstone with conglomerate at its base) is overlain by dark gray to black lagoonal mudstone and siltstone, which in turn is overlain by orange nearshore marine sandstone and interbedded shale. The Dakota Sandstone disconformably overlies the Morrison Formation where the early Cretaceous continental Burro Formation is not present. The top of the formation interfingers with the conformably overlying Mancos Shale. Together with the lower part of the latter formation, the Dakota Sandstone represents the first major late Cretaceous marine transgression recorded in the San Juan Basin.

The Dakota Sandstone has produced molluscan remains, including gastropods, bivalves, and ammonites, as well as plant fossils. Lists of taxa are provided in Cobban (1977); Pike (1947); and Tidwell, Ash, and Parker (1981).

MANCOS SHALE

The late Cretaceous Mancos Shale outcrops from northwestern Arizona and northwestern New Mexico northward to central Wyoming. Locally, the formation consists of roughly 300 to 2000 feet of gray offshore marine shales which conformably overlie and intertongue with the Dakota Sandstone and conformably underlie the Mesaverde Group. With the exception of its base, the Mancos Shale interfingers extensively with the Mesaverde Group. The lower and upper parts of the formation each represent a major marine incursion; they are separated by the regressive facies of the lower part of the Mesaverde Group (Gallup Sandstone and Crevasse Canyon Formation). A minor regression during the younger incursion is represented by a wedge of Mesaverde Group extending into the upper part of the shale formation.

The Mancos Shale has produced mostly molluscan fossils (primarily bivalves and ammonites), although microfossils and some crustacean, echinoid, and vertebrate remains are also reported (the latter specimen is from the northern San Juan Basin in Colorado). Lists of taxa are provided in Cobban (1973, 1977); Dane and Bachman (1957); Dane, Bachman, and Reeside (1957); Hazenbush (1973); Lamb (1973); O'Sullivan and others (1972); Owen (1973); Pike (1947); and Reeside (1924).

GALLUP SANDSTONE

The Late Cretaceous Gallup Sandstone occurs only in northwestern New Mexico and northeastern Arizona. The formation, roughly 50 to 450 feet thick, consists primarily of pale red to light gray coarse-grained cross-bedded sandstone representing nearshore marine and beach facies. Together with the conformably overlying Crevasse Canyon Formation, the unit comprises the lower part of the Mesaverde Group. The Gallup Sandstone and the lower part of the Crevasse Canyon Formation form a clastic wedge that extends between the upper and lower parts of the Mancos Shale. The Gallup Sandstone overlies and interfingers with the Mancos Shale and represents the first major Late Cretaceous marine regression recorded in the San Juan Basin.

The Gallup Sandstone has yielded molluscan remains, including gastropods, bivalves, and ammonites. Lists of taxa are provided in Dane, Bachman, and Reeside (1957); Pike (1947); and Reeside (1924).

CREVASSE CANYON FORMATION

The late Cretaceous Crevasse Canyon Formation crops out in northwestern New Mexico and northeastern Arizona. The formation, roughly 400 to 700 feet thick, is composed of strata representing continental, beach, and nearshore marine facies. The continental units are primarily interbedded grayish fine-grained sandstone, siltstone, and mudstone, and contain economically significant coal beds up to 10 feet thick. The formation overlies and interfingers with the Gallup Sandstone, and either underlies the Mancos Shale or underlies and is locally indistinguishable from the Menefee Formation. The Crevasse Canyon Formation is primarily a transgressive facies comprising the upper part of the lower Mesaverde Group clastic wedge that extends into the Mancos Shale. Together with the lower part of the upper part of the Mancos Shale, the unit represents the second major late Cretaceous marine transgression recorded in the San Juan Basin. Higher in the formation, a minor regressive facies occurs; this also extends into the Mancos Shale but conformably underlies the Point Lookout Sandstone.

The Crevasse Canyon Formation has yielded only plant remains. These are mentioned in Kues and others (1977).

POINT LOOKOUT SANDSTONE

The late Cretaceous Point Lookout Sandstone, which forms the base of the upper part of the Mesaverde Group, is developed only in northwestern New Mexico and southwestern Colorado. The formation, up to 400 feet thick, is composed primarily of orange sandstone with gray sandy-shale interbeds of nearshore marine and beach origin. The upper part of the unit, together with the lower part of the conformably overlying and interfingering Menefee Formation, represents the second major late Cretaceous marine regression recorded in San Juan Basin. This part of the Point Lookout Sandstone conformably overlies and interfingers with the Mancos Shale. The lower part of the Point Lookout Sandstone is a regressive facies separated from the upper part of the formation by a conformable wedge of Mancos Shale. The lower unit conformably overlies the Crevasse Canyon Formation.

The Point Lookout Sandstone has produced bivalves and ammonites in Colorado outcrops but not in New Mexico. The formation has also yielded plant remains. Taxa are listed by Cobban (1973), Kues and others (1977), Pike (1947), and Reeside (1924).

MENEFEE FORMATION

The late Cretaceous Menefee Formation occurs only in northwestern New Mexico and southwestern Colorado. The unit, 400 to 3000 feet thick, consists primarily of sandstone although the uppermost and lowermost parts of the formation are shale with economically significant coal beds up to 8 feet thick. The Menefee Formation, continental in origin, overlies and interfingers with the Point Lookout Sandstone, and either underlies and interfingers with the Cliff House Sandstone or underlies the undifferentiated Fruitland and Kirtland formations. The formation extends as a clastic wedge between adjacent marine strata. The upper part of the formation, together with the overlying Cliff House Sandstone and the lower part of the overlying Lewis Shale, represents the third and last major late Cretaceous marine regression recorded in the San Juan Basin.

The Menefee Formation has yielded plants and mollusks (gastropods, bivalves). Kues and other (1977), O'Sullivan and others (1972), and Tidwell, Ash, and Parker (1981) contain lists of taxa.

CLIFF HOUSE SANDSTONE

The late Cretaceous Cliff House Sandstone, locally the uppermost unit of the Mesaverde Group, is limited to outcrops in northwestern New Mexico and southwestern Colorado. The formation, roughly 100 to 800 feet thick, consists mostly of white to dark orangish sandstone representing regressive nearshore marine and beach facies. The Cliff

House Sandstone conformably overlies and interfingers with the Menefee Formation. It conformably underlies and interfingers with the Lewis Shale.

The fauna from the Cliff House Sandstone is composed almost entirely of mollusks, including gastropods, bivalves, and ammonites. Vertebrate (shark) remains are rare. Lists of taxa are provided in Cobban (1973), O'Sullivan and others (1972), and Reeside (1924).

LEWIS SHALE

Outcrops of the late Cretaceous Lewis Shale extend from northwestern New Mexico to central Wyoming. The formation consists of up to 2400 feet of gray to black shale with interbedded light brown sandstone and impure limestone, and represents an offshore marine facies. The Lewis Shale conformably overlies and interfingers extensively with the Cliff House Sandstone. It underlies and interfingers with the Pictured Cliffs Sandstone. Together with the Pictured Cliffs Sandstone and the overlying Fruitland and Kirtland formations, the upper part of the Lewis Shale represents the last marine regression recorded in the San Juan Basin.

The fauna from the Lewis Shale consists almost entirely of ammonites, most of which were collected outside of New Mexico. A marine reptile has also been collected from the Lewis Shale, as has a microfossil record. Anderson (1960), Cobban (1973), Reeside (1924), and Lucas and Reser (1981) present lists of taxa.

PICTURED CLIFFS SANDSTONE

The late Cretaceous Pictured Cliffs Sandstone occurs only in northwestern New Mexico and southwestern Colorado. The formation consists of roughly 50 to 300 feet of interbedded gray to orange and brown interbedded sandstone and shale representing nearshore marine and beach facies. The Pictured Cliffs Sandstone conformably overlies and interfingers with the Lewis Shale. It underlies and interfingers with the Fruitland Formation. The Pictured Cliffs Sandstone is the last marine unit to be deposited in the San Juan Basin.

The Pictured Cliffs Formation has produced mollusks (gastropods, bivalves, ammonites) as well as a diverse shark assemblage. Lists of taxa are provided by Cobban (1973), Fassett and Hinds (1971), and Reeside (1924).

FRUITLAND FORMATION

Exposures of the late Cretaceous Fruitland Formation occur only in northwestern New Mexico and southwestern Colorado. The formation consists of up to roughly 500 feet of yellow and gray to brown lenticular sandstone, siltstone, and mudstone beds representing fluvial and lacustrine facies, and more continuous beds of coal up to 15 feet thick representing coastal swamp deposits. These coal beds contain almost a third of the state's total reserves. The formation conformably overlies and interfingers with the Pictured Cliffs Formation. The Fruitland Formation becomes more shaley upsection, and its conformable contact with the overlying Kirtland Shale is gradational and arbitrarily placed.

The Fruitland Formation has yielded numerous plants and a diverse fauna that includes mollusks, sharks, fish, salamanders, frogs, turtles, crocodilians, dinosaurs, lizards, snakes, and primitive mammals. Taxa are provided by Lucas (1981); Reeside (1924); and Tidwell, Ash, and Parker (1981).

KIRTLAND FORMATION (EXCLUSIVE OF NAASHOIBITO MEMBER)

Outcrops of the late Cretaceous Kirtland Formation occur only in northwestern New Mexico and southwestern Colorado. The lower part of the formation, primarily fluvial in origin, consists of lower and upper shale members, greenish gray in color and roughly 100 to 475 and 200 to 1000 feet thick respectively and a middle yellowish green sandstone member, roughly 100 to 600 feet thick. The Naashoibito Member is conformably overlying, and the Kirtland Formation itself conformably overlies the Fruitland Formation. The latter contact is gradational, the Kirtland Formation being distinguished by the absence of coal beds and carbonaceous shales. Volcanic ash near the middle of the Kirtland has been dated at 64.6 million years before the present (Lindsay, Butler, and Johnson 1981).

The lower part of the Kirtland Formation has produced plants (including pollen), mollusks, and a diverse vertebrate assemblage that includes sharks, fish, turtles, crocodiles, dinosaurs, and primitive mammals. The vertebrates comprise the Hunter Wash local fauna. Lists of taxa are provided by Anderson (1960), Lehman (1981), Lucas (1981), and Reeside (1924).

KIRTLAND FORMATION, NAASHOIBITO MEMBER

The late Cretaceous Naashoibito Member is restricted to northwestern New Mexico. This member has been assigned to both the Kirtland Formation (Baltz, Ash, and Anderson 1966) and the locally overlying Ojo Alamo Sandstone (Powell 1973). The unit is here considered to be uppermost member of the Kirtland Formation because of lithologic similarities between their respective strata and the angular unconformity separating the Naashoibito Member from the Ojo Alamo Sandstone. The member consists of up to approximately 90 feet of fluvial strata, a buff fine-grained to conglomeratic sandstone overlain by banded gray and purple shale with interbedded grayish white sandstone.

The Naashoibito Member has produced a diverse vertebrate assemblage termed the Alamo Wash local fauna, which contains fish, turtle, crocodilian, and dinosaur remains. The unit appears to contain the last record of dinosaurs in the San Juan Basin. Lehman (1981) provides a list of taxa.

OJO ALAMO SANDSTONE

Outcrops of the early Palocene (Puercan) Ojo Alamo Sandstone are found only in northwestern New Mexico and southwestern Colorado. The formation consists of roughly 20 to 400 feet of fluvial deposits, including gray to buff, brown, and red banded shales interbedded with white to tan fine-grained to conglomeratic sandstone. The contact with the underlying Kirtland Shale may be locally conformable, but elsewhere is represented by an angular and erosional unconformity with up to 50 feet of relief. The Ojo Alamo Sandstone conformably underlies and interfingers with the Nacimiento Formation.

Although the Ojo Alamo Sandstone was first considered to be late Cretaceous in age, on the basis of dinosaur remains, these remains were later found to have been collected in or reworked from the underlying Kirtland Formation (Baltz, Ash, and Anderson 1966; Lucas 1981). The Ojo Alamo Sandstone has produced fossil plant remains (including pollen) and a diverse mammal assemblage. Anderson (1960); Kues and others (1977); and Tidwell, Ash, and Parker (1981) present lists of taxa.

NACIMIENTO FORMATION

The early to middle Paleocene Nacimiento Formation crops out only in northwestern New Mexico and southwestern Colorado. The unit consists of drab siltstone and mudstone with maroon bands, and interbedded lenticular sandstone. The Nacimiento Formation conformably overlies and interfingers with the Ojo Alamo Sandstone, or, where the Ojo Alamo Sandstone is not present, the Kirtland Shale. The formation is overlain by the Eocene San Jose Formation.

The Nacimiento Formation has produced plant fossils (including pollen) and invertebrates, as well as vertebrate assemblages of early (Puercan) and middle Paleocene (Torrejonian) age. Lists of taxa are provided by Kues and others (1977), Sloan (1981), Sullivan (1981), Tidwell and others (1981), and Tsentas (1981).

GLOSSARY

Fluvial--of, or pertaining to, rivers; produced by river action; e.g., fluvial sediments.

Formation--the primary unit of geologic mapping; a set of rocks that share some distinctive feature of lithology.

Invertebrate--animals without a notochord or backbone.

Lacustrine--produced by or belonging to lakes, e.g., lacustrine sediments.

Lithology--the physical character of a rock; the study and description of rocks.

Paleocology--the science of the relationship between ancient organisms and their environment.

Paleontology--the science that deals with the life of past geological ages, based on the study of the fossil remains of plants and animals.

Stratigraphy--the branch of geology that deals with the formation, composition, sequence, and correlation of stratified rocks.

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