HYDROLOGY 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 11 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
(303) 234-2368 FTS 234-2368

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 Gaspar 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

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Prepared by

Woodward-Clyde Consultants

for the

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

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NEW MEXICO GENERATING STATION

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.

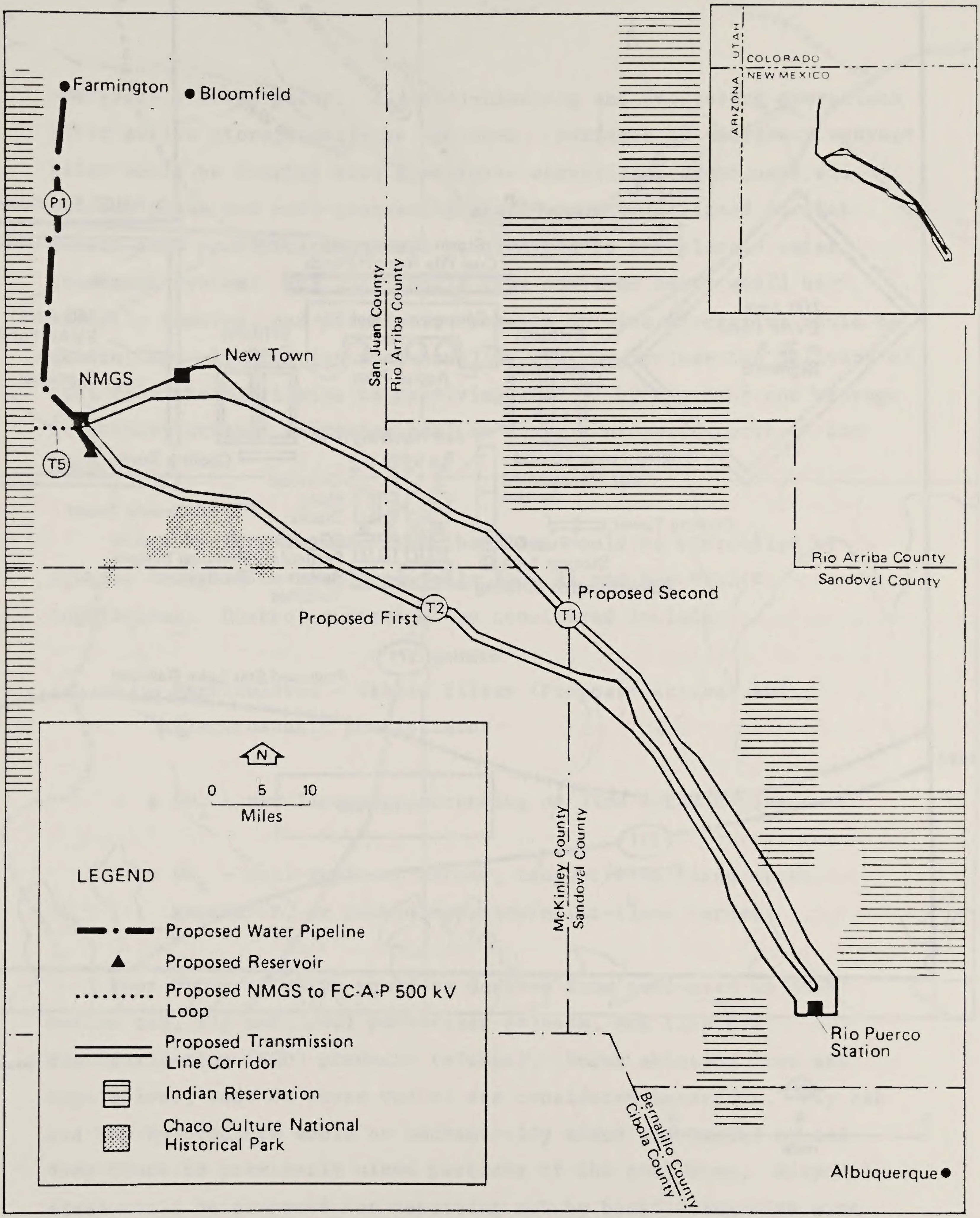
In order to accomplish these objectives and still provide the depth and background required for an analytic impact statement, this technical report has been prepared for the New Mexico Generating Station (NMGS) project. In this report, impacts that were not identified as significant but which are still 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

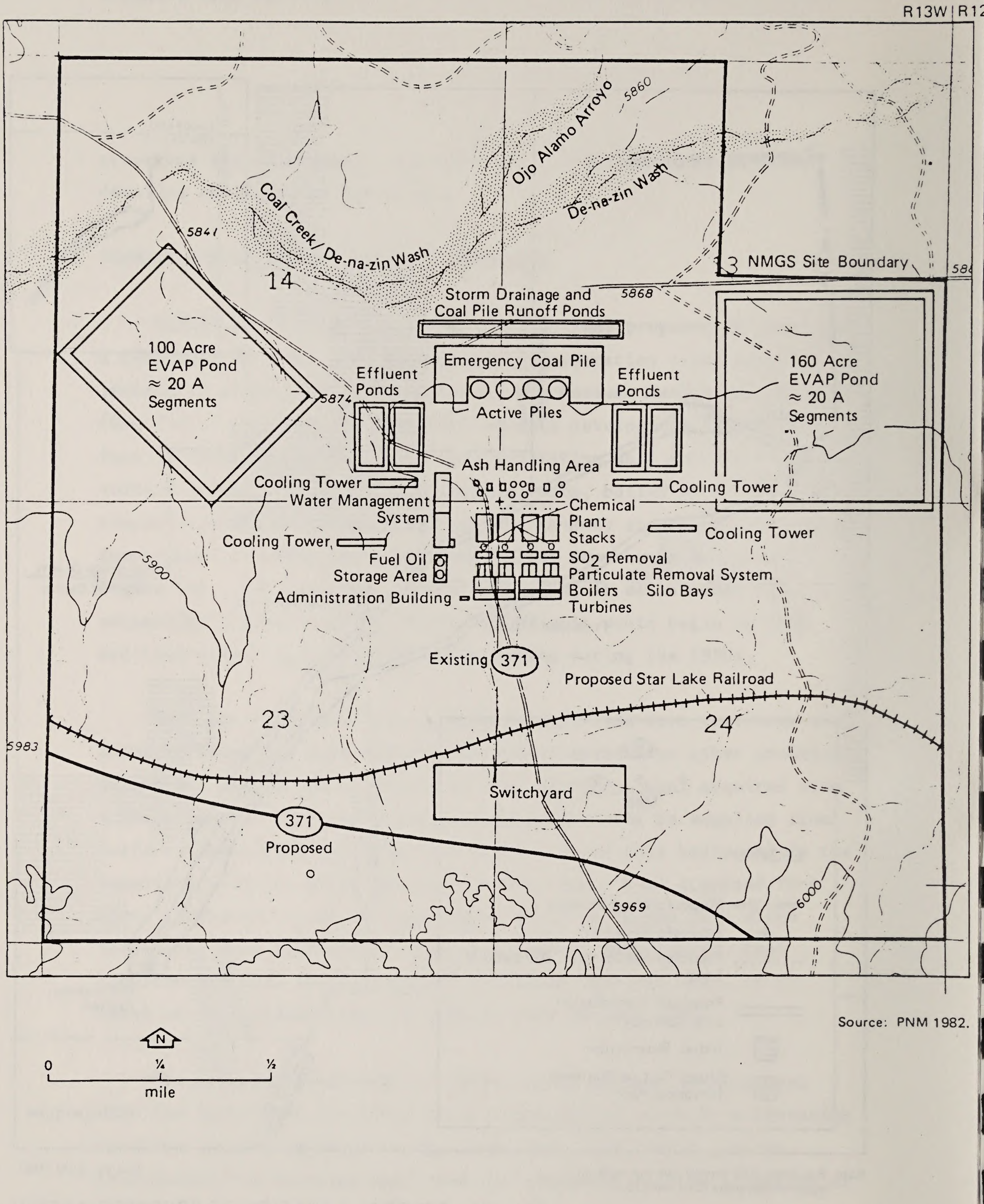


Figure 1-1. STATION LAYOUT

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.

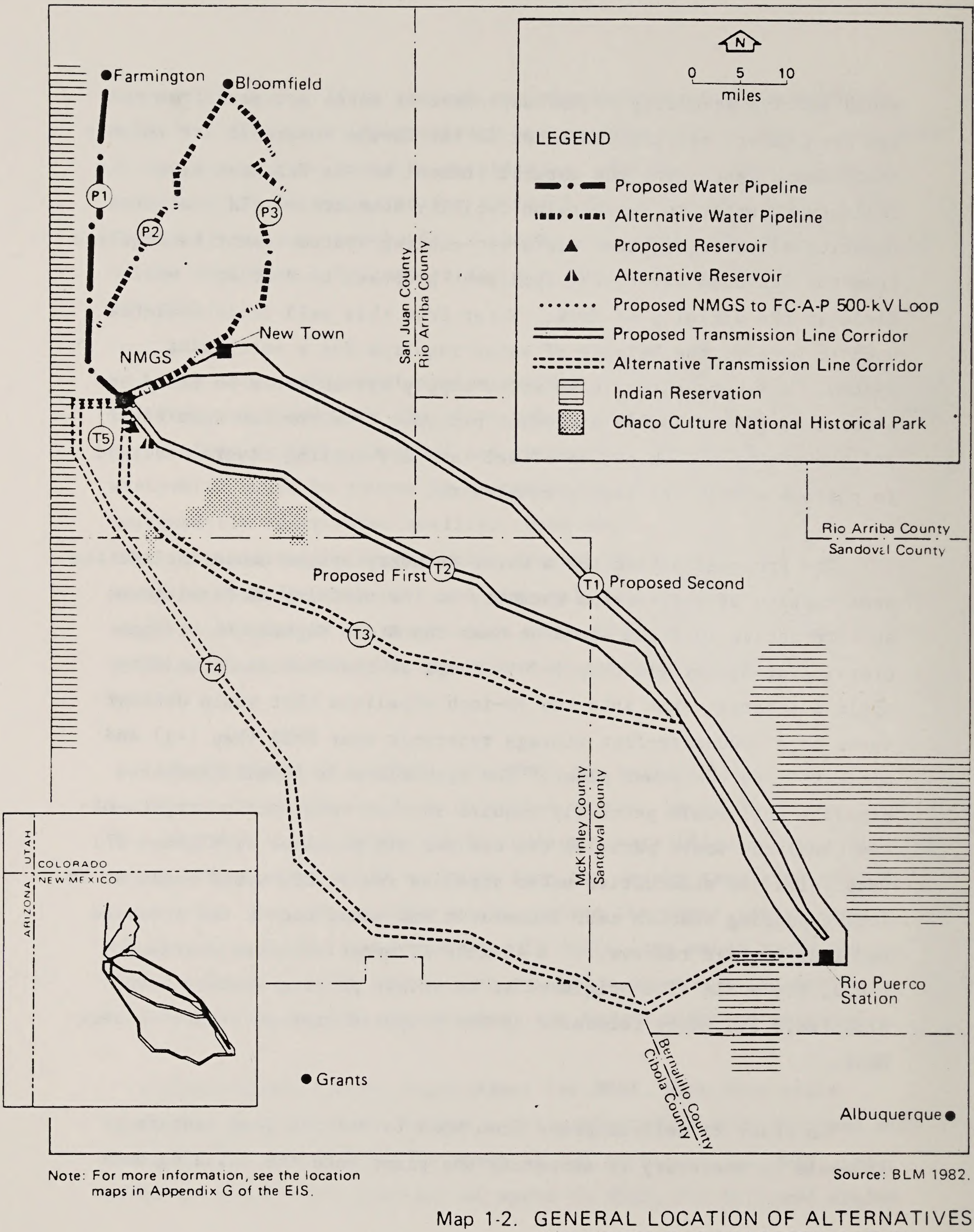
The water management system would contain all equipment necessary to treat and supply all the plant makeup water and potable water. The power plant would be designed and operated as a zero-discharge plant; wastewater would be reused by cascading it to uses requiring successively lower water quality. 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 about 35,000 acre-feet per year. In order to supply this quantity of water to NMGS, the Proposed Action would involve acquiring 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 wetcooling 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											
	Intake Pipeline and	500-kV Trans-mission	Construction					Operation					Total	Annual
Year	Reservoir	Line	Unit 1	Unit 2	Unit 3	Unit 4	Total	Unit 1	Unit 2	Unit 3	Unit 4	Total	Employment	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 (Baseline 1 and Baseline 2) were considered, along with criteria for each, in developing a status for the various non-SJBAP actions proposed for the San Juan Basin area. Each level of project development would have a corresponding use of resources (i.e., water supply) and consequently would affect the environment. These development levels were assumed to constitute the existing conditions during NMGS and were used as reference levels of development against which the effects due to NMGS may be considered.

- 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 were in some phase of the application stage by June 1, 1981. 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.

2.0

FRAMEWORK FOR ANALYSIS

2.A PURPOSE AND SCOPE

The purpose of this report is to assess the potential impacts of the proposed New Mexico Generating Station (NMGS) on ground-water and surface-water hydrologic conditions and water users. The potential impacts that have been considered consist of declines in water levels in wells, reductions in streamflow and spring flow, flooding, potential for land subsidence due to ground-water withdrawal, and changes in runoff conditions. These impacts have been evaluated for the proposed and alternate sources of cooling water for NMGS, the plant site, the components of the water supply system (pipelines and intake structures), and transmission lines.

The scope of this impact assessment has conformed to the general process for identifying hydrologic impacts for an EIS, which is as follows:

- Evaluate which aspects of the hydrologic environment are most likely to be affected by NMGS
- Identify the potentially affected geographical region (study area)
- Define indicators that can be applied to assess whether or not a potential impact would be considered significant
- Project future hydrologic conditions in the study area without NMGS, including projects planned for the same approximate time period
- Project future hydrologic conditions in the study area with NMGS

- Evaluate which changes in future hydrologic conditions could be directly or indirectly attributed to NMGS
- Develop mitigation measures that could help to alleviate any potentially adverse NMGS-related and cumulative impacts or enhance any potentially beneficial impacts

In northwestern New Mexico, many energy resource development projects are currently taking place or are planned to occur within the next decade. In the EIS, the potential additive impacts of these concurrent developments on the hydrologic environment must be addressed. The projects, on which the impact analysis has been based, are part of the Baseline 1 and Baseline 2 that the Bureau of Land Management (BLM) has compiled. Those projects included in Baselines 1 and 2 that would comsumptively use water from the same sources as the proposed NMGS, along with several water users not on the BLM baselines, have been used to project future hydrologic conditions in the study area.

The aspects of the hydrologic environment most likely to be affected by NMGS (principal hydrologic issues) and the indicators that can be applied to assess whether or not an impact would be considered significant (indicators of significance) are discussed in Sections 1.C and 1.D, respectively. These steps in the impact assessment were performed during the scoping process conducted by the BLM in early 1981.

Most of this report is a discussion of the affected environment and related hydrologic impacts of the various components of NMGS. Because the study areas of the components of NMGS are quite different, each applicable project facility is discussed in a separate section of the technical report. The methods of investigation, study areas, affected environment and impacts of each applicable project facility are presented as follows:

- Section 3 - Proposed Source of Cooling Water (Navajo Reservoir on the San Juan River)
- Section 4 - Alternate Source of Cooling Water (well field in San Juan Underground Water Basin)
- Section 5 - NMGS Plant Site

- Section 6 - Water Supply System (pipelines and intake structure)
- Section 7 - Transmission Lines

2.B SOURCES OF INFORMATION

Published and unpublished reports, streamflow records, modeling studies, water level measurements, well logs, aquifer tests and other hydrologic data were collected from federal, state and private organizations. Streamflow records for selected surface-water gaging stations were obtained from the U.S. Geological Survey's WATSTORE computer data storage and retrieval system in Albuquerque, New Mexico. Information on the ground-water resources of the study area was obtained from reports and data compilations prepared for the San Juan Basin Study, which has been performed cooperatively by the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey. In addition to the numerous publications that were reviewed (and are listed in Appendix A), personal contacts were made with individuals in a number of organizations. Among the more important of these contacts were:

- New Mexico Bureau of Mines and Mineral Resources (Socorro)
- New Mexico Energy and Minerals Department (Santa Fe)
- New Mexico Interstate Stream Commission (Santa Fe)
- New Mexico State Engineer Office (Santa Fe)
- John Shomaker (private consultant, Albuquerque)
- U.S. Bureau of Land Management (Albuquerque, Farmington and Santa Fe, New Mexico)
- U.S. Bureau of Reclamation (Amarillo, Texas; Durango, Colorado; Salt Lake City, Utah)
- U.S. Fish and Wildlife Service (Albuquerque)
- U.S. Geological Survey, Water Resources Division (Albuquerque)
- Upper Colorado River Commission (Salt Lake City, Utah)

2.C PRINCIPAL HYDROLOGIC ISSUES

The principal hydrologic issues that have been addressed in this impact assessment are those aspects of the hydrologic environment that are most likely to be affected by the proposed NMGS. These issues were first developed by Woodward-Clyde Consultants in consultation with the Bureau of Land Management during preparation of a Preliminary Data Collection Plan in March, 1981. The issues were selected on the basis of: (1) the description of the proposed action and alternatives; and (2) generalized knowledge of hydrologic conditions in the potentially affected geographic region. From initial analysis of the project description and hydrologic conditions, it became apparent that some aspects of the hydrologic environment would be more likely than others to be affected by the proposed NMGS, or that some could be affected much more seriously than others. The hydrologic issues preliminarily identified were reviewed by BLM for completeness with respect to (1) issues raised during the scoping meetings in early 1981, and (2) compliance with required permits and applicable regulations. A revised set of hydrologic issues was submitted by Woodward-Clyde Consultants to BLM in a Final Data Collection Plan, which BLM approved in November, 1981. On this basis, subsequent collection and analysis of data were focused on issues that would be most relevant to the assessment of potential hydrologic impacts related to NMGS and to other actions proposed to occur contemporaneously and in the same approximate geographic region.

The principal hydrologic issues that have been addressed are:

1. <u>Impact of proposed water uses for NMGS on other surface-water users</u>. This issue includes: (1) the availability of water from Navajo Reservoir and the Upper Colorado River Basin for uses in New Mexico; (b) provisions of interstate compacts and treaties that pertain to proposed surface-water uses; (c) effects of diversion of water from the San Juan River on downstream users; (d) discussion of the San Juan River stream-system adjudication

suit and other conflicts or controversies that may affect water rights proposed for project uses; and (e) effects of pumping the well field on streamflow or spring flow.

2. Impact of proposed water uses for the project on other ground-water users. This issue inclues (a) the effects of pumping the well field that would tap the Westwater Canyon Member aquifer on other wells within the study area; and (b) effects of other project components on ground-water users.

3. Flooding potential (comparison of 100-year floodplain with locations of project facilities). For "critical actions" associated with the proposed NMGS, the 500-year floodplain is used for comparison. This issue also inclues an evaluation of an increase in flooding potential associated with a project facility.

4. Subsidence potential (evaluation of potential for land subsidence due to withdrawal of ground water from the well field).

5. Changes in runoff conditions. This issue includes: (a) effects on peak discharge; (b) effects of impoundments and/or diversions associated with the proposed NMGS; and (c) effects on recharge to alluvial aquifers.

2.D INDICATORS OF SIGNIFICANCE

The proposed NMGS is likely to result in certain changes to the existing hydrologic environment. The purpose of an EIS is not only to identify potential changes but also to evaluate which changes should be considered as significant impacts (in either beneficial or adverse ways). For this purpose, certain threshold values were selected during the scoping process for use as indicators for assessing the significance of environmental impacts on the hydrologic systems associated with NMGS. One or more indicators were established to correspond to each of the principal hydrologic issues discussed in Section 2.C. In general, an environmental impact would be considered to be significant if the predicted effect exceeds the value of the indicator(s) for that particular hydrologic issue. The rationale for selecting each indicator is also presented.

The indicators of significance are as follows:

1. <u>Impact on Surface-Water Users</u>. (a) Indicator: project causes a predictable decrease in water available to existing users. Various statistical low flow measures (e.g., 10-year 15-day streamflow) or historic drought periods are adopted as standards of reference by which to judge the impacts on existing surface-water users. Rules for water allocation in the event of shortages, which are specified in interstate compacts and in federal and state regulations, are complied with in the evaluation of these impacts. (Impacts on in-stream users, such as habitat for aquatic life, are addressed in the Draft Technical Report on Wildlife and Aquatic Biology.)

   rationale: predictable change in water availability based on statistical treatment of streamflow data.

   <u>or</u>

   (b) Indicator: project causes the average daily flow of any perennial stream or spring to decrease by more than 15 percent.

   rationale: average accuracy of flow measurement.

2. <u>Impact on Ground-Water Users</u>. Indicator: the New Mexico Generating Station water supply systems cause the potentiometric surface in any aquifer to decline by more than 25 feet.

   rationale: estimated accuracy of ground-water basin model.

3. Impact Due to Flooding Potential. (a) Indicator: project facilities that are located within a 100-year floodplain. The 500-year floodplain is used for comparison for "critical actions" associated with NMGS.

rational: quidelines prepared by Water Resources Council, "Floodplain Management": Federal Register, v. 43, n. 29, Friday, February 10, 1978, p. 6030-6055.

and

(b) Indicator: Flood elevations are increased by more than one foot.

rationale: adopted from "Rules and Regulations of the National Flood Insurance Program": Federal Register, v. 41, n. 207, October 26, 1976.

4. Impact Due to Subsidence Potential. Indicator: ground-water withdrawal for the project that causes a potential for land subsidence of greater than 1 foot.

rationale: value judgment based on possible damage to well casings and change in slope of irrigation canals.

5. Impact Due to Changes in Runoff Conditions. Indicator: (a) project causes an increase of more than 15 percent in the peak runoff in an ephemeral stream from a precipitation event with a 10-year recurrence interval.

rationale: adopted from Section 816.44 of Surface Coal Mining and Reclamation Operations, Permanent Regulatory Program, U.S. Department of Interior: Federal Register, v. 44, n. 50, March 13, 1979, p. 15399.

or

(b) Indicator: project causes the recharge to alluvial aquifers to decline by more than 15 percent, due to impoundment of ephemeral streamflow.

rationale: average accuracy of flow measurement.

2.E DISCLAIMER

This report does not evaluate whether the proposed water uses for New Mexico Generating Station would impair existing surface-water or ground-water rights in New Mexico. The determination of impairment of water rights is the responsibility and jurisdiction of the New Mexico State Engineer.

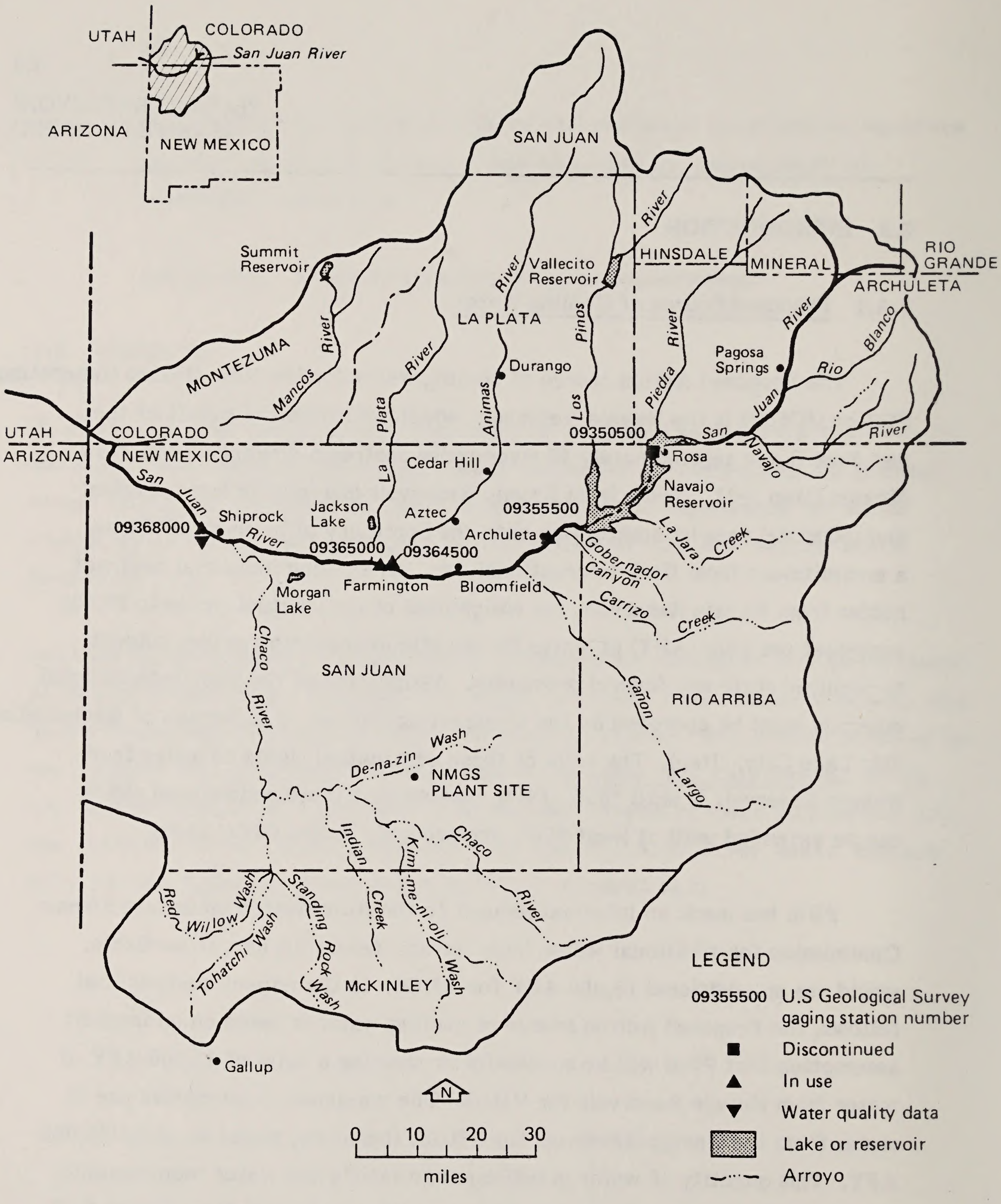
Nothing in this impact assessment is intended to interpret the provisions of the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with the United Mexican States, the decree entered by the Supreme Court of the United States in Arizona vs. California, et al., the Boulder Canyon Project Act, the Boulder Canyon Project Adjustment Act, the Colorado River Storage Project Act, the Colorado River Basin Project Act, or the Colorado River Basin Salinity Control Act.

3.A INTRODUCTION

3.A.1 Proposed Source of Cooling Water

The Proposed Action source of cooling water for the New Mexico Generating Station (NMGS) is the Navajo Reservoir, which impounds the runoff of the San Juan River approximately 47 river-miles upstream of Farmington, New Mexico (Map 3-1). Water from Navajo Reservoir is available for municipal and industrial uses by contracting with the Secretary of Interior. PNM has a commitment from Utah International, Inc., an existing industrial contract holder from Navajo Reservoir, for assignment of contractual rights to 20,000 acre-feet per year (AFY) of water for beneficial consumptive use, subject to required state and federal provisions. Assignment of the Utah International contract must be approved by the Contracting Officer (U.S. Bureau of Reclamation, Salt Lake City, Utah). The term of these contractual rights to water from Navajo Reservoir is until 2005. PNM expects that these contractual rights can be extended until at least 2040, and probably longer (WCC 1982).

PNM has made an informal request to the New Mexico Interstate Stream Commission for additional water from Navajo Reservoir, and, if available, would use an additional 15,000 AFY for NMGS. In the impact analysis that follows, the Proposed Action source of cooling water is based on an implicit assumption that PNM will be successful in securing a total of 35,000 AFY of water from Navajo Reservoir for NMGS. The maximum consumptive use of water from the Navajo Reservoir for NMGS, therefore, would be about 35,000 AFY. This quantity of water is sufficient to satisfy the water requirements of the power plant (see Technical Report on Project Description, Figure 2-3) and any channel losses that would occur during conveyance of water from Navajo Dam to the point of diversion. The water requirements of the power plant are 34,560 AFY, which assumes a 100-percent plant capacity. The long-term



Source: Adapted from U.S. Bureau of Reclamation (1976b)

Map 3-1. SAN JUAN RIVER BASIN

average annual capacity factor for NMGS is assumed to be 65 percent, which would correspond to water requirements of 22,500 AFY (WCC, 1982).

Water from Navajo Reservoir for NMGS would be released from Navajo Dam and would flow downstream in the main channel of the San Juan River to a diversion facility near Farmington (Map 3-1). An alternative diversion facility near Bloomfield, approximately 10 river-miles upstream of Farmington, is also being evaluated (Map 3-1). The water required to be diverted from the San Juan River for NMGS, assuming 100-percent plant capacity, would be relatively uniform throughout the year and would average approximately 48 cubic feet per second (cfs). This quantity of water is equivalent to about 35,000 AFY. The 35,000 AFY used in the subsequent impact analysis is, therefore, a conservative value.

3.A.2 Methods of Investigation

Available hydrologic information about the San Juan River Basin and the Colorado River Basin was compiled in order to evaluate: (1) regional conditions, such as drainage basin boundaries, principal watercourses, floodplains, and water users; and (2) streamflow characteristics. Information on water law, major water projects, and water planning activities in the San Juan River and Colorado River basins was also obtained. The hydrologic characteristics of and availability of water from the San Juan River were characterized using this information and provided a baseline with which to evaluate the impacts of NMGS on existing and proposed future surface-water users and on runoff conditions.

3.A.3 Study Area

The San Juan River was the principal geographic area investigated for the assessment of impacts of water use from Navajo Reservoir for NMGS. The Colorado River was also considered because the apportionment of San

Juan River water for use in New Mexico is influenced by interstate compacts and a treaty pertaining to the Colorado River Basin.

3.B ADMINISTRATION OF WATER RESOURCES

3.B.1 Introduction

The San Juan River is a tributary of the Colorado River, and the rights of New Mexico to waters from the San Juan River are governed by the terms of two compacts between the various states in the Colorado River Basin, and a treaty between the United States and Mexico. Water rights in the San Juan River in New Mexico are administered by the State Engineer. The New Mexico Interstate Stream Commission works with other states and the federal government to administer the interstate compacts and to protect, conserve, and develop New Mexico's water resources.

3.B.2 New Mexico State Engineer

All surface water flowing in streams and watercourses in New Mexico belongs to the public and is subject to appropriation for beneficial use. Beneficial use is the basis, measure, and limit of the right to use water, and priority in date of appropriation gives the better right. Water rights are administered by the State Engineer, in accordance with provisions of the New Mexico Constitution and statutes, the adjudications of the courts, the terms of the interstate water compacts, and the State Engineer's rules and regulations.

Surface water throughout the state of New Mexico is subject to regulation by the State Engineer under the 1907 water code (New Mexico Statutes, Article 5, Chapter 72, NMSA, 1978, Annotated). In New Mexico a water right is a property right, and an important value of that right is the right to change the point of diversion, place, or purpose of use of the water right, provided that the change can be made without impairing or having a detrimental effect on any existing water right. Water rights may be transferred, sold, or leased. Water rights are based on the doctrine of prior appropriation, which separates the ownership of land from the right to use water. The water may be used on or in connection with land whether or not it is contiguous to the water supply. All beneficial uses of water are on an equal footing without regard to the economic value produced by any beneficial use; use of water for power-plant cooling is as appropriate a beneficial use as the use of water for irrigation. Finally, New Mexico does not recognize in-stream uses, such as protection of aquatic life, as a beneficial use of water.

3.B.3 Compacts and Treaties

The rights of New Mexico to beneficially use waters of the San Juan River are governed by the terms of the Colorado River Compact (1922), the La Plata River Compact (1922), the treaty between the United States and Mexico (1944), the Upper Colorado River Basin Compact (1948), and the Animas-La Plata Project Compact (1968).

3.B.3.a Colorado River Compact. The Colorado River Compact, an interstate agreement between the states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, was negotiated by representatives of those states in 1922, and became effective after congressional ratification in 1928 and presidential proclamation in 1929. Because the compact is of major significance in analyzing the availability of water from the San Juan River, and since commonly used terms in the administration of the water resources of the Colorado River Basin are defined there, the full text of the Colorado River Compact is presented in Appendix C.

The Colorado River Compact divided the Colorado River Basin into two basins—the Upper Basin and the Lower Basin—with the dividing point being Lee Ferry, Arizona, a point in the river 1 mile below the mouth of the Paria River. Lee Ferry is approximately 29 river-miles downstream from the Utah-Arizona border, and about 15 river-miles downstream from Glen Canyon Dam. Lee Ferry should not be confused with Lee's Ferry, Arizona, a stream-flow gaging station on the Colorado River upstream of its confluence with the Paria River.

Article III of the Colorado River Compact stipulates how the water of the Colorado River system is apportioned to the Upper and Lower basins, with the provision that further equitable apportionment may be made. The compact allocates to the Upper Basin and to the Lower Basin, respectively, the beneficial consumptive use of 7.5 million AFY (Article III[a]). In addition to the 7.5 million AFY, the Lower Basin is entitled to increase its beneficial consumptive use of such waters by 1 million AFY (Article III[b]). The states of the upper division (Colorado, New Mexico, Utah, and Wyoming) must not cause the flow of the Colorado River at Lee Ferry to be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive years (see Appendix C).

The Colorado River Compact also stipuates how waters of the Colorado River system shall be supplied to Mexico if the United States should recognize in Mexico any right to use such waters (Article III[c]). Such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b) of Article III. If this surplus is insufficient, then the deficiency shall be borne equally by the Upper Basin and the Lower Basin. Whenever necessary, the states of the upper division shall deliver water at Lee Ferry to supply one-half of the deficiency (in addition to the 75 million acre-feet every 10 years). This provision of the Colorado River Compact is discussed further in the next section.

3.B.3.b Treaty Between the United States and Mexico. A treaty between the United States and Mexico, whose purpose is to fix and delimit the rights of the two countries with respect to the waters of the Colorado and other rivers, was signed in 1944. Article 10 of the treaty allots to Mexico, of the waters of the Colorado River, a guaranteed annual quantity of 1.5 million acre-feet (1,850,234,000 cubic meters) (Upper Colorado River Commission 1959). This allotment of 1.5 million AFY is to be delivered in accordance with Article III(c) of the Colorado River Compact.

The interpretation of the compact with respect to the obligation of the states of the upper division to deliver water to Lee Ferry to satisfy the Mexican treaty is controversial. The states of the upper division take the position that they have no such obligation if a proper accounting of water uses in the Lower Basin is made. The states of the upper division believe that sufficient "surplus waters" under Article III(c) exist in the Lower Basin to supply the entire Mexican treaty guarantee (Reynolds 1975; Mutz 1981). On the other hand, if no "surplus waters" exist in the Lower Basin, the states of the upper division would be obligated to deliver an additional 750,000 AFY to supply one-half of the waters guaranteed by the Mexican treaty.

3.B.3.c Upper Colorado River Basin Compact. The Upper Colorado River Basin Compact was signed at Santa Fe, New Mexico, on October 11, 1948, with the states of Arizona, Colorado, New Mexico, Utah, and Wyoming as parties. It subsequently was ratified by the respective legislatures, consented to by the Congress, and approved on April 6, 1949. The Upper Colorado River Basin Compact apportions the water to each of the Upper Basin states from the supply made available to the Upper Basin by the Colorado River Compact. The full text of the Upper Colorado River Basin Compact is presented in Appendix C.

Rather than specific quantities of water, the Upper Colorado River Basin Compact apportions to each state a quantity of consumptive use per year that is a share of the Upper Basin's allotment under the Colorado River Compact. Fifty thousand acre-feet per year are allocated to Arizona; and of the remainder, 51.75 percent is allocated to Colorado, 11.25 percent to New Mexico, 23.00 percent to Utah, and 14.00 percent to Wyoming.

The Upper Colorado River Basin Compact allows an Upper Basin state to exceed its apportioned use in any water year as long as the excess use does not deprive another Upper Basin state of its apportioned use during that water year (Article III[b]). Article IV of the Compact requires that if curtailment of use of water by the states of the upper division is necessary in order to meet delivery obligations at Lee Ferry (Article III of Colorado River Compact), then such curtailment shall be made, first, by any state that has consumptively used more than its apportioned share of water for the 10 preceding years by an amount equal to the excess use and, secondly, by each of the states of the upper division in proportion to the state's use in the prior year (see Appendix C).

Article VIII of the compact created an interstate administrative agency known as the Upper Colorado River Commission. The commission administers the provisions of the Upper Colorado River Basin Compact and conducts various engineering, hydrologic, and legal studies.

3.B.4 Acts Of Congress

3.B.4.a Colorado River Storage Project Act. The Colorado River Storage Project Act, Public Law 84-485, was authorized by the U.S. Congress on April 11, 1956. The purposes of the Act were to provide for comprehensive water development, regulate the flow of the Colorado River, store water for beneficial consumptive use, control floods, and produce power. An additional purpose was to make use of the apportionments to the Upper Basin states by the Upper Colorado River Basin Compact.

To carry out these purposes, the Act directed the construction of four storage units: (1) Glen Canyon Dam and Lake Powell on the Colorado River in Arizona and Utah; (2) Navajo Dam and Reservoir on the San Juan River in New Mexico and Colorado; (3) Flaming Gorge Dam and Reservoir on the Green River in Utah and Wyoming; and (4) the Curecanti Storage Unit (Blue Mesa, Morrow Point, and Crystal reservoirs) on the Gunnison River in Colorado. Public Law 96-375, approved October 3, 1980, authorized the renaming of the Curecanti Storage Unit as the Wayne N. Aspinall Storage Unit.

The Act authorized the construction of 11 participating irrigation projects. Ten additional participating projects have been authorized by subsequent congressional legislation (Upper Colorado River Commission 1981).

3.B.4.b Navajo Indian Irrigation Project Act. Public Law 87-483, enacted on June 13, 1962, authorized the Secretary of the Interior to construct the Navajo Indian Irrigation Project and the initial stage of the San Juan-Chama Project as participating projects in the Colorado River Storage Project. The Navajo Indian Irrigation Project (NIIP) was to be constructed for the principal purpose of furnishing irrigation water to 110,630 acres of land, and to provide capacity for municipal and industrial water supplies or miscellaneous purposes over and above the diversion requirements for irrigation. The Act requires all users of water from Navajo Reservoir to have a water delivery contract with the Secretary of the Interior. The Secretary may not issue a long-term contract until he has determined by hydrologic investigations that sufficient water to fulfill this contract is available for use in the state of New Mexico, during the term of the contract, under the allocations made in Articles III and XIV of the Upper Colorado River Basin Compact (see Appendix C). The Secretary of the Interior must submit this determination to the Congress of the United States, and Congress must approve such a long-term contract.

The Navajo Indian Irrigation Project Act (Public Law 87-483) requires that all users of water from Navajo Reservoir share proportionately in water shortages on the basis of their respective authorized diversion.

3.B.5 Indian Water Rights

Water rights available to the three Indian tribes in the San Juan River Basin in New Mexico (Navajo, Jicarilla Apache, and Ute Mountain tribes) have never been quantified, nor have they been adjudicated by the courts. The tribes may possess rights under the so-called "Winters doctrine," a term which, as a matter of convenience, is used to group together various Indian claims to water. The Winters doctrine is derived from the Supreme Court decision in Winters v. United States, 207 U.S. 564 (1908), which holds that inherent in the establishment of an Indian reservation is a reservation of sufficient water to accomplish the originally intended purposes. The Navajo, Jicarilla Apache, and Ute Mountain tribes have not yet had a Winters doctrine right decreed in the courts.

On March 13, 1975, the state of New Mexico initiated an adjudication suit (State of New Mexico ex rel. State Engineer v. United States of America, et al., Civil No. 75-184, District Court, 11th Judicial District, San Juan County, State of New Mexico) of the San Juan River system. The rights of the United States in this suit include those of the Indian tribes in the San Juan River Basin. This action is still pending. The legal staff of the New Mexico State Engineer Office is proceeding with interrogatories to discover the water-rights claims of the Navajo, Jicarilla Apache, and Ute Mountain tribes.

In congressional hearings on bills to authorize the Navajo Indian Irrigation Project and the San Juan-Chama Project, the Navajo Tribe consented to the provision that all Navajo Reservoir water users would have equal priority. The Navajo Tribe also "relinquished its rights under the Winters doctrine for the water necessary to irrigate the Navajo Indian Irrigation Project, in order to provide a practicable plan for comprehensive development of the resources and industrial potential of the San Juan Basin" (testimony by J. Maurice McCabe, Executive Secretary, Navajo Tribe, on Senate Bill S.107, March 15, 1961). The Navajo Tribe further qualified its position with respect to its Winters doctrine rights in a resolution passed by a duly called session of the Navajo Tribal Council, and made part of the record of testimony presented to the House of Representatives Committee on Interior and Insular Affairs on April 24, 1961. That testimony is as follows:

The Navajo Tribe
Window Rock, Ariz., April 24, 1961

Hon. Wayne N. Aspinall
Chairman, Interior and Insular Affairs Committee
House of Representatives
Washington, D.C.

Dear Mr. Aspinall:

Please permit me to supplement my testimony of this date before the committee as follows:

In reaching an agreement with the State of New Mexico and other members of the Upper Colorado River compact, the Navajo Tribe qualified its position in respect to legal rights which the tribe enjoys under the doctrine of Winters v. United States (207 U.S. 564), assuring to it certain paramount rights in respect to waters of the San Juan River, among others, in order to accomplish a practical and equitable division of water among all parties concerned. This concession was only agreed to by the tribe in consideration of getting the Navajo irrigation project established in New Mexico as provided in the above bills.

It should be known to the committee and other interested parties that the Navajo Tribe will not consider itself bound by this agreement unless the irrigation project is in fact established. It is clearly understood by all interested parties, I believe, that the tribe's concession in respect to the Winters doctrine applies to no other situation than this one.

In answer to Congressman Haley's question after I had left the witness stand today, the resolutions adopted by the Advisory Committee of the Navajo Tribal Council and by the tribal council in support of this project are already a part of the hearings, and can be found in House Document No. 424, 86th Congress, 2d session, June 20, 1960, at pages 282 and 394, respectively.

Permit me to thank you for the courtesies extended to me while appearing as a witness before the committee today.

Sincerely yours,

J. Maurice McCabe
Executive Secretary

The water entitlement of the Navajo Tribe is the subject of a memorandum from the Solicitor to the Under Secretary, U.S. Department of the Interior, dated December 6, 1974. The full text of this memorandum is presented in Appendix C. The Solicitor indicates that the Navajo Tribe is limited to the use of so much project water as would be reasonably necessary to irrigate the 110,630 acres authorized in the Navajo Indian Irrigation Project Act (Public Law 87-483), except to the extent it contracts to purchase other waters for municipal and industrial purposes under the separate procedures established in Section 4 of the Act. Irrigation of 110,630 acres of land by a sprinkler system is estimated by the Bureau of Reclamation to require a diversion of 357,000 AFY of water, resulting in an estimated consumption of 254,000 AFY (U.S. Bureau of Reclamation 1981b). The New Mexico Interstate Stream Commission estimates the net depletion to be 226,000 AFY (New Mexico Interstate Stream Commission 1981). Under the authorizing Act, depletion of the San Juan River by NIIP could be less than 226,000 or more than 254,000 AFY.

The entitlement of the Navajo Tribe to waters of the San Juan River system, based on the NIIP authorizing Act (Public Law 87-483), is not clear, and another opinion by the Solicitor of the Department of the Interior is being prepared at present (J. Morrison 1982).

The effects of the various compacts, acts of Congress and New Mexico water law on the availability of water for NMGS and other existing and proposed future uses in the San Juan River Basin will be discussed in Section 3.D.

3.C HYDROLOGY OF THE SAN JUAN RIVER BASIN

3.C.1 Surface Water Features

The San Juan River Basin includes all of the surface drainage system of the San Juan River in New Mexico, an area of approximately 9740 square miles (Map 3-1). The river's headwaters begin on the continental divide in the San Juan Mountains, north and east of Pagosa Springs, Colorado. Elevations in the San Juan River Basin in New Mexico range from over 9000 feet (MSL) along the drainage divide in the Chuska Mountains to less than 5000 feet where the San Juan River leaves New Mexico in the Four Corners area. The major tributaries entering the San Juan River in New Mexico are the Los Pinos, Animas, and La Plata rivers, which originate in Colorado, and the Chaco River, an intermittent stream that originates in New Mexico (Map 3-1). The San Juan River Basin in New Mexico contains two major surface-water impoundments: (1) Navajo Reservoir on the San Juan River, which has a usable capacity of 1,696,000 acre-feet and a drainage area of 3230 square miles (U.S. Geological Survey 1981b); and (2) Morgan Lake, an off-river impoundment, which is used as a cooling lake for the Four Corners Power Plant.

A more detailed discussion of the drainage network and surface-water environment of the San Juan River Basin is presented by Busby (1979b).

3.C.2 Streamflow Characteristics

Gaging stations operated and maintained by the U.S. Geological Survey may be used to evaluate the streamflow characteristics of the San Juan River in New Mexico. Of relevance to estimating the effects of use of water from Navajo Reservoir for NMGS are the gaging stations 09355500 (San Juan River near Archuleta, New Mexico), 09364500 (Animas River at Farmington, New Mexico), and 09365000 (San Juan River at Farmington, New Mexico) (see Map 3-1). The two stations on the San Juan River are located on the reach of the river that would be used to transport water from Navajo Dam to the Proposed Action intake structure at Farmington. The gaging station on the San Juan River at Farmington is located just downstream of the confluence of the Animas River. The streamflow characteristics of these three stations are summarized in Table 3-1 which gives a general idea of the water-supply potential of the San Juan River.

Use of a common period of time during which representative streamflow records were collected (base period) allows one to examine the relative contributions of the Animas River and San Juan River (upstream of the Animas River) to the streamflow in the San Juan River at the Farmington gage. The average discharge for the San Juan River near Archuleta, New Mexico was 1321 cfs (956,400 AFY), and for the Animas River at Farmington, New Mexico was 810 cfs (586,400 AFY), for the base period 1931-1973 (Table 3-1). The relative duration of discharges at the Archuleta Station for this period is shown in Figure 3-1.

The streamflow records for the San Juan River near Archuleta were extended to the base period for an unregulated condition (without storage in Navajo Reservoir) using data for station 09350500 (San Juan River at Rosa, New Mexico) (Reiland 1980). These average discharges for the base period indicate that the contribution to the streamflow in the San Juan River at Farmington from the Animas River is about 35 percent of the total. Other contributions, such as runoff from small tributaries and ground-water discharge, are about 10 percent of the total (see Table 3-1).

Table 3-1. STREAMFLOW CHARACTERISTICS OF THE SAN JUAN RIVER

Characteristics	Gaging Station		
	09355500[a]		
Drainage Area	3260 mi^2 (approx.)		
Period of Record[d]	1954 to present		
Average Discharge, by Period	1931 to 1973[e,f]	1956 to 1961	1962 to 1981
Cubic feet per second	1321	1307	1104
Acre-feet per year	956,400	946,300	799,300
Remarks	Flow completely regulated by Navajo Dam approx. 7 mi upstream except for minor tributary inflow.		

Table 3-1. STREAMFLOW CHARACTERISTICS OF THE SAN JUAN RIVER (continued)

Characteristics	Gaging Station		
	09365000[b]		
Drainage Area	7240 mi^2 (approx.)		
Period of Record[d]	1912 to present		
Average Discharge, by Period	1931 to 1973[e]	1931 to 1961	1962 to 1981
Cubic feet per second	2095	2211	1825
Acre-feet per year	1,517,000	1,601,000	1,321,000
Remarks	Approx. 1 mi downstream from Animas River. Approx. 2.3 mi upstream of La Plata River. Since June 1962, flow is partly controlled by operation of Navajo Reservoir.		

Table 3-1. STREAMFLOW CHARACTERISTICS OF THE SAN JUAN RIVER (concluded)

Characteristics	Gaging Station 093654500[c]
Drainage Area	1360 mi^2 (approx.)
Period of Record[d]	1912 to present
Average Discharge, by Period	1931 to 1973[e]
Cubic feet per second	810
Acre-feet per year	586,400
Remarks	Approx. 1.5 mi upstream from mouth of river.

Sources: U.S. Geological Survey 1981b; Reiland 1980; U.S. Geological Survey, 1981d.

[a]San Juan River near Archuleta, New Mexico.

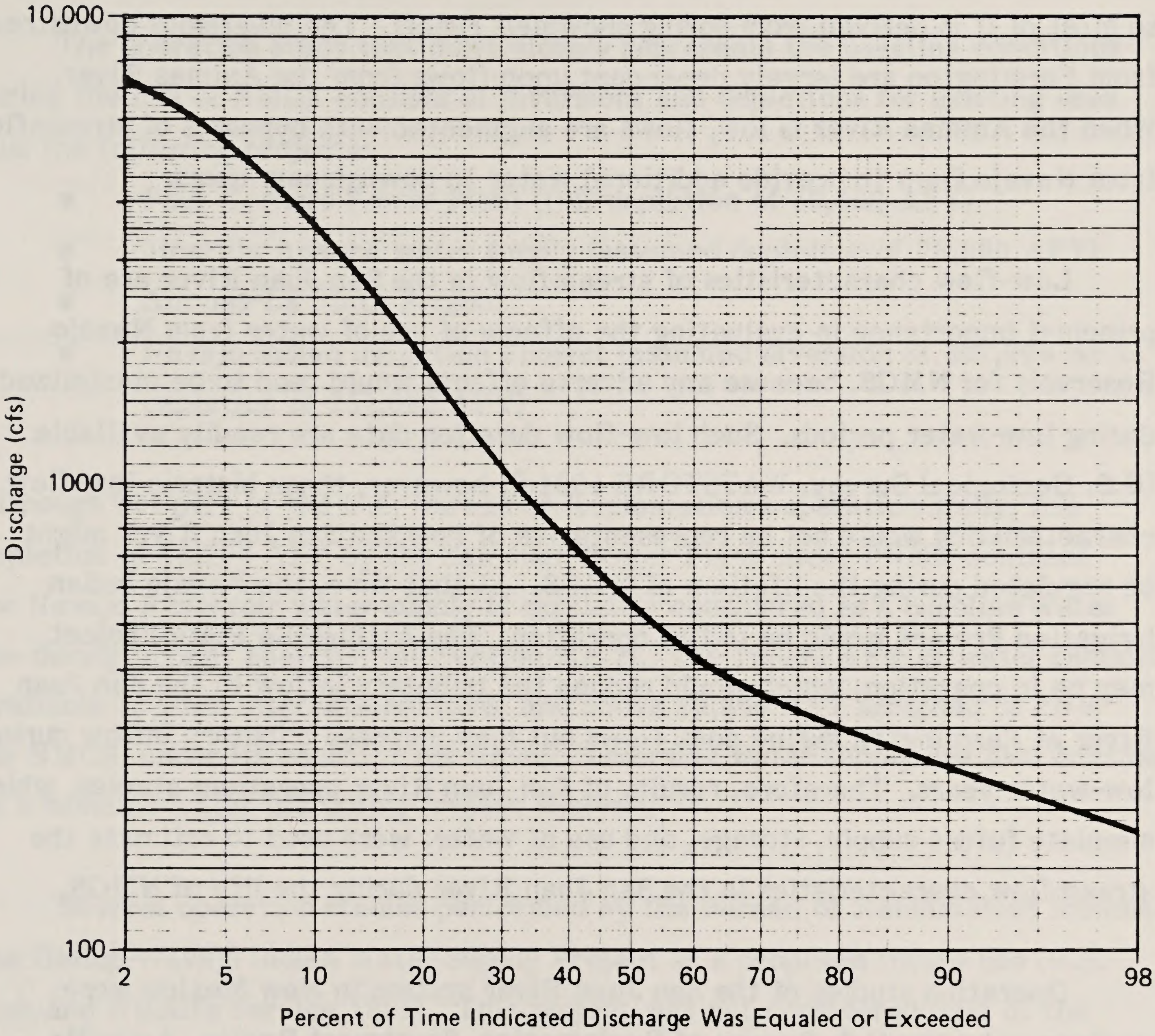
[b]San Juan River at Farmington, New Mexico.

[c]Animas River at Farmington, New Mexico.

[d]Water year: October 1 to September 30.

[e]1931 to 1973 was defined as "base period" (Reiland 1980).

[f]Records extended to base period for unregulated condition using data for Station 09350500 (San Juan River at Rosa, New Mexico).



Source: Reiland 1980

*Extended to the base period for an unregulated condition (no storage in Navajo Reservoir) using data for Station 09350500 (San Juan River at Rosa, New Mexico).

Figure 3-1. FLOW-DURATION CURVE FOR SAN JUAN RIVER NEAR ARCHULETA, NEW MEXICO, FOR BASE PERIOD 1931-1973*

The Animas River contributes significantly to the flow of the San Juan River downstream from Farmington, particularly during the peak runoff periods. The flow of the Animas River at present is not regulated by upstream dams, so most of it is derived from spring snowmelt runoff. The diversions downstream from Farmington are largely dependent upon flows from the Animas River. When the Animas River is low, flows are augmented with bypasses of streamflow from Navajo Dam to provide additional water to downstream users.

Low-flow characteristics of streamflow in the San Juan River are of principal importance in evaluating the effects of use of water from Navajo Reservoir for NMGS, because any adverse effects would tend to be maximized during low-water periods. Such low-flow duration data are readily available (U.S. Geological Survey, WATSTORE 1981d); however, these historic low-flow characteristics would not be representative of how the San Juan River might be regulated during the lifetime of NMGS. At that time, the Navajo Indian Irrigation Project would be in full operation. The Animas-La Plata Project may be in operation, which would reduce the tributary inflow to the San Juan River at Farmington during peak flows but may increase tributary inflow during low-water years. Therefore, results of San Juan River operations studies, which simulate future supply, storage, and use of water, were used to estimate the streamflow characteristics in the San Juan River during the life of NMGS.

Operation studies of the San Juan River system in New Mexico were performed by the U.S. Bureau of Reclamation, Southwest Region, Amarillo, Texas, to estimate the streamflow for historic conditions and future conditions in year 2030 (U.S. Bureau of Reclamation 1981b; J. Morrison 1982). These operation studies were made using a flow model of the San Juan River system, which is essentially a water balance computation on a monthly basis that accounts for runoff from tributaries, changes in reservoir storage, diversions and depletions for beneficial uses, channel losses, and irrigation return flows. Inflow to Navajo Reservoir was simulated using the historic sequence of recorded streamflow from 1929 to 1974, which was adjusted to account for existing and proposed upstream diversions. Tributary inflow from the Animas River was estimated in a similar fashion. Diversions and depletions for existing uses and various combinations of proposed, authorized, or contracted future uses were simulated in the various operation studies.

The operation study that most closely represents the baseline conditions during the life of NMGS consists of diversions and depletions for existing uses plus the following projects:

- Four Corners Power Plant (full depletion of 39,000 AFY)
- Jicarilla Apache water supply (assumed depletion of 26,000 AFY)
- Animas-La Plata Project
- Navajo Indian Irrigation Project (assumed diversion of 357,000 AFY, depletion of 254,000 AFY)

Although not part of the U.S. Bureau of Reclamation's operation study, full depletion of 16,200 AFY by the San Juan Power Plant under PNM's contract for Navajo Reservoir water supply is explicitly considered as a baseline water use during impact analysis (see Section 3.E.2). The 15,000 AFY of water remaining available to Utah International (over and above 20,000 AFY assigned to PNM for NMGS) under its contract for Navajo Reservoir water supply are also considered as a baseline water use during impact analysis.

Several operation studies performed by the Bureau of Reclamation included the Gallup-Navajo Indian Water Supply Project as a proposed future use (U.S. Fish and Wildlife Service 1981). This project was not considered part of the baseline conditions for NMGS because right-of-way applications had not been filed with the BLM for this project as of June 1, 1981, the date on which BLM established Baselines 1 and 2 (see Section 1.0). Commitments of 8,000 AFY made to the City of Gallup by the New Mexico Interstate Stream Commission were also not considered part of the baseline conditions for NMGS, because provision of this water is assumed to be part of the Gallup-Navajo Indian Water Supply Project.

Estimates of streamflow in the San Juan River system during low-flow conditions were simulated using the historic sequence of recorded streamflow for the "critical" dry period. The critical period is a historic sequence of natural streamflow on record for the San Juan River system. For the operation studies discussed herein, the length of the critical period depends principally on the carryover storage of water in Navajo Reservoir and corresponds historically to the period August 1952 to October 1956. The streamflow in the San Juan River system during the critical period, as simulated by the operation studies, represents the "firm yield" of the system. The firm yield is the maximum quantity of water that can be delivered during a critical dry period, the use of which will result in no monthly shortages. Under the firm yield assumption, Navajo Reservoir would have zero usable water storage (above elevation 5990 feet) at the end of the critical period (October 1956) but would start to refill in the following months. Some water in Navajo Reservoir would be present below elevation 5990 feet, which is the invert elevation to the NIIP canal at its diversion from Navajo Reservoir. Inactive storage below this elevation is approximately 672,500 acre-feet (Upper Colorado River Commission 1980).

The flow model developed by the Bureau of Reclamation to perform the operation studies of the San Juan River system estimates streamflow at eight locations between Navajo Dam and Bluff, Utah, including the gaging stations: (1) San Juan River near Archuleta, New Mexico; (2) San Juan River at Farmington, New Mexico; and (3) Animas River at Farmington, New Mexico (U.S. Fish and Wildlife Service 1981). The streamflows at Archuleta are essentially those flows released and/or bypassed from Navajo Dam, since no diversions between the dam and the gaging station occur. The streamflows at these three gaging stations for the critical dry period, as estimated by the operation study that approximates the baseline conditions during the life of NMGS, are presented in Appendix D and summarized in Table 3-2.

3.C.3 Present and Projected Water Uses

Present and projected consumptive uses of surface water in the San Juan River Basin in New Mexico are presented in Table 3-3. Historically the largest use of surface water has been for irrigation. Irrigated acreage is located along the Animas, La Plata, and San Juan rivers, and is scattered throughout the Chaco River drainage area (Map 3-1). Irrigation will continue to be the dominant water use in the future as the Navajo Indian Irrigation Project reaches full

Table 3-2. BASELINE FUTURE STREAMFLOW AT THREE LOCATIONS IN THE SAN JUAN RIVER BASIN, NEW MEXICO, DURING THE CRITICAL PERIOD[a]

	Streamflow[b]			
Location	Winter[c] Average (cfs)	Summer[d] Average (cfs)	Minimum (cfs)	Duration of Minimum (Percent of time)
San Juan River near Archuleta, NM[e]	342	380	341	67
San Juan River at Farmington, NM	660	778	410	2
Animas River at Farmington, NM	160	405	3.4	2

Sources:

U.S. Bureau of Reclamation 1981b, U.S. Fish and Wildlife Service 1981, J. Morrison, personal communication, 1982.

[a]Derived from operations study performed by U.S. Bureau of Reclamation, Southwest Region. Critical period is August 1952 to October 1956 (51 months).

[b]Streamflow estimated by operations study that approximates baseline conditions during life of NMGS. The following projects are assumed to be in full operation: Four Corners Power Plant, Jicarilla Apache water supply, Animas-La Plata Project, and Navajo Indian Irrigation Project (assumed diversion of 357,000 AFY, depletion of 254,000 AFY). Monthly streamflow for critical period shown in Appendix D.

[c]October through March.

[d]April through September.

[e]Essentially the same as release flows and bypasses from Navajo Dam.

Table 3-3. PRESENT AND PROJECTED WATER USES IN THE SAN JUAN RIVER BASIN, NEW MEXICO

	DEPLETION (acre-feet per year)			
			Planned Future Uses	
Water User	1970[a]	1975[b]	NMISC[c]	USBR[d]
Irrigated Agriculture	80,400	97,600	e	e
• NIIP	0	0[i]	226,000	254,000
• Animas-La Plata Proj.	0	0	15,000	15,000
• Hogback Expansion	0	2,000	10,000	10,000
• Jicarilla Apache	(no data)	(no data)	26,000	3,000
Municipal (urban)	3,900	5,800	e	e
• Farmington M & I	(no data)	(no data)	5,000	5,000
• Animas-La Plata Proj.	0	0	19,000	19,000
• Gallup-Navajo Indian Water Supply Proj.	0	0	8,000	24,000
Domestic (rural)	700	300	e	e
Mining[g]	1,500	1,700	e	e
Livestock Watering	400	400	e	e
Stockpond Evaporation	3,500	3,300	e	e
Power Production	16,400	22,700	e	e
• Utah International Inc. (Four Corners Power Plant)	(no data)	15,000[j]	39,000	39,000
• PNM (San Juan Generating Station)[f]	0	4,960 (diversion)	16,200	16,200
Navajo Reservoir Evap.	24,200	24,200	26,000	26,000
Manufacturing	0	0	-	-
• Utah International Inc. coal gasification[f]			35,300	35,300
San Juan-Chama Diversion Project[h]	0	110,000	110,000	110,000
TOTAL	131,000	266,000	641,500	662,500

[a] Source: U.S. Bureau of Reclamation 1976a.

[b] Source: Sorensen 1977.

[c] New Mexico Interstate Stream Commission commitments.
Source: New Mexico Interstate Stream Commission 1981.

[d] U.S. Bureau of Reclamation projections.
Source: U.S. Bureau of Reclamation 1981a.

[e] Total of all uses in this column except those specified is assumed to be 106,000 AFY (1977 USBR data - source: New Mexico Interstate Stream Commission 1981).

[f] Municipal and industrial contract from Navajo Reservoir; term of contract ends in 2005.

[g] Includes industrial water rights of Plateau, Inc., for oil refining and El Paso Natural Gas Co. for natural gas processing plants. These projects are part of Future 1 baseline for assessment of cumulative impacts.

[h] Interbasin diversion. Use of water made in Rio Grande River Basin.

[i] Releases from Navajo Reservoir in water year 1980 for use on NIIP were approximately 108,000 acre-feet (U.S. Geological Survey 1981b).

[j] Diversion of approximately 25,000 AFY. Return flow, through the Chaco River, is estimated to be about 10,000 AFY. Source: U.S. Fish and Wildlife Service 1981.

development. Surface water in the San Juan River Basin provides a municipal water supply for the communities of Aztec, Blanco, Bloomfield, Farmington, Fruitland, Kirtland, Nenahnezad, and Shiprock. Major industrial uses of water are for power-plant cooling, oil refining, and natural gas processing. Other uses of surface water in the San Juan River Basin are for domestic supply, livestock watering, interbasin diversion, and evaporation from impoundments.

The future water uses shown in Table 3-3 are planning forecasts used by the New Mexico Interstate Stream Commission and the U.S. Bureau of Reclamation for administration of New Mexico's share of water allocated under Article III(a) of the Upper Colorado River Basin Compact (see Appendix C). These future uses have been committed by the two agencies to (1) users that have legal entitlement to the water; (2) projects that have been authorized by Congress for planning and/or development; and (3) other formal commitments made by the New Mexico Interstate Stream Commission. Projection of future uses of surface water from the San Juan River Basin should be limited to that water apportioned to New Mexico by provisions of the Colorado River and Upper Colorado River Basin Compacts.

Use of 20,000 AFY out of the 35,000 AFY for NMGS from the San Juan River Basin is not shown as a separate item on Table 3-3 but is assumed to be included among those water uses committed from Navajo Reservoir. Because PNM is planning to have assigned 20,000 AFY of water from Utah International, Inc. ("coal gasification"), an existing industrial contract holder from Navajo Reservoir, planning forecasts made by the New Mexico Interstate Stream Commission and the U.S. Bureau of Reclamation have not specifically identified this water use for NMGS. At the time this report was prepared, PNM had made an informal request to the New Mexico Interstate Stream Commission for an additional 15,000 AFY from Navajo Reservoir for NMGS. The Interstate Stream Commission has not made a commitment to PNM for this water. They indicate that PNM would be in competition with other prospective users for any new contracts for water from Navajo Reservoir for municipal and industrial uses (P.B. Mutz 1982). Other applicants for this water are Consolidated Coal Co. and Arch Minerals Co. Consolidated Coal Company's Burnham Mine and ConPaso Railroad are on BLM's Baseline 1 and Baseline 2 for NMGS, respectively. Arch Minerals Co. has filed a Preference Right Lease Application with the BLM.

The Gallup-Navajo Indian Water Supply Project has been identified by the New Mexico Interstate Stream Commission and the U.S. Bureau of Reclamation as a projected future user of water from the San Juan River Basin (Table 3-3). The historical background of the Gallup-Navajo Indian Water Supply Project is as follows:

> A reconnaissance investigation to formulate and evaluate plans for providing an additional water supply for the City of Gallup and other possible customers from the San Juan River Basin and other water sources was initiated by the Bureau of Reclamation in October 1968. A feasibility study of the "Gallup Project in McKinley, Valencia, and San Juan Counties in New Mexico" was authorized by Public Law 92-199, December 15, 1971. The project at that time was a single-purpose plan to obtain 7,500 acre-feet (ac.-ft.) of municipal and industrial water annually from the San Juan River for use by Gallup. The Gallup Project Reconnaissance Report was completed by the Bureau of Reclamation in 1973. It presented findings on several possible plans of obtaining water from the San Juan River and the possibility of obtaining ground water from several areas in the vicinity of Gallup.
>
> In early 1975, the Navajo Nation, through the Navajo Tribal Utility Authority (NTUA), requested that the project investigation be expanded to include municipal-domestic water supplies for a number of Indian communities in New Mexico and Arizona (U.S. Fish and Wildlife Service 1981).

Two alternatives are being considered by the U.S. Bureau of Reclamation for obtaining and delivering water to the Navajo communities and Gallup. The first would consist of a diversion dam on the San Juan River about 3000 feet upstream from the confluence of the Animas River at Farmington. The second alternative would consist of a dam and reservoir on the Cottonwood Arroyo on the Navajo Indian Reservation. Water would be diverted to Cottonwood Reservoir directly from Navajo Reservoir Water would be diverted to Cottonwood Reservoir directly from Navajo Reservoir via the NIIP's Amarillo Canal and a new lateral Cottonwood Canal (U.S. Fish and Wildlife Service 1981). At the time this report was prepared, the Bureau of Reclamation estimated that a depletion of 24,000 AFY would be required for the Gallup-Navajo Indian Water Supply Project. The New Mexico Interstate Stream Commission has made a tentative commitment to hold 7,500 AFY (rounded to 8,000) of the Navajo Reservoir supply for the City of Gallup, pending completion of feasibility studies. The Interstate Stream Commission has not yet considered the question of an additional commitment to the Gallup-Navajo Indian Water Supply Project. As discussed in Section 3.B.2, this project is not part of BLM's Baselines 1 and 2 for NMGS.

Other water users, for which planning forecasts used by the New Mexico Interstate Stream Commission and those used by the Bureau of Reclamation differ, are the Navajo Indian Irrigation Project (NIIP) and the Jicarilla Apache Tribe (Table 3-3).

3.C.4 Data Gaps

Available information is generally adequate for evaluating hydrologic conditions in the San Juan River Basin. These data were used to delineate drainage basin boundaries, principal watercourses, water users, and streamflow characteristics. Water discharge records collected at the three gaging stations, San Juan River near Archuleta, San Juan River at Farmington, and Animas River at Farmington (Table 3-1), are rated as good except for winter months (U.S. Geological Survey 1981b). The gaging stations at Farmington have relatively long periods of record. A gaging station on the San Juan River at Rosa, New Mexico (near Colorado state line), also has a relatively long period of record, and was used to extend the record for Archuleta. This station at Rosa was discontinued in the early 1960s when submerged by the flow line of Navajo Reservoir.

The streamflow records from these gaging stations are considered to be sufficient for performing operations studies of the San Juan River system. For the study discussed in Section 3.C.2, the water supply was based on recorded or estimated flows of approximately 45 years (1929 to 1974). The critical dry period for the river was simulated by the historic sequence of streamflow from August 1952 to October 1956. Use of historic records to simulate the critical dry period is an accepted engineering method. This historic record is of sufficient length as to provide a sound statistical basis for assuming that future streamflows are very unlikely to contain drought periods of significantly greater length or severity than those experienced in the 45-year period.

3.D AVAILABILITY OF WATER

3.D.1 Introduction

The availability of water from Navajo Reservoir for uses in New Mexico (including NMGS) is dependent on the physical supply of water and on institutional limitations such as existing water rights and provisions of compacts and treaties. The physical availability of water may be estimated by operations studies that use historic streamflow data and take into account available water storage facilities and projections of water use. The institutional availability of water from Navajo Reservoir is limited to the allocations provided by the Colorado River and Upper Colorado River Basin Compacts, by the obligations of the Mexican Treaty, and by the water requirements of the existing and projected uses in the Upper Basin. Under the apportionment of the Colorado River Compact, the share of the water in the Colorado River Basin available to the Upper Basin (including New Mexico) is that water which exceeds the required delivery at Lee Ferry for use in the Lower Basin (and also satisfies the obligations of the Mexican Treaty). If the states of the upper division can meet these delivery requirements, then the Upper Basin states can consume up to 7.5 million acre-feet annually under the apportionment of the Colorado River Compact (see Section 3.B.3.a). However, available storage space and hydrologic records to date indicate that the long-term sustained yield of the Colorado River available to the Upper Basin states is significantly less than 7.5 million AFY. The sustainable yield is, of course, an estimated figure based on projections of future conditions of storage, streamflow, and water use.

The subjects of physical and institutional availability of water are discussed in detail in the sections that follow.

3.D.2 Physical Availability

The development of water for new projects in the Upper Colorado River Basin is almost entirely dependent on storage, which regulates the seasonal shortages at points of diversion and the annual variations in runoff to provide, to the Lower Basin, streamflow required by the Colorado River Compact. Prior to construction of the Colorado River Storage Project reservoirs (Lake Powell, Flaming Gorge, Blue Mesa, Morrow Point, Crystal, and Navajo), the lowest 10-year period of virgin flow was that of 1931-1940 in which the average annual estimated flow was 11.8 million acre-feet. Assuming an Upper Basin delivery obligation to the Lower Basin at Lee Ferry of somewhere between 7.5 million acre-feet and 8.25 million acre-feet annually, the pre-Colorado River Storage Project residual water usable in that or similar periods in the Upper Basin would have been limited on a firm yield basis to between 3.6 million acre-feet and 4.3 million acre-feet if the entire 11.8 million acre-feet were controllable for beneficial application.

With the construction of the mainstream storage dams in the Upper Basin, it became possible to store water in a year, or series of years, of high streamflow for release to the Lower Basin in years of low flows, as required by the Colorado River Compact, so that the development of additional water uses could proceed in the Upper Basin. Even though the Upper Basin was thereby somewhat relieved of the need to curtail uses in dry years to meet Lower Basin delivery obligations, it still had to accept physical shortages in upstream tributaries, which served as sources of supply for water consuming projects. Thus, the mainstream reservoirs can serve to permit additional development of water resources in the Upper Basin by assuring delivery obligations to the Lower Basin. They cannot completely alleviate shortages in water development projects if there are water supply deficiencies at the points of diversion caused by below-average runoff.

Operations studies conducted by the Southwest Region of the U.S. Bureau of Reclamation, to evaluate the actual water that physically could be diverted and depleted from the San Juan River system utilizing the storage capacity of Navajo Reservoir, showed that all the demands could be met from the system for all of the San Juan River model operation studies considered (see Section 3.C.2). The operations study discussed in Section 3.C.2 estimates that, with the Navajo Indian Irrigation Project (assumed diversion of 357,000 AFY) and other projects in full operation, releases and bypasses of natural streamflow from Navajo Dam of at least 341 cfs could be maintained through the critical dry period (Table 3-2). These releases of water would satisfy the direct flow rights to the San Juan River in New Mexico that have priority to water rights granted to the United States for storage of water in Navajo Reservoir for use by NIIP, the Hammond Project (irrigation), the San Juan-Chama Project, and certain municipal and industrial contracts (see Section 3.C.2). (The direct flow rights do not have storage rights in Navajo Reservoir.) The maximum simulated depletion for uses in New Mexico was 705,000 AFY. Under the simulated conditions, enough additional water was available in Navajo Reservoir to provide for additional releases of 120,000 AFY (average of 166 cfs) during the critical period (U.S. Bureau of Reclamation 1981b). These additional releases of 120,000 AFY were not assigned to particular uses, but conceivably could be used for municipal and industrial contracts, maintenance of aquatic life, or other uses.

The operations studies discussed above demonstrate that, physically, there appears to be no reasonable chance of shortage to contemplated users from Navajo Reservoir (projects authorized by Congress, and municipal and industrial contracts; see Section 3.C.3 and Table 3-3) or to rights in the San Juan River Basin that are senior to U.S. rights in Navajo Reservoir. NMGS, which proposes to use 35,000 AFY from Navajo Reservoir, also would not be expected to experience a physical shortage of that quantity of water over the life of the project.

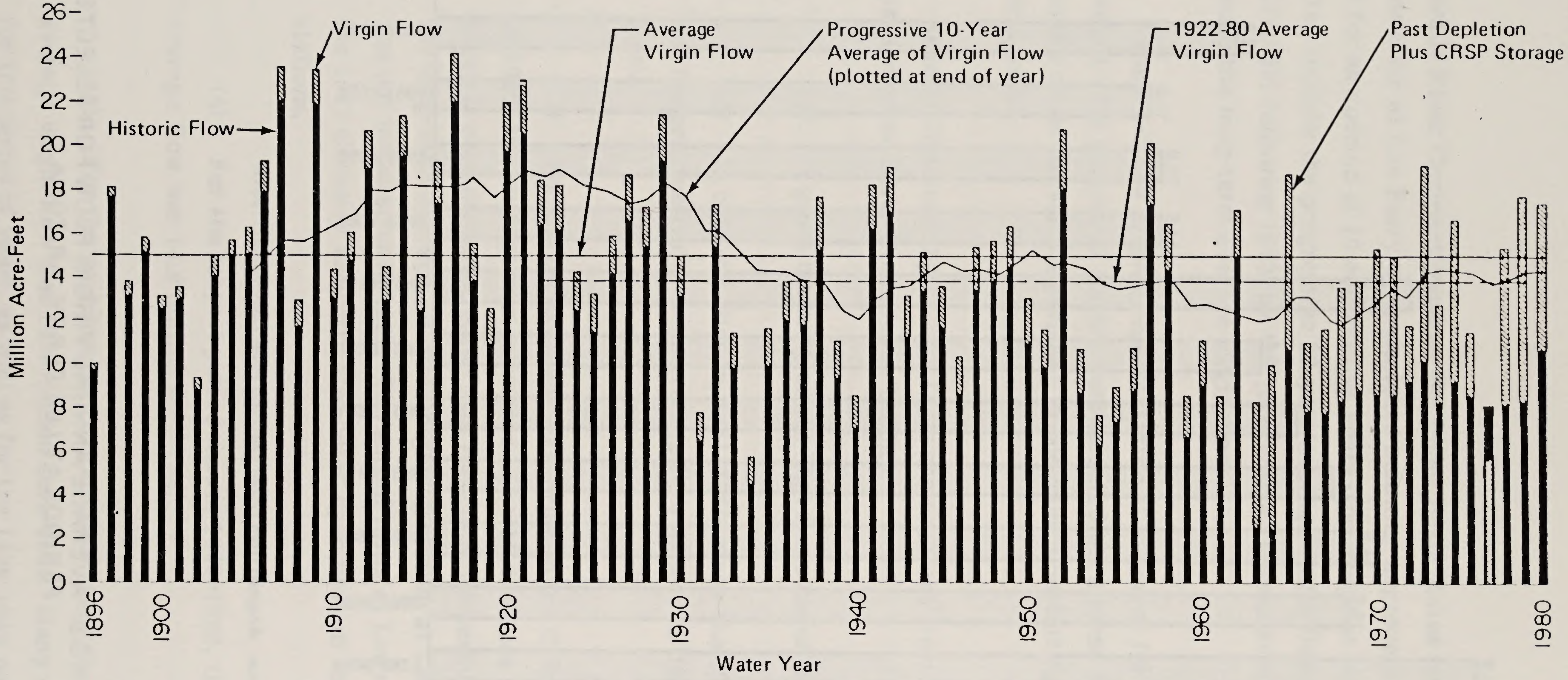
3.D.3 Institutional Availability

The quantity of water available to the Upper Basin for beneficial use in New Mexico is apportioned by the Upper Colorado River Basin Compact (see Section 3.B.3.c). Rather than allot specific quantities, the Upper Basin Compact alloted to each state a share of the Upper Basin's apportionment under the Colorado River Compact. Fifty thousand acre-feet per year are allocated to Arizona; New Mexico is allocated 11.25 percent of the remainder of this apportionment. This allocation by percentage-shares requires an estimate of the long-term sustainable yield of the Colorado River system as a basis for planning new water uses in the Upper Basin. The Upper Colorado River Basin Compact also allows any Upper Basin state to use water in excess of that state's permanent allocation. This provision recognizes the possibility of an overuse and provides for restitution by the state responsible (see Section 3.B.3.c).

3.D.3.a Virgin Flow of the Colorado River

In order to evaluate the water available to the Upper Basin, it is necessary to estimate the "virgin flow" of the Colorado River at Lee Ferry, Arizona, the division point between the Upper and Lower Basins of the Colorado River as defined in the Colorado River Compact (see Section 3.B.3.a). The virgin flow is the estimated flow of the river if it were undepleted by the activities of man. Hydrologic models, which have been developed to estimate the institutional availability of water in the Upper Basin, use the estimates of virgin flow and available storage in Upper Basin reservoirs to simulate the deliveries of water that would be made in the Colorado River at Lee Ferry, Arizona.

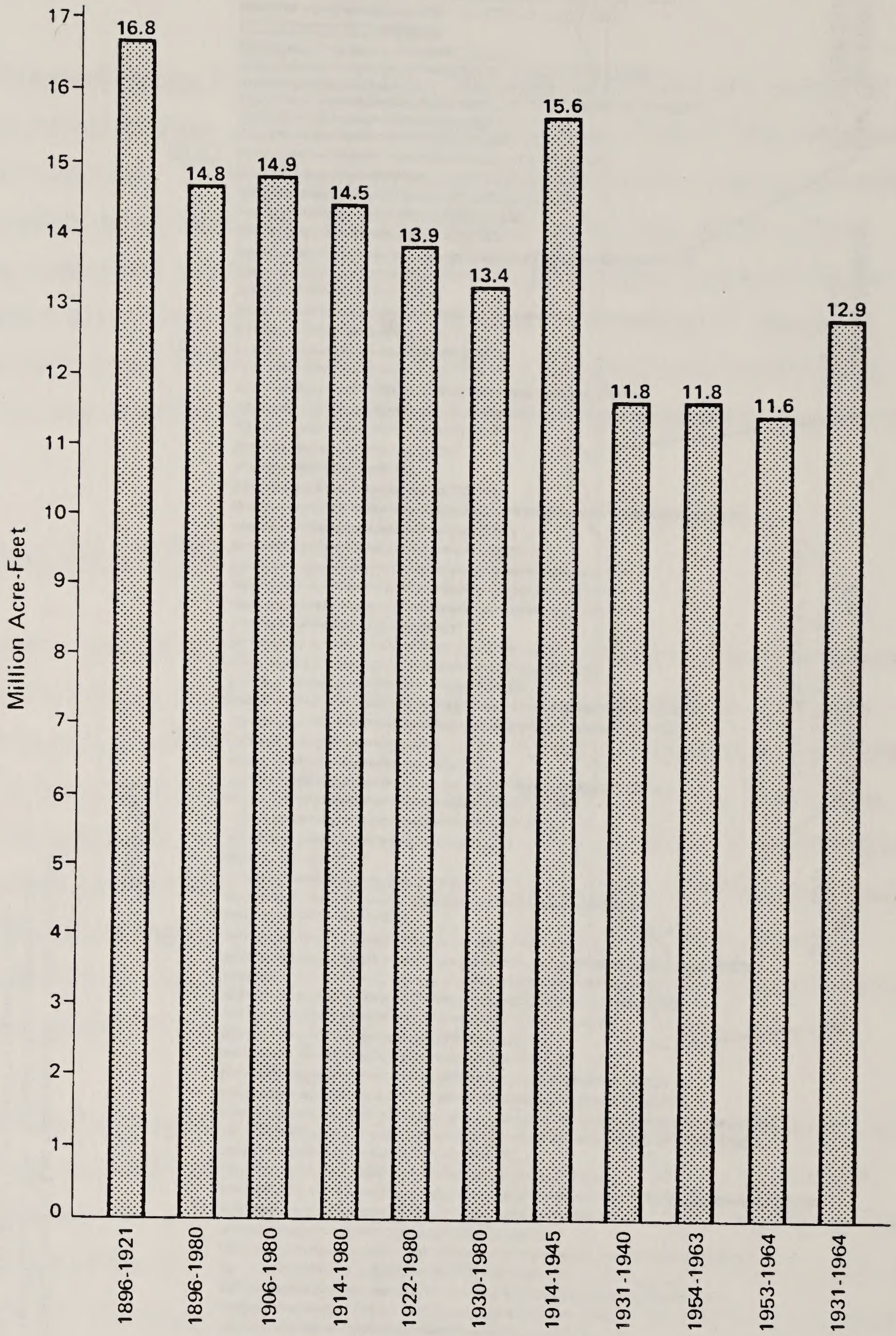
Figures 3-2 and 3-3 illustrate some of the pertinent historical facts related to the amounts of water produced by the Colorado River system above Lee Ferry. In general, the water supply of the Colorado River that originates from the Upper Basin drainage area is highly erratic from season to season and from year to year. On Figure 3-2, the top of each vertical bar represents the estimated virgin flow of the river. Each vertical bar has two components. The lower black part represents the estimated or measured historic flow at Lee Ferry. The upper, lighter vertical-hatched portion represents the stream depletion, or the amount of water estimated to have been removed by man from the virgin supply upstream from Lee Ferry. Beginning in 1962, part of this depletion at Lee Ferry was caused by the retention and storage of water in storage units of the Colorado River Storage Project. The horizontal line (at approximately 15 million acre-feet) shows the long-term average virgin flow. Because the



Note: In water year 1977, historical flow at Lee Ferry was 8.27 million acre-feet and virgin flow was 5.78 million acre-feet. Releases from reservoirs of Colorado River Storage Project (CRSP) were used to augment flows.

Source: Adapted from Upper Colorado River Commission (1981).

Figure 3-2. COLORADO RIVER FLOW AT LEE FERRY, ARIZONA



Source: Adapted from Upper Colorado River Commission (1981).

Figure 3-3. AVERAGE ANNUAL VIRGIN FLOW FOR SELECTED PERIODS AT LEE FERRY, ARIZONA

Colorado River Compact requires the Upper Basin states not to cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive years, the irregular horizontal line is plotted to show the progressive 10-year average virgin flows. In only one decade (1941-1950) following 1933 has the progressive 10-year average virgin flow exceded the long-term average virgin flow.

Figure 3-3 is a graphic representation of averages for several periods of record. The periods of water years selected were those to which reference is usually made for various purposes in documents pertaining to the Colorado River System.

Several important hydrologic facts are apparent from these two figures (Upper Colorado River Commission 1980):

(1) A great majority of the high flows occurred prior to 1929.

(2) In only one decade, 1941-1950, since the 1924-1933 decade has the progressive 10-year average flow exceeded the average virgin flow.

(3) For the period 1896-1921, prior to the Colorado River Compact of 1922, the average was estimated to be 16.8 million acre-feet per year, which is considerably greater than for any other period selected, including the long-term average. A stream-gaging station at Lee's Ferry, Arizona was not installed until 1921. The annual flows at Lee's Ferry prior to the 1922 Compact are estimates based upon records obtained at other stations.

(4) For the longest period shown, 1896-1980, the estimated annual average flow was 14.8 million acre-feet.

(5) For the next longest period, 1906-1980, the estimated annual average virgin flow was 14.9 million acre-feet. Many of the early records for this series of years, as well as for the 1896-1980 period, were based

upon the estimates of flows made at other gaging stations, as mentioned in (3) above.

(6) The estimated annual average virgin flow during the 1914-1980 period was 14.5 million acre-feet. This period is an extension of the 1914-1965 period used in the Upper Colorado Region Comprehensive Framework Studies of 1971.

(7) The average annual virgin flow for 1914-1945 was 15.6 million acre-feet. This is the period of record used by the negotiators of the Upper Colorado River Basin Compact of 1948.

(8) For 1922-1980, the period since the signing of the Colorado River Compact, the annual average was 13.9 million acre-feet. Records for this series of years are based upon actual measurements of flows at Lee's Ferry. The 10-year moving average flow since 1922 has been considerably less than the 10-year moving average prior to 1922.

(9) For the 51-year period, 1930-1980, the annual average virgin flow dropped to 13.4 million acre-feet.

(10) Two completely unrelated 10-year periods of minimum flows have occurred since 1930. These are series of years, 1931-1940 and 1954-1963, for which the average annual virgin flow for each 10-year period amounted to only 11.8 million acre-feet.

(11) The annual average virgin flow for a 12-year period, 1953-1964, amounted to only 11.6 million acre-feet.

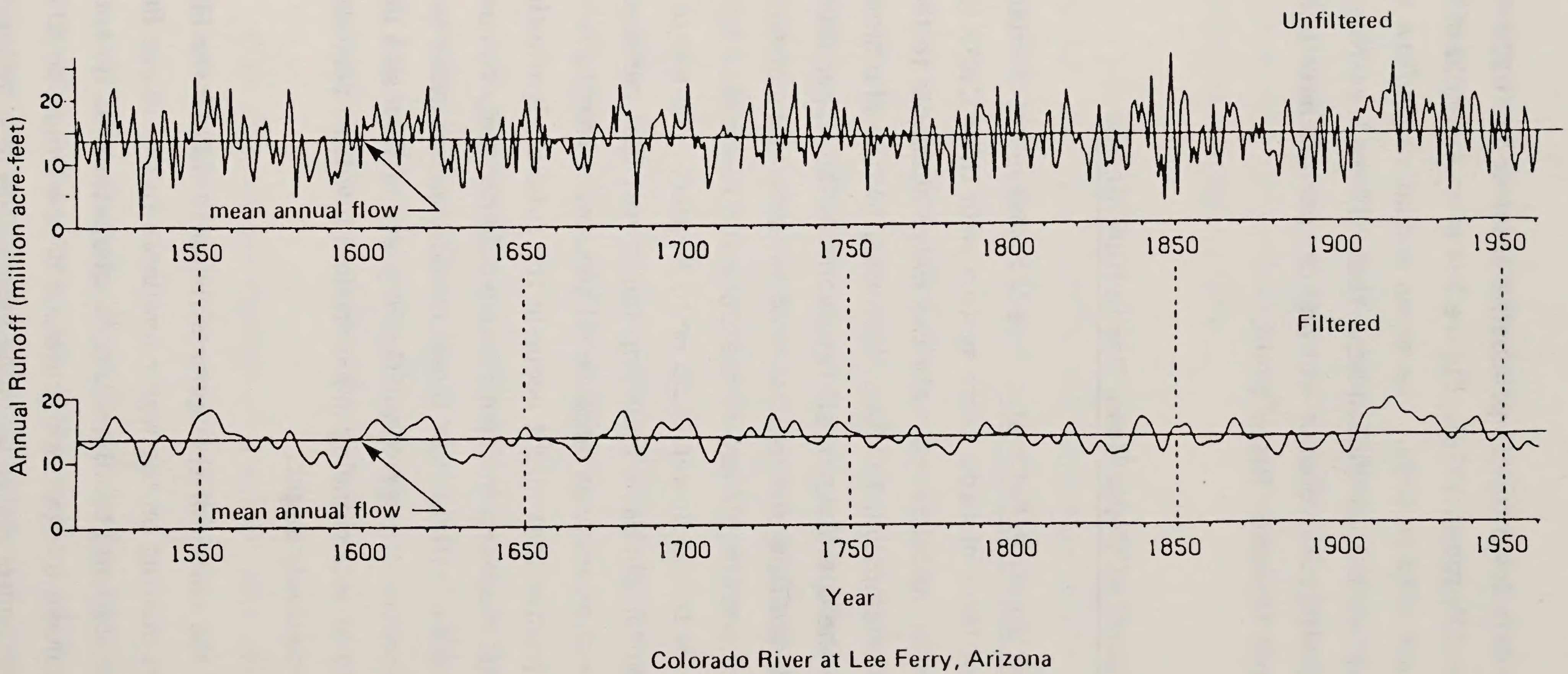
(12) The average virgin flow for a 34-year period, 1931-1964, amounted to only 12.9 million acre-feet. This sequence of flows is the dry period that is critical in evaluating the sustainable depletions in the Upper Basin (Barnett 1981).

The virgin flow at Lee Ferry has been reconstructed by performing statistical analyses with tree-ring data from runoff-producing areas of the Upper Colorado River Basin (Stockton and Boggess, 1979). Figure 3-4 is an example of such a reconstruction for years 1512 to 1960. The mean annual virgin flow calculated from this extended sequence is 13.6 million acre-feet. These tree-ring studies also demonstrate that multiyear cycles of wet and dry periods have been occurring for centuries in the Upper Colorado River Basin.

3.D.3.b Evaluation of Limit of Upper Basin Use in New Mexico

U.S. Bureau of Reclamation Estimate. The U.S. Bureau of Reclamation conducted simulations of the Colorado River system with their CRSP (Colorado River Simulation Program) model to estimate the water available to the Upper Basin (U.S. Bureau of Reclamation, 1976b; J. Newman, 1981). The model, developed in 1967, simulates the operation of all reservoirs in the Upper Basin, using historic sequences of streamflow and estimates of future water consumption, to evaluate the limits of sustainable use of the Colorado River that would not impair assumed deliveries to the Lower Basin or to Mexico. The use of all historic sequences of hydrologic data, including the lowest that has been recorded in the past, incurs some shortcomings because all sequences that have occurred may not include the extremes that might occur in the future. Synthetic sequences, if generated in sufficient numbers, in some cases would be likely to contain sequences of low-flow more critical than those actually experienced to date. With a fairly complete record of approximately 70 years of flow as a basis, however, the probability of experiencing more critical low flow periods in the future is judged to be relatively slight.

The obligation of the states of the upper division to satisfy the Mexican Treaty has an important bearing on the water available to the Upper Basin. Because the issue is disputed and the Bureau of Reclamation has no authority or desire to attempt to make a legal interpretation of the Colorado River Compact, the Bureau has made the conservative planning assumption of a delivery of 750,000 acre-feet annually at Lee Ferry for Mexico in estimating the residual streamflow available for Upper Basin use, i.e., it has assumed the "worst case" will occur and the upper division states will deliver an additional 750,000 acre-



Note: Curves based on an average of the results of two reconstructions with random component added. The upper graph shows the actual year-by-year values; the lower graph is the same data but with the high-frequency components—those with a period less than 10 years—removed.

Source: Stockton and Boggess (1979).

Figure 3-4. LONG-TERM HYDROGRAPH OF ANNUAL RUNOFF AT LEE FERRY, ARIZONA feet per year to supply one-half of the Mexican Treaty obligation. The total average annual delivery requirement at Lee Ferry would then be 8.25 million acre-feet.

Trial and error simulated operations of the Colorado River system based on the 1906-1972 hydrologic sequence indicate that even if a delivery of 8.25 MAF to the Lower Basin is required, the Upper Basin can develop a nominal use of about 5.8 MAF annually, including evaporation from all Upper Basin reservoirs. The critical dry period for these simulations is 1931 to 1964 (Figure 3-4). This yield of 5.8 MAF is based on the ability of reclamation irrigation projects to tolerate some shortages of water. Reclamation irrigation projects are usually designed to attain reasonable economic efficiency with the result that it is often feasible to develop more irrigable land than can be fully supplied every year. When properly formulated, the economic consequences of a shortage in supply in occasional dry years is more than compensated by the reduced cost of storage or conveyance facilities which would be needed for a full supply every year. The firm yield of water available to the Upper Basin is 5.50 to 5.55 MAF (D. Barnett, 1981; U.S. Bureau of Reclamation, 1976b).

On the basis of the Bureau of Reclamation's estimate of 5.8 million AFY available for use in the Upper Basin, New Mexico may consumptively use 647,000 AFY. This quantity is calculated as follows, in conformance with Article III(a) of the Upper Colorado River Basin Compact:

	5,800,000 AFY	available to Upper Basin
(subtract)	50,000 AFY	apportionment to Arizona
	5,750,000 AFY	remainder
(multiply)	11.25 percent	New Mexico's share
	647,000 AFY	apportionment to New Mexico

The Bureau of Reclamation has projected future depletions from the Upper Colorado River Basin in New Mexico (San Juan River Basin) to consist of planned future uses of 662,500 AFY (Table 3-3) plus New Mexico's share (58,000 AFY) of evaporation from Colorado River Storage Project reservoirs (U.S. Bureau of Reclamation 1981a). Therefore, total projected future depletions from the Upper Colorado River Basin by New Mexico are 729,500 AFY. This quantity is greater than the Bureau's planning estimate of 647,000 AFY available for use in New Mexico; however, some of these projected depletions involve contracts for water that is available to the Upper Basin and not used in the other states for a given period of time.

The Secretary of the Interior has found that up to 100,000 AFY of water from the San Juan River Basin in New Mexico, above its permanent allocation provided by Article III(a) of the Upper Colorado River Basin Compact, would be available through year 2005 (S.E. Reynolds 1975). Industrial water contracts from Navajo Reservoir made with Public Service Company of New Mexico and Utah International, Inc. are based on this finding, and the terms of these contracts end in year 2005. Hydrologic studies conducted for the Secretary of the Interior demonstrated that sufficient water would be available to allocate to the industrial users from Navajo Reservoir through 2005 even though such use may cause total Upper Basin uses to exceed 5.8 million acre-feet for the latter part of the contract term (see Section 3.B.4.b). This situation arises because the Upper Basin storage reservoirs now contain more than enough water to make downstream deliveries to Lee Ferry through any foreseeable low flow periods without impairing the projected uses in any other Upper Basin state throughout the term of the contracts (U.S. Bureau of Reclamation, 1976b).

On the basis of more recent hydrologic studies and projections of water use in the Upper Basin by the U.S. Bureau of Reclamation, "about 60,000 acre-feet annually of remaining Upper Basin water underdeveloped by other Upper Basin States could be considered available for long-term use until about year 2040" (U.S. Bureau of Reclamation 1981b). This finding potentially could be used by the Secretary of the Interior to extend the terms of the contracts made with Public Service Company of New Mexico and Utah International, Inc., beyond their 2005 ending dates (total consumptive use of contracts is 51,500 AFY). However, renegotiation of the contracts with the Secretary of the Interior by the respective parties probably would be required.

The position of the New Mexico Interstate Stream Commission with respect to the municipal and industrial contracts from Navajo Reservoir is summarized in the following statement:

> The New Mexico Interstate Stream Commission concurred in the 2005 term for contracts so long as it did not inhibit the development and use of New Mexico's water resources. It is, of course, New Mexico's position that at least the full amount of 100,000 acre-feet will be available for such contracts in perpetuity. (S.E. Reynolds 1975)

New Mexico Interstate Stream Commission Estimate. The New Mexico Interstate Stream Commission estimates that 6.3 million AFY of water are available for beneficial consumptive use in the Upper Colorado River Basin (P.B. Mutz, 1981). Both New Mexico and the other states of the upper division disagree with the conservative planning assumption used by the Bureau of Reclamation that the Upper Basin must deliver an additional 750,000 AFY at Lee Ferry to satisfy the obligations of the Mexican Treaty. In their interpretation of the Colorado River Compact, the states of the upper division claim that reservoir evaporation and uses from Lower Basin tributaries are accountable as beneficial consumptive uses (S.E. Reynolds, 1975). If reservoir evaporation and tributary uses are accounted for, then it can be shown that sufficient "surplus" waters exist in the Lower Basin to fulfill the entire Mexican Treaty obligation. Therefore, the Upper Basin would be required to deliver an annual average of 7.5 million acre-feet (MAF) (75 MAF in each period of ten consecutive years) to Lee Ferry, as opposed to the 8.25 MAF assumed by the Bureau of Reclamation.

The New Mexico Interstate Stream Commission bases its estimate of 6.3 million AFY available for beneficial use in the Upper Basin on a study prepared by Tipton and Kalmbach, Inc. for the Upper Colorado River Commission in 1965. The study shows that operation of the Colorado River Storage Project reservoirs during the period simulated by historic streamflows of 1921 through 1964 (average annual virgin flow of the Colorado River at Lee Ferry was 14 MAF) would allow the Upper Basin to deplete the flow of the river at Lee Ferry by 6.3 MAF annually while delivering 7.5 MAF annually to the Lower Basin

(S.E. Reynolds, 1975). This value (6.3 MAF) is also the sum of the firm yield of the Upper Basin (5.55 MAF), estimated by reservoir operations studies conducted by the Bureau of Reclamation, plus the Mexican Treaty obligation that the Bureau assumes for the states of the upper division (750,000 acre-feet).

On the basis of the New Mexico Interstate Stream Commission's estimate of 6.3 million AFY available for use in the Upper Basin, New Mexico may deplete the flow of the San Juan River system at sites of use by 727,000 AFY. This quantity is computed as follows:

	6,300,000	AFY	available at Upper Basin
(subtract)	50,000	AFY	apportionment to Arizona
	6,250,000	AFY	remainder
(multiply)	11.25	percent	New Mexico's share
	703,000	AFY	
(add)	24,000	AFY	salvage by use
	727,000	AFY	apportionment to New Mexico

The quantity of 24,000 AFY in the above computation requires an explanation. Article VI of the Upper Colorado River Basin Compact states that consumptive use shall be measured as man-made depletions of the virgin flow at Lee Ferry (see Appendix C). The use of water at sites in the Upper Basin probably would result in a reduction in natural losses (i.e., evaporation and channel losses) between the sites of use and Lee Ferry, which is referred to as "salvage by use" (S.E. Reynolds, 1975). Under this concept, each Upper Basin state's consumption at sites of use may exceed, by the amount of salvage by use, the depletion of flow at Lee Ferry that the state is entitled to make. New Mexico's share of such salvage by use is estimated to be 24,000 AFY (approximately 3.5 percent) (S.E. Reynolds, 1975).

The New Mexico Interstate Stream Commission has projected future depletions from the Upper Colorado River Basin in New Mexico (San Juan River Basin) to consist of existing, authorized, and committed future uses of 641,500 AFY (Table 3-3) plus New Mexico's share (58,000 AFY) of evaporation from Colorado River Storage Project reservoirs (New Mexico Interstate Stream

Commission, 1981). Therefore, total existing, authorized, and committed future depletions from the Upper Colorado River Basin by New Mexico are 699,500 AFY. This quantity is less than the New Mexico Interstate Stream Commission's estimate of 727,000 AFY available for beneficial consumptive use in New Mexico. The Interstate Stream Commission conceivably could commit part of the remaining 27,500 AFY of water for use by NMGS.

3.D.4 Conflicts and Controversies

Conflicts and controversies over the quantity of water available for beneficial consumptive use from the San Juan River Basin in New Mexico may arise in three general areas: (1) Indian water rights; (2) interpretation of the Colorado River Compact; and (3) salvage by use.

Quantification of water rights that the Indian tribes in the San Juan River Basin in New Mexico may possess under the Winters doctrine may affect the water available to present and projected users. If the rights of the Navajo, Jicarilla Apache and Ute Mountain tribes to the waters of the San Juan River system in New Mexico exceed the present and projected water uses planned for these tribes by the New Mexico Interstate Stream Commission and the U.S. Bureau of Reclamation, then cutbacks in depletions by other users may be necessary. The adjudication suit of the San Juan River system that the State of New Mexico initiated in 1975 is an attempt to quantify the rights of the Indian tribes. The subject of Indian water rights is discussed in more detail in Section 3.B.5.

Different interpretations of the Colorado River Compact could affect the amount of water available for beneficial consumptive use from the San Juan River Basin in New Mexico by as much as 56,000 AFY. The interpretation of the Compact plays a significant role in determining the obligations of the states of the upper division in satisfying the Mexican Treaty of 1944. For example, a definition of the Compact obligation of the Upper Basin to deliver water to satisfy the Mexican Treaty obligation of 1.5 million AFY is highly controversial, with the upper division states taking the position that they have no such obligation if a proper accounting of water uses in the Lower Basin is made. The upper division states believe that sufficient "surplus waters" under Article III(c) of the Compact exist in the Lower Basin to supply the entire Mexican Treaty obligation (U.S. Bureau of Reclamation, 1976b; P. Mutz, 1981). This subject is discussed in detail in Section 3.D.3.b.

The 24,000 AFY claimed by New Mexico as salvage by use (see Section 3.D.3.b) could be disputed by other parties that administer water in the Colorado River Basin. The Bureau of Reclamation's older reports include salvage by use, but more recent reports do not mention it (P.B. Mutz, 1981). Salvage by use is not included in the Bureau's value of 5.8 million acre-feet available for beneficial consumptive use in the Upper Basin. The Bureau of Reclamation may not recognize salvage by use until after results of studies in progress, on evaporation and bank storage in Lake Powell, have been completed. These studies appear to indicate: (1) an increase of approximately 15 percent in estimates of evaporation from Lake Powell; and (2) approximately 10 million acre-feet of bank storage in Lake Powell that is unaccounted for over the life of the Glen Canyon Storage Unit (D.H. Barnett, 1981).

3.E IMPACTS OF USE OF WATER FROM NAVAJO RESERVOIR FOR NEW MEXICO GENERATING STATION

3.E.1 Water Availability

NMGS would, at a maximum, deplete the available supply of water in the San Juan River Basin in New Mexico by 35,000 acre-feet per year. However, no significant impacts on the physical and institutional availability of water in the San Juan River Basin or the Colorado River would result from use of 35,000 AFY of water from Navajo Reservoir for NMGS.

Institutionally, water could be made available for NMGS without affecting New Mexico's ability to satisfy provisions of the Colorado River Compact and the Upper Colorado River Basin Compact (see Sections 3.B.3 and 3.D.3.b). The 20,000 AFY, for which PNM has a committment to lease from Utah International, Inc. (existing industrial contract from Navajo Reservoir), represents an approved use of the water through year 2005, which is recognized by the agencies (New Mexico Interstate Stream Commission and U.S. Bureau of Reclamation) that administer the water resources of the San Juan River system. The point of diversion of this water differs from that proposed by Utah International, Inc. The effects of this change in diversion will be addressed in Section 3.E.2. PNM's use of an additional 15,000 AFY from Navajo Reservoir would be possible only by assignment from an existing contract holder or by negotiating a new contract with the Secretary of the Interior. Before making a new long-term contract for water from Navajo Reservoir, the Secretary must certify that sufficient water to fulfill this contract is available for use in New Mexico during the term of the contract. Congress then must approve such a contract (see Section 3.B.4.b). The Secretary has made such a certification for contracts aggregating 100,000 AFY through the year 2005 (see Section 3.D.3.b).

Physically, use of 35,000 AFY from Navajo Reservoir for NMGS does not appear to cause a shortage of water to present and projected water users in the San Juan River Basin. Planned future uses in the San Juan River Basin in New Mexico for projects authorized by Congress, for municipal and industrial contracts from Navajo Reservoir, and for water rights senior to United States' rights in Navajo Reservoir are estimated by the New Mexico Interstate Stream Commission and U.S. Bureau of Reclamation to be 641,500 AFY and 662,500 AFY, respectively. These uses include the 20,000 AFY committed to be assigned to PNM from Utah International, Inc. Adding to these figures the additional 15,000 AFY that PNM proposes to use from Navajo Reservoir, the total projected future uses range from 656,500 to 677,500 AFY. These quantities are less than the 705,000 AFY estimated, by operation studies of the San Juan River system conducted by the Bureau of Reclamation, to be physically available for depletion from the San Juan River Basin upstream of Shiprock, New Mexico, during the critical dry period (see Section 3.D.2). Therefore, a decrease in water available for present and projected baseline users in the San Juan River Basin in New Mexico due to NMGS is not anticipated.

3.E.2 Streamflow Characteristics

NMGS would deplete the streamflow in the San Juan River downstream of the intake structure by an average of 48 cubic feet per second (cfs). This depletion is not significant, since it is only 2 to 4 percent of the average annual streamflow of the river, depending on the location of the intake (see Table 3-1). The greatest impacts to water users, however, would occur during a drought period. Therefore, the following discussion presents an assessment based on a historic drought period in the San Juan River Basin.

No significant impacts to existing and projected baseline water users in New Mexico, due to a change in streamflow characteristics of the San Juan River, would result from the diversion of 35,000 AFY for NMGS using the Proposed Action intake structure at Farmington. Although not predicted by the operation studies used to estimate future baseline streamflow conditions, use of the alternative intake structure at Bloomfield to divert 35,000 AFY for NMGS is judged to have a qualitatively small chance of causing shortages to users of Navajo Reservoir during a drought period. Impacts due to construction and operation of the Proposed Action and alternative intake structures on river conditions other than water supply are discussed in Section 6.C.

As shown by operation studies of the San Juan River system conducted by the U.S. Bureau of Reclamation, there is sufficient water physically available to permit releases and bypasses of natural streamflow from Navajo Dam of at least 341 cfs during the critical period (see Section 3.C.2). This quantity of water includes the release from Navajo Reservoir of 120,000 AFY (approximately 166 cfs distributed uniformly throughout the year) that was considered by the Bureau of Reclamation to be unused (U.S. Bureau of Reclamation 1981b). "Unused" water is the water that would be physically available to supply municipal and industrial contracts from Navajo Reservoir (i.e., San Juan Power Plant (PNM), Utah International, Inc. (WESCO gasification plant) and New Mexico Generating Station (PNM)) if these contracts are extended and/or authorized beyond year 2005 (see Section 3.C.3). These municipal and industrial uses from Navajo Reservoir were not considered in the operation studies for year 2030 performed by the Bureau of Reclamation, because the terms of existing municipal and industrial contracts end in year 2005 (U.S. Fish and Wildlife Service 1981). Contracts for future delivery of water after year 2005 would be subject to negotiation with the Secretary of Interior, if such negotiation is authorized by law. However, the impact analysis that follows does consider municipal and industrial uses from Navajo Reservoir for San Juan Power Plant, Utah International, Inc., and NMGS.

Water rights were granted to the United States by the state of New Mexico for NIIP, the Hammond Project (irrigation), the San Juan-Chama Project, and municipal and industrial contracts. Water rights for the proposed Animas-La Plata Project in New Mexico have been granted by the State of New Mexico to the United States, and are junior to the above rights. The United States also has been granted water rights to the return flow from NIIP and to all seepage and tributary flow below Navajo Dam to optimize the use of streamflow in the San Juan River and the regulated storage available in Navajo Reservoir.

The streamflow in the San Juan River at Farmington that is required to satisfy the authorized diversions of water rights senior to those of the United States during the growing season is approximately 450 cfs (P. Mutz 1982). These senior rights are: (1) the Farmers' Mutual Ditch, the Hogback Diversion, the Jewitt Ditch, Utah International, Inc. (Four Corners Power Plant), and the Fruitland Canal in the reach of the San Juan River between Farmington and Shiprock (see Map 3-1); and (2) the Citizens Ditch, several small ditches, and industrial users near Bloomfield in the reach between Navajo Dam and Farmington. This requirement is largely controlled by the Hogback Diversion, which will have a future diversion requirement of 300 cfs and is also the most downstream large diversion from the San Juan River in New Mexico. During years with average streamflow, the diversions downstream from Farmington, including the Hogback Diversion, have in the past been supplied largely by tributary inflows from the Animas River. During years of low flow and during the critical dry period, diversions downstream from Farmington would have to be supplied in large measure from bypasses of natural streamflow entering Navajo Reservoir and from return flows that enter the reach downstream of Farmington.

Since shortly after completion of Navajo Dam and Reservoir the release schedule has been set to provide, as a minimum, sufficient quantity of water to meet the demand of all downstream diversion requirements in New Mexico and to maintain the quality trout fishery immediately below the dam. This schedule was adopted taking into account the fact that, until the Navajo Indian Irrigation Project is completed, it is not necessary to operate the reservoir to maximize its yield for beneficial consumptive use under the rights held by the Secretary of the Interior. Therefore, the reservoir at present could be used for river regulation, for maintenance of the environment and for power head at the Glen Canyon Power Plant. This schedule has obviated priority calls by senior downstream water rights and administration of the river on a priority basis (New Mexico Interstate Stream Commission, 1981).

Institutionally, during a dry period when the river would be administered on a priority basis, the Bureau of Reclamation would not have to release more water from Navajo Dam to satisfy senior water rights than the natural streamflow entering Navajo Reservoir. The Bureau of Reclamation could potentially release sufficient water from Navajo Reservoir, when physically available, to meet the downstream diversion requirements of senior water rights, because of an added interest to preserve the trout fishery in the 7-mile reach immediately below Navajo Dam (U.S. Fish and Wildlife Service, 1981). Part of the 120,000 AFY of "unused" water discussed in the operations studies (Section 3.D.2) might be released for this purpose; however, there is no legal requirement to release water from Navajo Reservoir to preserve the trout fishery (see Section 3.B.2).

Physically, the operations studies conducted by the Bureau of Reclamation show that shortages to senior water rights and to the U.S. rights in Navajo Reservoir would not occur during the critical period for projected future uses of water from the San Juan River system (see Section 3.D.2). In a "worst-case" condition (no tributary inflow from the Animas River) when the 450 cfs required for diversions of senior water rights downstream of Farmington would have to be met from the main stem of the San Juan River, shortages to these senior water rights conceivably could result. These shortages are illustrated by Figure 3-1, which shows that unregulated streamflow at Archuleta, New Mexico (equivalent to bypasses of natural streamflow entering Navajo Reservoir) would be less than 450 cfs for approximately 40 percent of the time. This analysis of worst-case conditions illustrates that careful management of the San Juan River system, including releases from storage reservoirs, would be necessary during a drought period.

The streamflow required to satisfy consumptive use demands of the municipal and industrial contracts for San Juan Generating Station, Utah International, Inc. (WESCO gasification plant) and NMGS is:

New Mexico Generating Station - 35,000 AFY or 48 cfs
(20,000 AFY from Utah International, Inc. contract)

San Juan Generating Station - 16,200 AFY or 22 cfs

Utah International, Inc. - 15,300 AFY or 21 cfs
(remainder of contract water after 20,000 AFY is assigned to NMGS)

The municipal and industrial contract from Navajo Reservoir for the San Juan Power Plant (PNM) diverts water from the same reach of the San Juan River as the Hogback Diversion (Farmington to Shiprock) but upstream of some of the return flows from irrigation diversions in that reach (Farmers' Mutual Canal, NIIP, Fruitland Canal, Jewitt Valley Canal). The Proposed Action and alternative intake locations for NMGS are located upstream of the confluence of the Animas River and would depend, therefore, on streamflow in the main stem of the San Juan River, plus return flow from both existing irrigation and NIIP. The diversion for the WESCO project proposed by Utah International, Inc. (municipal and industrial contract water) is located downstream of the Hogback Diversion and of irrigation return flows from the Farmers' Mutual, Fruitland, and Jewitt Valley Canals.

Conservatively, it is assumed that diversion of 70 cfs for PNM projects (22 cfs for San Juan Generating Station and 48 cfs for NMGS would be supplied by releases from Navajo Reservoir, if necessary, to augment the flow of the San Juan River at Farmington. It is assumed that the 21 cfs required for the Utah International, Inc. (WESCO) diversion would be met by irrigation return flows. The total streamflow requirement for the San Juan River at Farmington that is assumed in this impact analysis is, therefore, 520 cfs (450 cfs for downstream diversion requirements of senior water rights and 70 cfs for PNM industrial uses).

In the operation study of the San Juan River system discussed in Sections 3.C.2 and 3.D.2, the streamflow in the San Juan River at Farmington, New Mexico is estimated to be less than 520 cfs for 10 months out of the 51-month critical period (see Appendix D). All of these 10 months are considered to be during the growing season when demands for water would be the highest. Bypasses of natural streamflow and/or additional releases of water from Navajo Reservoir would be required for these 10 months during the critical period. The total quantity of these bypasses and releases (deficit) during the critical period is approximately 32,300 acre-feet (Table 3-4). Releases of water that PNM would be entitled to under municipal and industrial contracts for the San Juan Generating Station and NMGS are 70 cfs, or 42,900 acre-feet for those 10 months during the critical period, which is more than enough to supply the deficit. The operation study assumed a uniform release of 166 cfs, during the critical period, of additional available water not assigned to particular uses in the study. In this impact analysis, 70 cfs of this water is assumed to be assigned to PNM. From a management standpoint, an average reduction in releases from Navajo Reservoir of 13.3 cfs would be required during the other 41 months of the critical period, in order to supply the deficit of approximately 32,300 acre-feet with no shortages to existing and projected baseline users.

The above analysis demonstrates that Navajo Reservoir could supply the additional releases of water required for NMGS during the critical dry period so that no significant impacts to existing and projected baseline water users would occur. An environmental effect of the diversion of 35,000 AFY for NMGS is that, from a water management standpoint, an additional 48 cfs would have to be released from Navajo Reservoir during low-flow periods to supply this diversion. This water includes 20,000 AFY (28 cfs) of Utah International, Inc.'s contract water from Navajo Reservoir which is assumed to be assigned to PNM. The effect of changing the point of diversion of some of Utah International's contract water from the proposed WESCO diversion (near the Hogback) to the proposed NMGS diversion at Farmington is that an

Table 3-4. MONTHS DURING CRITICAL PERIOD WHEN STREAMFLOW IN SAN JUAN RIVER AT FARMINGTON IS LESS THAN 520 CFS[a]

Month	Streamflow (cfs)[b]	Monthly Deficit (cfs)	Monthly Deficit (acre-feet)
August 1952	484	36	2120
July 1953	410	110	6750
August 1953	440	80	4910
August 1954	487	33	2025
July 1955	476	44	2700
September 1955	440	80	4750
October 1955	508	12	740
July 1956	472	48	2945
August 1956	514	6	370
September 1956	437	83	4930
		TOTAL DEFICIT	32,300 acre-feet

cfs = cubic feet per second

[a] Based on operations studies of San Juan River system conducted by U.S. Bureau of Reclamation.

[b] From values presented in Appendix D.

additional 28 cfs would have to be released from Navajo Reservoir during low-flow periods.

The operations study performed by the Bureau of Reclamation, which has been used to evaluate streamflow characteristics during the life of NMGS (see Section 3.C.2), does not permit a quantitative comparison of the effects on water users of locating the intake structure for NMGS at Farmington (Proposed Action location, approximately 1000 feet upstream of confluence of Animas River) versus the alternative location at Bloomfield. This deficiency in the streamflow model results from accounting for channel losses and return flows in a reach of the San Juan River (i.e., Archuleta to Farmington) at the downstream end of that reach (i.e., Farmington). The additions and subtractions of water, therefore, would affect the next downstream reach (i.e., Farmington to Shiprock) (J. Morrison, 1982).

The proposed intake structure for NMGS at Farmington would be located downstream of irrigation return flows from the Citizen's Ditch, Hammond Diversion, and NIIP (in part), whereas the alternative intake structure at Bloomfield would be upstream of some of these flows (U.S. Fish and Wildlife Service, 1981). A qualitative comparison of the two locations suggests that, because the alternative location at Bloomfield cannot take advantage of these irrigation return flows, more water might have to be released from Navajo Reservoir to supply an intake at Bloomfield during a drought period. These additional releases could conceivably reduce the carryover storage in Navajo Reservoir, which could result in shortages to United States rights in Navajo Reservoir (NIIP, Hammond Diversion, municipal and industrial contracts). Under the authorizing Act for NIIP (Public Law 87-483), any shortages to the U.S. rights must be shared equally among the users in proportion to each use.

3.E.3 Aquatic Life

During low-water periods, streamflow in the San Juan River may not be sufficient to maintain the excellent trout fishery within the first 7 miles downstream of Navajo Dam. The Bureau of Reclamation office in Salt Lake

City, Utah, develops the operating schedules for Navajo Dam, which generally provide a minimum release of 530 cfs. This flow was considered by the U.S. Fish and Wildlife Service and the New Mexico Department of Game and Fish to be capable of maintaining the trout fishery for short periods of time. Recent analysis of instream flow data indicates that a release flow of no less than 720 cfs would provide for the long-term maintenance of the tailwater fishery. Flows of 1200 cfs would provide optimum habitat for this fishery (U.S. Fish and Wildlife Service, 1981). Operations studies of the San Juan River system performed by the Bureau of Reclamation indicate that average bypasses of natural streamflow entering Navajo Reservoir and releases from Navajo Reservoir would average approximately 360 cfs during the critical dry period (see Section 3.C.2). Besides the physical availability of water, another factor that would affect releases of water from Navajo Dam to provide minimum flows for the trout fishery is that New Mexico water law does not recognize instream uses as a beneficial use of water (see Section 3.B.2).

The effects of use of water from Navajo Reservoir for NMGS on aquatic life are discussed in detail in the Draft Technical Report on Wildlife and Aquatic Biology (Woodward-Clyde Consultants, 1982).

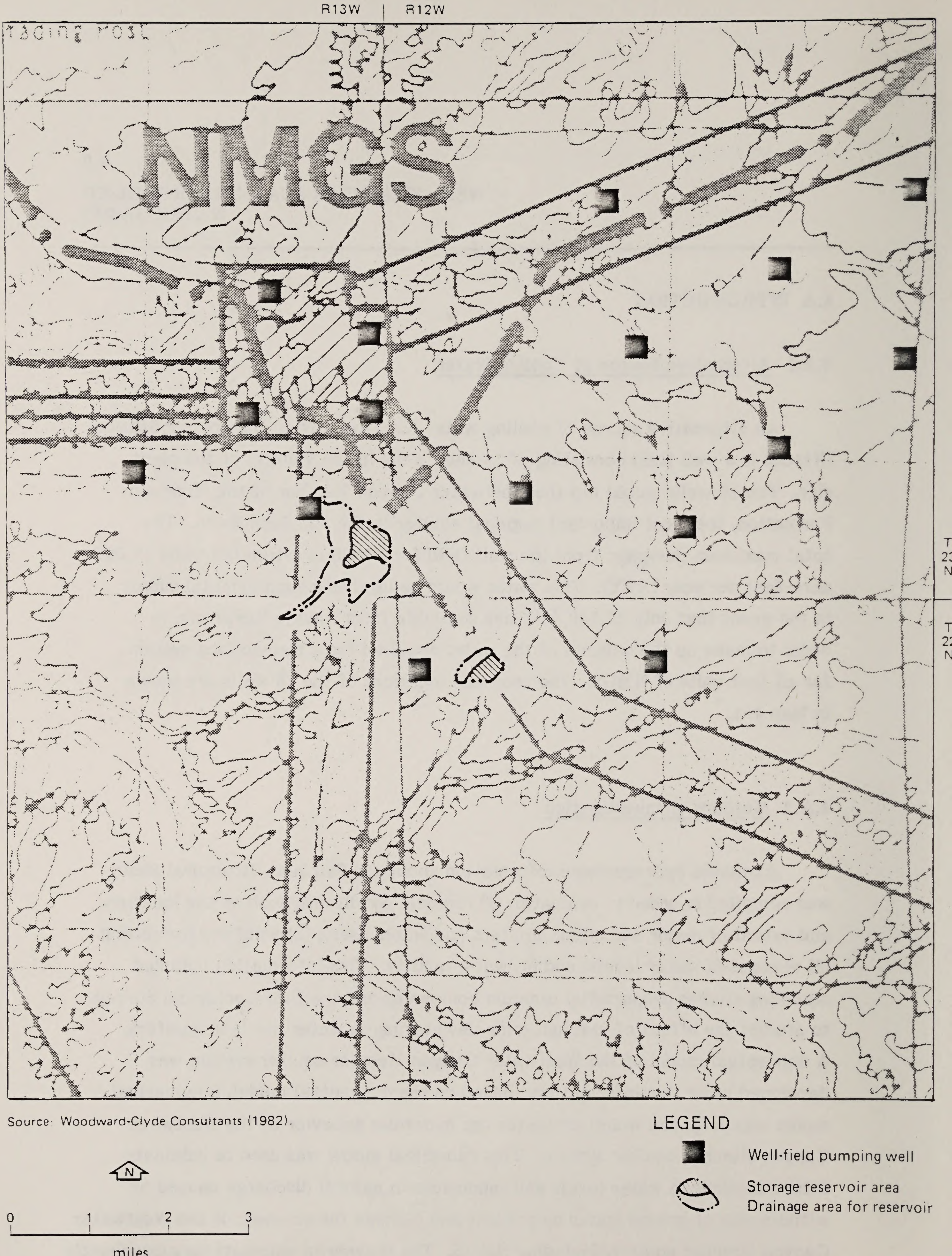
4.A INTRODUCTION

4.A.1 Alternative Source of Cooling Water

An alternative source of cooling water for New Mexico Generating Station (NMGS) is a well field consisting of 16 deep wells in the vicinity of the plant site. The 16 wells would tap the Westwater Canyon Member of the Morrison Formation, the most important regional aquifer in the San Juan Basin. The total maximum pumpage from the well field for NMGS is estimated to be 15,000 acre-feet per year (AFY). This water would be used as a supplemental supply in the event that only 20,000 AFY are available from Navajo Reservoir, in order to make up the balance of the water required for a wet-cooling system for all four units of NMGS. The proposed locations of the 16 wells are shown in Map 4-1.

4.A.2 Methods of Investigation

Available hydrogeologic information about the San Juan Structural Basin was compiled in order to evaluate: (1) regional conditions, such as the location and extent of major and minor aquifers and water users; (2) aquifer parameters; (3) changes in water levels; and (4) water quality. This information included modeling studies prepared by uranium companies and the U.S. Geological Survey to predict the effect of uranium mine dewatering on water levels in aquifers. A conceptual model of the Westwater Canyon Member aquifer system was developed using this information. Based on the conceptual model, a numerical model was prepared which simulates the hydraulic behavior of the Westwater Canyon Member aquifer system. This numerical model was used to calculate future declines in water levels and reductions in natural discharge caused by withdrawals of ground water by present and planned future users of the Westwater Canyon Member aquifer, including NMGS. The drawdown calculations subsequently



Source: Woodward-Clyde Consultants (1982).

Map 4-1. LOCATION OF STORAGE RESERVOIRS AND PUMPING WELLS were used to evaluate the impacts of NMGS on ground-water users and on changes in natural discharge to rivers and springs.

4.A.3 Study Area

The San Juan Structural Basin was the geographic area investigated for the assessment of impacts of use of water from a well field for NMGS. This study area includes the entire geographic extent of the Westwater Canyon Member aquifer system that would be hydraulically connected with the proposed well field. The study area includes parts of three states (Arizona, Colorado, and New Mexico) and is larger than the San Juan Underground Water Basin declared by the New Mexico State Engineer.

4.B ADMINISTRATION OF WATER RESOURCES

4.B.1 New Mexico State Engineer

All ground water in New Mexico belongs to the public and is subject to appropriation for beneficial use. Ground water in certain areas of New Mexico is subject to control by the State Engineer under the ground-water code enacted in 1931 (New Mexico Statutes, Article 12, Chapter 72, NMSA, 1978 (Annotated). The authority of the State Engineer exists only in "declared underground water basins," basins declared by the State Engineer to have reasonably ascertainable boundaries and for which he determines that management controls are necessary. The State Engineer may declare an underground water basin without obtaining judicial approval. At the present time, there are 31 declared underground water basins in New Mexico, encompassing approximately 82,000 square miles, or 67 percent of the land area of the state.

The administration of rights to ground water in New Mexico is under the jurisdiction of the State Engineer. The State Engineer declared the San Juan Underground Water Basin, in which the proposed well field for NMGS is located, in 1976. He will review applications for water rights therein, most likely on the basis of priority of application. The concepts of New Mexico water law discussed in Section 2.B.2 are also important with respect to the use of a well field that taps the Westwater Canyon Member aquifer as an alternative water source for NMGS. An additional concept, which is applicable to the well field, is that the mining (overdrafting) of ground-water basins is permitted in New Mexico. The State Engineer decides whether the ground water in a particular basin will be mined. In a mined basin, the State Engineer determines the rate at which the ground-water reservoir will be depleted. The lowering of water levels in a mined basin caused by the pumping of ground water by relatively junior appropriators, together with the resulting increase in pumping costs and decrease in well yields, does not necessarily constitute an impairment of the rights of relatively senior appropriators.

In a ground-water basin that may provide natural discharge to a perennial stream, the State Engineer would also evaluate whether a proposed ground-water appropriation would affect this natural discharge and possibly impair surface-water rights. A new permit to appropriate ground water may not be allowed by the State Engineer unless the immediate and potential effects of this appropriation are offset by the retirement or commitment to retire existing surface-water rights.

The Mine Dewatering Act [72-12A-1 to 72-12A-13 NMSA 1978], enacted on March 5, 1980, granted the right of replacement to any person whose appropriation or mine dewatering would otherwise impair existing water rights. The applicant may submit a "Plan of Replacement" to the State Engineer, after which the State Engineer would review the plan in accordance with existing laws and procedures governing the appropriation of ground water. Replacement of water could consist of "the furnishing of a substitute water supply, the modification of existing water supply facilities, the drilling of replacement wells, the assumption of additional operating costs, the procurement of documentation establishing a waiver of protection by owners of affected water rights, artificial recharge or any other reasonable means to avoid impairment of water rights [72-12A-3, NMSA 1978]."

4.B.2 Paragon Resources, Inc. Permit Application

Paragon Resources, Inc., a wholly owned subsidiary of PNM, filed an application (SJ-189) with the New Mexico State Engineer for rights to 40,000 AFY from the San Juan Underground Water Basin. This application was initially submitted on March 30, 1977 (priority date) and proposes to divert water from 16 deep wells located on land owned by the Bureau of Land Management as follows:

1. SW 1/4 NW 1/4 sec. 9, T.23N, R.12W
2. NE 1/4 NE 1/4 sec 12, T.23N, R.12W
3. NE 1/4 NE 1/4 sec. 24, T.23N, R.12W
4. NW 1/4 NW 1/4 sec. 14, T.23N, R.12W
5. NW 1/4 NW 1/4 sec. 26, T.23N, R.12W
6. NW 1/4 NW 1/4 sec. 34, T.23N, R.12W
7. NW 1/4 NW 1/4 sec. 21, T.23N, R.12W
8. SW 1/4 SW 1/4 sec. 29, T.23N, R.12W
9. SE 1/4 SE 1/4 sec. 26, T.23N, R.13W
10. SW 1/4 SW 1/4 sec. 28, T.23N, R.13W
11. NW 1/4 NW 1/4 sec. 14, T.23N, R.13W
12. SW 1/4 SW 1/4 sec. 23, T.23N, R.13W
13. NE 1/4 SE 1/4 sec. 13, T.23N, R.13W
14. SE 1/4 SE 1/4 sec. 24, T.23N, R.13W
15. SW 1/4 SW 1/4 sec. 6, T.22N, R.12W
16. SE 1/4 SE 1/4 sec. 4, T.22N, R.12W

Ground water from these wells would be consumptively used for domestic, agricultural, and industrial purposes in conjunction with a mine-mouth coal-fired power plant. The rights to use 15,000 AFY for NMGS from 16 wells that tap the Westwater Canyon Member of the Morrison Formation would be based on this permit application.

Paragon Resources, Inc., is continuing to pursue this water rights application and is planning to provide the State Engineer with information required for consideration of this application. The State Engineer will review the application to determine if the proposed uses of water would impair existing surface or ground-water users. If the State Engineer should determine that an existing water user would be impaired by Paragon Resources' proposed appropriation, he could take several actions, including: (1) specifying conditions, in granting Paragon Resources a right to beneficially use the water, that would remedy the impairment of the existing water right; or (2) denying Paragon Resources a right to beneficially use the water. Alternatively, Paragon Resources could file a Plan of Replacement with the State Engineer in which Paragon Resources, in effect, would agree to the replacement of water to avoid impairing an existing water right.

Four water rights applications were filed in the San Juan Underground Water Basin prior to that of Paragon Resources, Inc. The applicants are: (1) Phillips Uranium Co. (SJ-109); (2) CONOCO (SJ-125); and (3) Mobil Oil Corporation (SJ-146 and SJ-147). The State Engineer most likely will review these applications before acting on Paragon Resources' water rights permit. At present, each of these three prior applicants has filed a Plan of Replacement with the State Engineer. Water users in the San Juan Underground Water Basin prior to July 29, 1976 (date of declaration of basin) do not require a permit from the State Engineer but may proceed with their project provided that continued diligence is shown in applying water to its intended use and that the existing well or wells have sufficient capability to accomplish the intent established at or prior to the declaration of the basin. As a notice of intent, the water users prior to July 29, 1976, may file a Declaration of Owner of Underground Water Rights with the State Engineer.

4.B.3 Protests

An applicant for a permit to appropriate ground water in New Mexico is required to publish a notice, prepared by the State Engineer, in a newspaper of general circulation within the county in which the well is to be drilled. This notice must be published weekly for three consecutive weeks. Any person deeming that the granting of an application, as summarized in the notice, would be detrimental to his rights may submit a written protest to the State Engineer stating why the application should not be approved. This protest must be filed not later than 10 days after the date of the last publication of the notice (New Mexico State Engineer 1966).

Paragon Resources' application (SJ-189) was originally protested by six parties; three of these parties have subsequently withdrawn their protests. The protests still outstanding by the National Park Service, the Bureau of Indian Affairs, and the Navajo Tribe are on file in the office of the State Engineer. The principal concerns raised by each of the protestants are as follows:

- National Park Service - impairment of well at Chaco Culture National Historical Park.
- Bureau of Indian Affairs - impairment of rights of individual Navajo Indians who have land allotments held in trust by the United States and of the Navajo Nation; water rights in the San Juan Underground Water Basin stated to have accrued to said parties by prior appropriation under New Mexico law, or by federal reserved rights.
- Navajo Tribe - water rights and ownership of water in the area are uncertain; under federal law, water in the area is the property of, or subject to prior appropriation by or for, the Navajo Tribe.

Some of the concerns raised by the protestants probably will be resolved before or during the State Engineer's review of Paragon Resources' application. Concerns that involve Indian and federal reserved water rights are not clear-cut and may have to be determined by other proceedings, such as the adjudication suit of the San Juan River system filed by the State Engineer in District Court, San Juan County, New Mexico (see below).

4.B.4 Indian and Federal Reserved Water Rights

Water rights available to the three Indian tribes in the San Juan Underground Water Basin (Navajo, Jicarilla Apache, and Ute Mountain tribes) have never been quantified, nor have they been adjudicated by the courts. The tribes may possess rights under the so-called "Winters doctrine," which is discussed in more detail in Section 2.B.5.

The federal government, when it withdraws land from the public domain and reserves it for a federal purpose (e.g., national forest, military reservation), by implication reserves appurtenant water that is still unappropriated to the extent needed to accomplish the purpose of the reservation. This concept is known as federal reserved rights. The priority date of these water rights is the date of reservation of the land. Federal reserved rights have evolved through several court decisions; however, in none of the court decisions, thus far, has the concept of federal reserved rights been extended to ground water. Should federal reserved rights be extended to ground water, it might affect existing water rights and applications for water rights, including Paragon Resources, Inc. (Section 4.B.2).

The water rights of the United States, including those of the Indian tribes in the San Juan Underground Water Basin (part of San Juan River system), are being adjudicated in a suit filed by the State Engineer on March 13, 1975 (State of New Mexico ex rel. State Engineer v. United States of America, et al., Civil No. 75-184, District Court, 11th Judicial District, San Juan County, State of New Mexico). This action is still pending and most likely will not be decided for several years.

The Bureau of Land Management submitted a notification of a federal reserved water right claim for the "Bisti well" (Apache Oil-Foshay #1) to the State Engineer on August 7, 1980 (L.P. Applegate, 1980). The BLM claim is based on the reservation of the land that contains the well as a public water hole. The priority date claimed is December 1, 1974, the date that BLM purchased the well.

4.C HYDROGEOLOGY

4.C.1 Introduction

The purpose of this section is to provide baseline geologic and hydrogeologic information from which to evaluate the effects of the proposed well field for NMGS on existing hydrologic conditions in the San Juan Basin. These baseline data include: (1) a general discussion of the geologic structure of the San Juan Basin; (2) lithologic and stratigraphic descriptions of formations present within the basin; (3) descriptions of major and minor aquifers; (4) estimates of hydrologic parameters for the various aquifers; and (5) a discussion of historic, present, and projected ground-water use.

The San Juan Basin is a topographic and structural basin that comprises approximately 25,000 square miles of the northeast section of the Colorado Plateau physiographic province of the United States (Gutierrez, 1979). Use of the term "San Juan Basin" often results in confusion as to what is included within the basin. Throughout this section of the report, the following terminology is used to qualify the area under discussion:

San Juan Structural Basin -	the structural basin as defined in Section 4.C.2
San Juan Underground Water Basin -	the ground-water basin as declared by the New Mexico State Engineer
San Juan River Basin -	the surface-water drainage basin of the San Juan River (west of the continental divide)

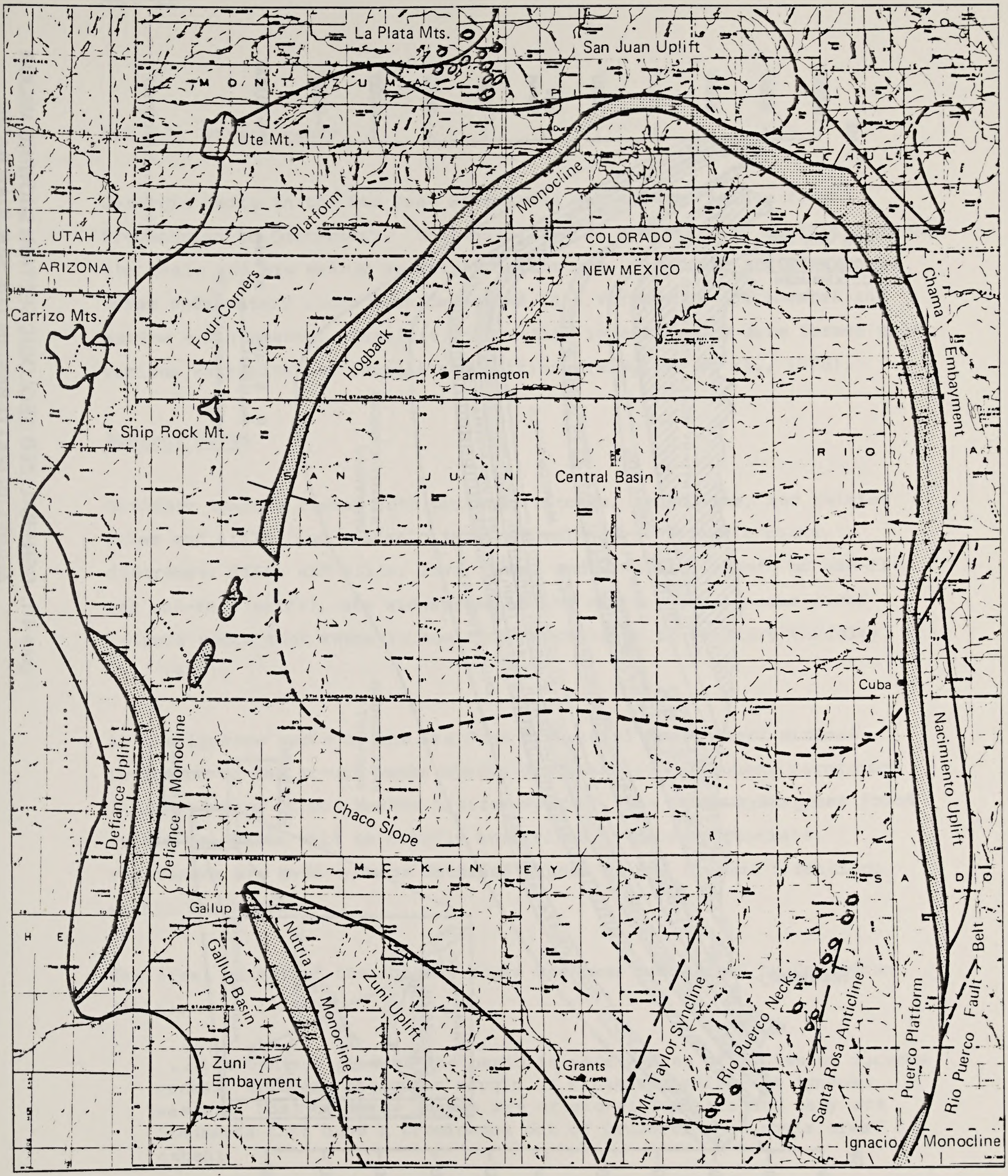
4.C.2 Geologic Setting

4.C.2.a Structure

The San Juan Structrual Basin generally is delimited by the extent of Triassic- and Jurassic-aged rocks, which crop out in the uplifts that form the margins of the basin (Green and Pierson, 1977). The basin is nearly circular in areal extent and strongly assymmetric in cross section, having steep dips on the eastern, western, and northern flanks and gentle dips on the southern flank (Map 4-2 and Figure 4-1). The boundaries of the San Juan Basin are structural elements consisting mainly of domal uplifts, platforms, or arches, and abrupt upthrusts (Kelley, 1950). The northern and eastern rims are structurally complex and include the La Plata Mountains, the San Juan Uplift, and the Nacimiento Uplift. The southern margin of the basin consists of the fractured Puerco fault zone, the Zuni Uplift, and the Mount Taylor syncline. At the western edge of the basin are the Defiance Uplift, the Chuska Mountains, and the Carrizo Mountains.

Maximum structural relief in the basin is approximately 6000 feet (Stone and Mizell, 1978). Structural development of the San Juan Basin and adjacent uplifts began during late Cretaceous and early Tertiary (Laramide) time. Uplifting of the basin to its present elevation was probably related to the evolution of the Rio Grande rift during late Tertiary and Quaternary time (Woodward and Callendar, 1977). Structure contour maps of the formations considered important to this study are discussed in later sections.

The roles played by the boundary structural features, as well as faults and monoclinal folds locally present, with respect to hydrogeologic conditions in the San Juan Basin are discussed in later sections of this report. A more detailed discussion of the regional structure of the San Juan Basin is found in Kelley (1950 and 1951).



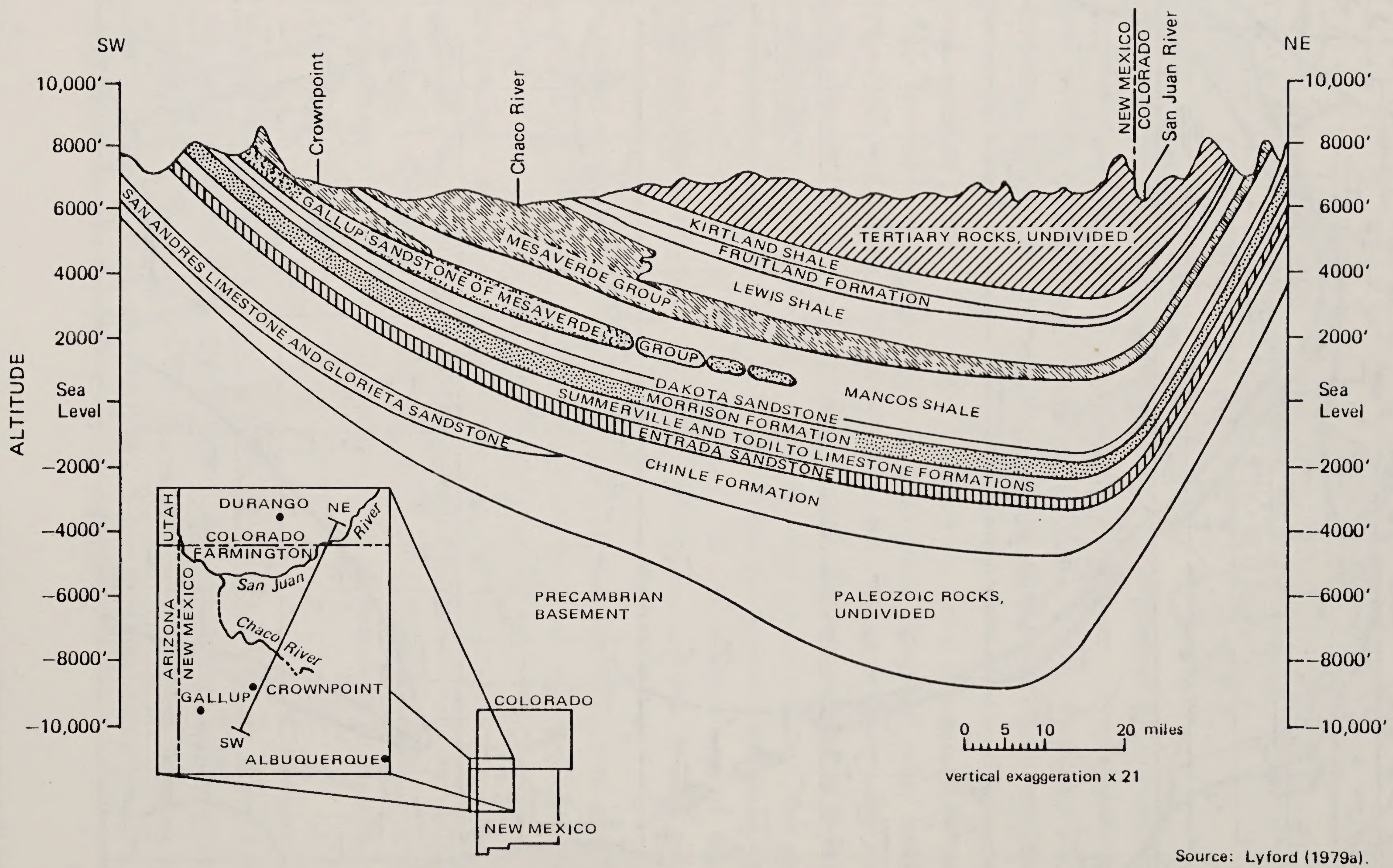
Source: Kelly, 1951

LEGEND

Outline of structural elements, San Juan Basin

0 10 20
miles

Map 4-2. STRUCTURAL ELEMENTS IN THE SAN JUAN BASIN



Source: Lyford (1979a).

Figure 4-1. GENERALIZED GEOLOGIC SECTION SHOWING MAJOR AQUIFERS (PATTERNS) IN THE SAN JUAN BASIN

4.C.2.b Stratigraphy

Geologic units in the San Juan Structural Basin range in age from Precambrian to Quaternary. Sedimentary rocks dominate the stratigraphy of the basin and are mainly sandstone, siltstone, mudstone, and limestone. These sedimentary rocks were deposited in a variety of continental and marine environments. Basaltic to granitic igneous rocks were formed under various extrusive and intrusive conditions (Ridgley, et al., 1978).

Igneous Units

Tertiary igneous rocks, both plutonic (stocks, laccoliths, and related dikes and sills) and volcanic (extinct volcanoes, volcanic rocks, diatremes, dikes and sills, lava flows, and extensive sheets of ash-flow and ash-fall tuffs), are widespread in the basin. The igneous rocks intrude rocks that range in age from Precambrian to Tertiary (Ridgley, et al., 1978).

As the igneous rocks of the San Juan Structural Basin exert minimal influence on the ground-water system discussed in subsequent paragraphs (the Westwater Canyon Member Aquifer System), the igneous features found within the basin will be briefly summarized. Where appropriate, references are made to more detailed papers on the igneous formations within the basin.

The areal extent of the igneous rocks has been summarized by Callaghan (1951):

> ...the central part of the basin is nearly free of bodies of igneous rocks. However, the outer margin is ringed by scattered igneous masses. Most of these masses are erosional remnants and many are landmarks that have a prominence out of proportion to their areal extent.

The prominent basin boundary volcanic rocks shown in Map 4-2 include the San Juan Mountains, Mt. Taylor, and Shiprock. Prominent intrusive igneous features include Ute Mountain (stock) and the La Plata and Carrizo Mountains (laccoliths) (see Map 4-2). Lava flows, ash flows, and ash-fall tuffs are common in the San Juan Mountains and areas beyond the eastern and western margins of the basin (not shown in Map 4-2). Ridgley, et al. (1978) provides a more detailed discussion of the igneous rocks in the San Juan Structural Basin, their associated features, and a list pertinent references for additional information.

Sedimentary Units

The sedimentary rocks of Jurassic and Cretaceous age crop out around the rim of the basin and dip under younger rocks toward the deepest part of the basin near the San Juan River (Figure 4-1). Tertiary sedimentary rocks cover most of the northeastern part of the central basin, and Quaternary deposits occur at the surface mainly in valleys (Stone, 1981). Table 4-1 and Figure 4-2 summarize the lithology and distribution of the Paleozoic, Mesozoic, and Cenozoic sedimentary formations present within the San Juan Structural Basin.

A full characterization of the stratigraphy of the basin is beyond the scope of this study. A more complete geologic discussion and references pertaining to depositional environments, tectonic activity and detailed lithologic description of the formations found in the San Juan Structural Basin is presented in Ridgley, et al. (1978).

TABLE 4-1

STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

p.1 of 6

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
PreCambrian	—	Undifferentiated basement complex	---	Entire basin	Northern, eastern, southern upland margins of the basin	?	?	Quartzite granite, schist, and igneous rocks of basic to intermediate composition with locally occuring pegmatites and quartz veins.
Cambrian	Upper	Ignacio Quartzite	---	Northern part of the basin	Southern flank of the San Juan Mts and in scattered areas of north-western New Mexico	0 - 100	Thins southward from the San Juan Mts	Light gray to grayish-orange-pink sandstone, quartzite, shale, and conglomerate.
Devonian	Upper	Aneth Fm	---	Northwestern part of the basin	San Juan Mts	0 - 100	Thins southward from the Four Corners Area	Brown to black bedded limestone, agrillaceous dolomite, and minor amounts of black shale and siltstone.
		Elbert Fm	McCracken SS	Northwestern part of the basin	San Juan Mts	0 - 150	Thins southward from the Four Corners Area	White, light-gray to red, fine- to medium-grained, poorly sorted glauconitic sandstone.
			Upper	Northwestern part of the basin	San Juan Mts	0 - 250	Thins southward from the Four Corners Area	Thin-bedded sandy dolomite and limestone and green to red waxy shales.
		Ouray LS	---	Northwestern part of the basin	San Juan Mts	0 - 50	Thins southward from the Four Corners Area	Siliceous limestone and dolomite and widespread thin green shale near the top and base. The limestone is oolitic and fossiliferous.
Mississippian	Osage	Leadville LS (Redwall LS)	---	Northern part of the basin	San Juan Mts	0 - 200	Thins southward from the Four Corners Area	Thin basal dolomite with a thick, light-gray, massive upper, limestone. Locally oolitic.
	Meramec	Arroyo Penasco Group	---	Eastern part of the basin	Western flanks of the San Pedro and Nacimiento Mts	0 - 150	Thins westward from the Nacimiento Mts	Conglomerate, sandstone, siltstone, and shale overlain by dolomite and oolitic and silty pilletoid, fine-grained limestone.
Pennsylvanian	Atoka	Molas Fm	---	Northwestern part of basin	?	0 - 100	Thins southward from northwestern corner of the basin.	Red-brown to variegated siltstone, red shale, calcareous sandstone, and gray to buff limestone. Basal part is a vegolith on a paleo karst surface.

TABLE 4-1
STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
Pennsylvanian	Des Moines	Hermosa Fm	Pinkerton Trail	Northwestern part of the basin	Along the flanks of the San Juan Mts		Thins southward from the Four Corners area and grades into the Madera Fm	Gray fossiliferous limestone, gray to gray-green shale, and lesser amounts of sandstone and siltstone.
			Paradox	Northwestern part of the basin		Entire Hermosa Fm, 0 - 3000		Complex sequence of interbedded evaporite, black shale dolomite, limestone, and siltstone.
	Missouri		Honaker Trail	Northwestern part of the basin				Numerous cycles of thin-bedded to massive limestone and dolomite overlain by gray calcareous shale and buff to gray siltaone and arkosic sandstone.
		Madera Fm	Lower	Eastern and southern parts of the basin	Along flanks of the San Pedro, Nacimiento and Zuni Mts			Gray, fossiliferous, cherty limestone interbedded with thin beds of arkosic sandstone, siltaone, and fossiliferous shale.
			Upper			0 - 1000	To the north and west grades into the Hermosa Fm	Interbedded arkosic sandstone, fossiliferous shale, and some cherty limestone.
Permian	Wolfcamp	Abo Fm	---	Entire basin	Flanks of the Chuska, Nacimiento and Zuni Mts	400 - 2000	Thickens and coarsens from south to north; north of 36°N it grades into the Cutler Fm	Reddish-browon shale, siltatone, and lenticular, carbonaceous arkosic sandstone.
		Cutler Fm	---	Entire basin	Flanks of the San Pedro and Chuska Mts	400 - 2000	Thins southward where facies change into the Abo Fm	Interbedded fluvially deposited crossbedded, purple arkosic sandstone that is locally conglomeratic and purple to orange mudstones.
	Leonard	DeChelly SS	---	Entire basin	Flanks of the San Pedro and Chuska Mts	0 - 600	Northward grades into the Cutler Fm	Fine-grained, reddish sandstone.
		Yeso Fm	---	Southern, western and northern parts of the basin	Nacimiento and Zuni Mts	0 - 500	From south to north, the Yeso Fm becomes coarser-grained, increasingly arkosic, contains less evaporite, and grades laterally into the Cutler Fm	Interbedded red-orange, crossbedded sandstone, and gray dolomitic limestone, gypsum and siltstone.
		Glorieta SS	---	Southern, western and northern parts of the basin	Nacimiento and Zuni Mts	0 - 250	Thins northeastward from Zuni Mts	White cliff-forming medium- to fine-grained crossbedded sandstone.
		San Andres LS	---	Southern part of the basin	Southern part of basin and Nacimiento Mts	0 - 300	Thins northward from the Chaco slope	Fossiliferous dolomitic limestone.

TABLE 4-1
STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
Triassic	Lower	Moenkopi (?) Fm	---	Southwestern and western parts of the basin	Zuni Mts	0 - 200	Thickens south-western from the Fort Wingate area	Red siltstone, sandstone, and locally conglomeratic sandstone sequence.
	Upper	Chinle Fm	Shinarump	Western and southern parts of the basin	Western flanks of the Nacimiento and San Pedro Mts	0 - 200	East of Fort Wingate occurs as discontinuous lenses	Very light grey, light tan and brown coarse-grained sandstone, conglomerate and minor mudstone beds.
			Monitor Butte	Western and southern parts of the basin	Western flanks of the Nacimnto and San Pedro Mts	0 - 300 (Entire Chinle Fm. 700-1500)	Thickest west of Chuska Mts, thinning eastward to the Zuni Mts	Red mudstones and siltstones intermixed with lighter colored sandstones and conglomerates.
			Petrified Forest (including Sonsela SS bed)	Entire basin	Western flanks of the Nacimiento and San Pedro Mts	0 - 300	In southwestern part of the basin, the Sonsela SS divides the member into an upper and lower part	Variegated blue, grey, red, brown, and purple fluviatile mudstone and siltstone. Sonsela sandstone bed within member is light-yellowish-gray cross bedded tuffaceous sandstone containing conglomerate lenses and interbedded siltstone and shale.
			Owl Rock	Western and northwestern parts of the basin	Western flanks of the Nacimiento and San Pedro Mts	0 - 250	Thickest west of Chuska Mts, thinning southeastward toward the Zuni Mts	Pink and red shale mottled light greenish gray. Shale is silty and calcareous.
		Wingate SS	Rock Point	Western part of the basin	----	0 - 300	Thin eastward from the Chuska Mts	Flat bedded dark-red calcareous siltstone.
			Lukachukai	Northwestern part of the basin	----	0 - 400	Thins eastward from the Chuska Mts	Reddish-brown to orange, fine- to medium-grained, cross bedded sandstone.

TABLE 4-1
STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
[J]urassic	Middle	Carmel Fm	---	Northwestern part of the basin	Margins of the basin	0 - 250	Absent at southern margin of the basin	Red siltstone and mudstone.
	Upper	Entrada SS	---	Entire basin	Margins of the basin	100 - 250	Absent at southern margin of the basin	Reddish-orange, fine- to medium-grained, well sorted quartzose sandstone beds.
		Todilto LS	---	Entire basin	Margins of the basin	limestone facies 0 - 30 gypsum anhydrite facies 0 - 95	Fairly uniform Absent in western part of the basin, thickens eastward	Interbedded grey to brownish-grey calcareous shale and limestone locally overlain by thick gypsum anhydrite sequence.
		Summerville Fm	---	Entire basin	Margins of the basin	20 - 100	Mudstone interbedding is restricted to eastern edge of the basin	Massive to planar bedded sandy siltstone and fine-grained sandstone interbedded with mudstone.
		Bluff/Cow Springs/Zuni SS	---	Southern part of the basin	Western and southern margins of the basin	0 - 350	In Grants Mineral Belt, Bluff SS grades laterally into Cow Springs SS	Well-sorted, fine- to medium-grained quartzose sandstone.
		Morrison Fm	Salt Wash	Northwestern part of the basin	Western margins of the basin	0 - 300	Thins southward from Four Corners area	Light yellow to grayish white fine- to very fine-grained sandstones, interbedded with gray to black shales and arenaceous gray limestone beds.
			Recapture	Entire basin	Western, southern, and eastern margins of the basin	200 - 300	Changes in facies south to north across the basin. Maximum thickness locally of 600ft northwestern part of the basin	Light reddish brown, calcareous fine- to very fine-grained sandstones and calcareous, arenaceous dark brown claystones.
			Westwater Canyon SS	Entire basin	Western, southern, and eastern margins of the basin	0 - 400	Thins northeastward from the southwest corner of the basin	White to red very fine- to coarse-grained partly conglomeratic sandstone.
			Brushy Basin	Entire basin (except the extreme southwest)	Western, southern, and eastern margins of the basin	200 - 400	In eastern part of the basin, the upper 0 - 200 ft of the member is a sandstone claystone sequence called Jackpile SS in economic usage (uranium)	Pale-red-orange and greenish-gray claystone and buff to rusty tan, medium- to fine-grained sandstone.

San Rafael Group (handwritten bracket spanning Carmel Fm through Bluff/Cow Springs/Zuni SS)

Entire Morrison Fm. 400-900 (handwritten bracket spanning Salt Wash through Brushy Basin)

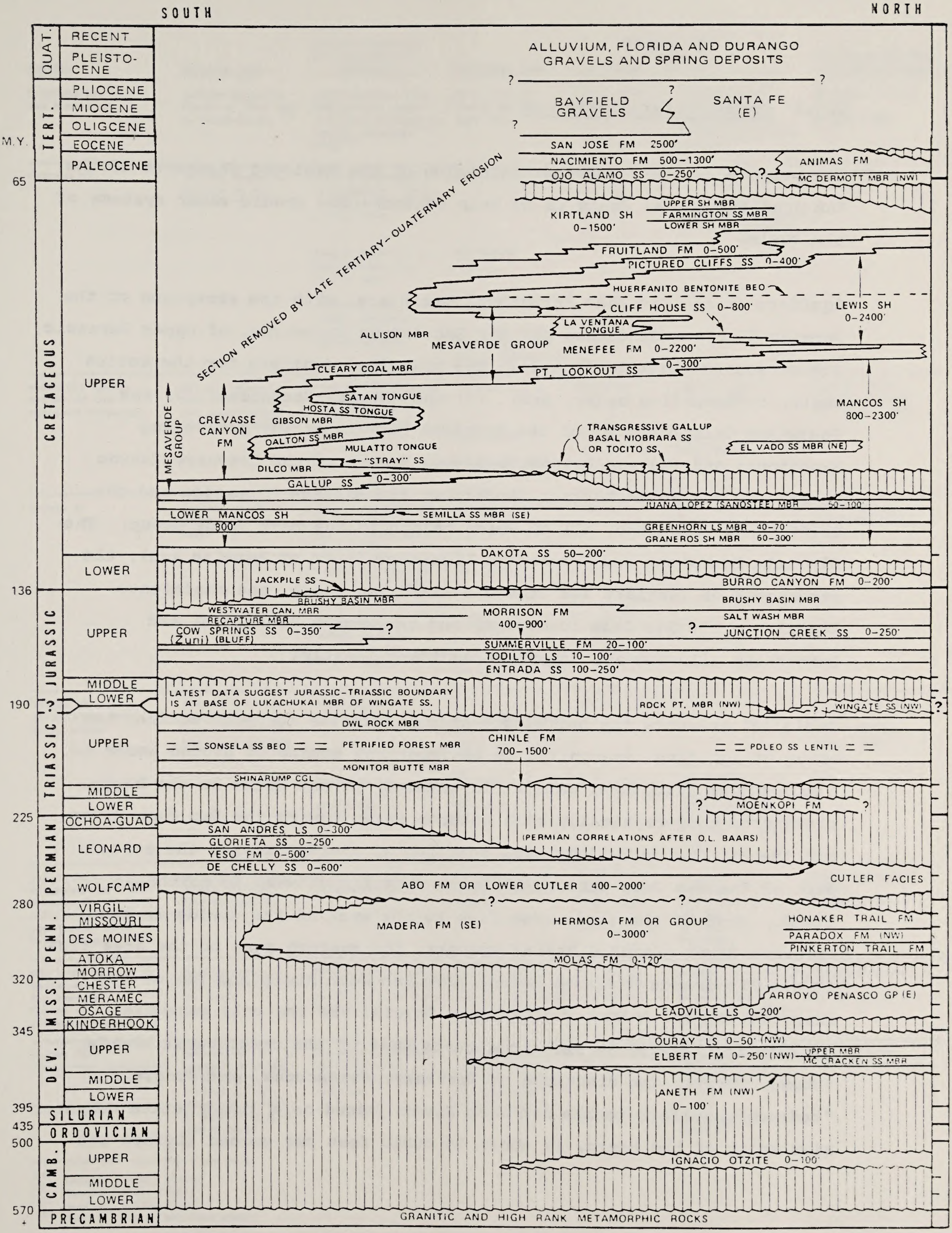
TABLE 4-1
STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
Cretaceous	Lower	Burro Canyon Fm	---	Northern part of the basin		0 - 200		Conglomerats and sandstone with thin red and green shale and mudstone lenses.
	Upper	Dakota SS	---	Entire basin	Margins of the basin	50 - 200	Fairly uniform thickness	Yellowish-buff to gray, massive quartz sandstone with local beds and lenses of conglomerate and coal.
		Mancos Sh	Graneros Sh Greenhorn LS Serrilla SS Juane Lopez (Sanostee) Mulatto Tongue Satan Tongue	Entire basin		800 - 2300	Intertounges with the Dakota Fm and Point Lookout SS to the south. The Mancos also intertounges with the Gallup SS and Crevasse Canyon Fm	Gray shale, siltstone, and lesser amounts of limestone, sandstone, and bentonite.
		Gallup SS	Including Niobrera (Tocito) SS	Southwestern part of the basin	Western and southern margins of basin	0 - 300	Thickest near Gallup, thinning northeastward where it pinches out into the Manco Sh	Light-gray, buff, and pale-red very fine- to very coarse-grained sandstone and thin to thick beds of shale.
		Crevasse Canyon Fm	Elvados SS Dilco Coal Dalton SS Gibson	Entire basin	Southern margin of the basin	0 - 750	Thickest in southwestern part of the basin, thinning to the northeast where it intertounges with the Mancos Sh	Sandstone, clay and several coal beds.
		Point Lookout SS	Including Hoste Tongue	Entire basin	Southern, western, and eastern margins of the basin	0 - 300	Grades laterally into the Mancos Sh to the north	Buff, gray, and tan medium- to fine-grained sandstone and lesser amounts of shale.
		Menefee Fm	Allison Cleary Coal	Entire basin except the southern margin		0 - 2200	Maximum near center of basin thinning from southwest to northeast across basin	Sandstone, shale, carbonaceous shale, and coal.
		Cliff House SS	---	Entire basin	Western, southern, eastern margins of the basin	0 - 800	Maximum in southwestern part of the basin, thinning north-eastward	Thick-bedded, gray, buff, and orange-brown, medium- to fine-grained sandstone and minor amounts of gray shale.
			La Ventana Tongue	Center of the basin	East-central part of basin, between Hwy 44 on east and Torreon area to west	0 - 800	Maximum thickness in northwestern Sandoval County, NM, thins northward	Sandstone.

TABLE 4-1
STRATIGRAPHY OF SAN JUAN STRUCTURAL BASIN

Period	Epoch	Formation	Member	Areal Extent (within the San Juan Basin)	Outcrop Areas (within the San Juan Basin)	Thickness Characteristics: Approximate Range (in feet)	Thickness Characteristics: Areal Variability	Lithology (general)
Cretaceous	Upper	Lewis Sh	Including Huerfanito Bentonite Bed	Absent in southwestern part of the basin	Locally in northern and central parts of the basin	0 - 2400	Thickest in northeastern part of the basin, thinning southeastward	Light-to-dark gray and black shale interbedded with light brown sandstone, sandy to silty limestone, calcareous concretions and several thin bentonite beds.
		Pictured Cliffs SS	---	Absent in southwestern part of the basin	Northern, western, southern sides of the basin	0 - 400	Thins northeastward	Lower part consists of interbedded thin sandstones and shales, while upper part consists of more massive sandstones interbedded with thin shale. The sandstones are generally fine- to medium-grained and well sorted.
		Fruitland Fm	---	Absent along eastern margin of the basin		0 - 500		Sandstone and siltstone interbedded with carbonaceous shale and coal. In the lower part of the formation a few limestone beds are also present.
		Kirtland Sh	Lower Sh Farmington SS Upper Sh	Absent along eastern margin of the basin		0 - 1500		Gray shale with a few thin beds of sandstone and siltstone and sandstone interbedded with shale.
Tertiary	Paleocene	Animas Fm	---	Northern part of the basin	Northeastern margin of the basin	0 - 3000 (including McDermott member)	South of north-central New Mexico, grades into the Nacimiento Fm	Conglomerate, siltstone, sandstone, and shale that contain abundant volcanic material of andesitic composition.
			McDermott	Northwestern part of the basin				Purple to brown sandstone, conglomerate, and shale.
		Ojo Alamo SS	---	Northeastern part of the basin; absent south of the outcrop belt	From Cuba, NM to Farmington, NM	0 - 250	Pebble size in the conglomerate decreases from west to east across the basin	Interbedded sandstone, conglomeratic sandstones, and shale. The sandstone is buff to rusty brown, arkosic, and locally conglomeratic near the base.
		Nacimiento Fm	---		Scattered areas in northeastern part of the basin	500 - 1300	Coarsens and thickens from south to north where it grades laterally into the Animas Fm	Grey to black banded shales and clays and lenticular channel sandstones.
	Eocene	San Jose Fm	---	Eastern and northern parts of the basin	Northeast part of the basin	2500	Maximum thickness in east-central part of the basin	Interbedded red, purple, and variegated shale or claystone and lenticular grey, red, and white sandstone.
		Chuska SS	---		Chuska Mts	600 - 1800	Minimum thickness to the south and maximum thickness to the north	Pinkish-grey to yellow-grey, massive to cross-bedded sandstone and interbedded siltstone and shale.
	Oligocene Miocene Pliocene	Bayfield Gravels	---	Central basin				Terrace gravels including pebbles, sand and caliche
Quaternary		Santa Fe	---	Northern half of the basin	Ladron Mts	3000 - 5000		Volcanic debris and gray to buff tuffaceous sandstone, siltstone, and conglomerate
	Pleistocene	Alluvium	---	Entire basin	Stream beds	<50 - 100	---	
	Holocene	Florida and Durango Gravels	---	Central basin	Adjacent to mountainous areas	?	---	Terrace gravels including pebbles, sand and caliche
		Spring Deposits	---	Nacimiento Mts	At springs	surface deposit only	---	?

SOURCES: Cooley and others, 1969
Cooper and John, 1968
Peterson and others, 1965
Ridgley and others, 1978



Source: Molenaar (1977), Bradish and Mills (1950).

Figure 4-2. SAN JUAN BASIN TIME-STRATIGRAPHIC NOMENCLATURE CHART

4.C.3 Ground-Water Conditions

The purpose of the foregoing discussion of the geologic framework of the San Juan Structural Basin is to help evaluate the ground-water systems of the basin.

Aquifers in the San Juan Structural Basin are, with the exception of the Permian Glorieta Sandstone and the San Andres Limestone, of upper Jurassic age or younger (see Table 4-2). The principal aquifers for the entire basin, in ascending order, are: (1) the Entrada Sandstone; (2) the Westwater Canyon Member of the Morrison Formation; (3) the Gallup Sandstone; and (4) the Dalton Sandstone Member of the Crevasse Canyon Formation, the Point Lookout Sandstone, the Menefee Formation and the Cliff House Sandstone, all of which belong to the Mesa Verde Group. The Glorieta Sandstone and San Andres Limestone (both of Permian Age), the sandstones of Tertiary age (the Ojo Alamo Sandstone, the Nacimiento Formation, the San Jose Formation, and the Chuska Sandstone) and Quaternary Alluvium are important aquifers locally.

Table 4-2 presents the hydrologic characteristics for each aquifer (or group of aquifers) recognized as an important source of ground water in the San Juan Structural Basin. In general, ground water in the basin flows from topographically high outcrop areas toward the San Juan River and the Rio Grande Valley. The continental divide crosses the eastern part of the San Juan Structural Basin with a southwest to northeast trend. Most of the basin area lies to the west of the divide in the Colorado River drainage basin; whereas, the eastern part of the area lies in the Rio Grande drainage basin. The San Juan River and two of its tributaries, the Animas and La Plata Rivers, are the only perennial streams in the arid to semi-arid basin west of the continental divide (Stone, 1981). The discharge of Tertiary, Cretaceous, and Jurassic "bedrock" aquifers to the San Juan River, based on a steady-state computer simulation of the basin, is about 16 cubic feet per second (Lyford and

Table 4-2

HYDROLOGICAL CHARACTERISTICS OF WATER-BEARING UNITS IN THE SAN JUAN BASIN

Aquifer	Recharge Area	General Direction of Ground-Water Movement	Discharge Area	Transmissivity[1] (range) Value	Transmissivity[1] (range) Area	References for More Detailed Discussion
Glorieta SS, San Andres LS	Outcrop areas on flanks of Zuni Mts. in Valencia Co.[4]	Northeastward into the central basin and southeastward to Grants Bluewater area[4]	Northeastern flanks of the Zuni Mts.	<5->70,000 ft^2/d[3]	Higher values near outcrop areas (generally northwest-southeast trending)[A]	Peterson, et.al. (1965) Spinks (1982)
Entrada SS	Outcrop areas on margins of the basin	Toward outcrops in northwestern (Four Corners area) part of the basin	San Juan River	100-300 ft^2/d	Center of the basin	Lyford (1979)
				<50 ft^2/d	Outcrops on the southern and western sides of the basin	
		Toward outcrops in southeastern part of the basin	Rio Grande			
		Southwestward (small amounts)	Puerco River(?)			
		Upward leakage	Shallower units and/or the surface			
Westwater Canyon Member of the Morrison Formation	Outcrop areas in the northeastern and southwestern parts of the basin	Toward the center of the basin, then northwestward	San Juan River	300 ft^2/d	Southwestern end of the basin	Lyford (1979) Lyford, Frenzel, and Stone (1980)
		Southeastward	Rio Grande	<50 ft^2/d	Northeastern end of the basin	
		Upward leakage	Shallower units and/or the surface			
Dakota SS	Outcrop areas on margins of the basin	Toward outcrops in northwestern (Four Corners area) part of the basin	San Juan River	44 ft^2/d	Nose Rock	Camp, Dresser and McKee (1981)
		Toward outcrops in southeastern part of the basin	Rio Grande			
		Southwestward (small amounts)	Puerco River (?)			
		Upward leakage	Shallower units and/or the surface			
Gallup SS (Cretaceous Mesa Verde Group)	Outcrop areas on southern and western sides of the basin margins	Northwestward	San Juan River indirectly, after leakage to underlying and overlying units)	100-300 ft^2/d[2]	Gallup area	Stone and Mizell (1978) Lyford (1979) Stone (1981)
		Northeastward	Rio Puerco	50-100 ft^2/d	Northeastern extent of massive SS (appoximately southeastward from Shiprock to Star Lake)	
		Southwestward (small amounts)	Puerco River			
Dalton SS Pt Lookout SS Menefee Fm Cliff House SS (Cretaceous Mesa Verde Group)	Outcrop areas and upward leakage from underlying units	Northwestward and northeastward	Land surface or alluvium-filled channels	<25 ft^2/d	Northern part of the basin	Stone and Mizell (1978) Lyford (1979)
				25-50 ft^2/d	Central part of the basin	
				50-100 ft^2/d	Southern part of the basin	
Ojo Alamo SS Nacimiento Fm San Jose Fm Chuska SS (Tertiary Rocks)	Outcrop areas near the center of the basin	Toward the San Juan River and the lower reaches of the major tributaries	San Juan River; springs on the eastern and western sides of Chuska Mts (Chuska SS only)	≤100 ft^2/d	General estimate for the entire basin	Stone and Mizell (1978) Lyford (1979)
				≤150 ft^2/d	Local estimate occurs in thicker units	
Valley Fill (Quaternary Deposits)	Percolation of irrigation water, infiltration of surface runoff, and small amounts of leakage upward from bedrock	Downward into underlying units or downstream through alluvium	Evapotransporation, leakage into underlying units or downstream through alluvium	>40,000 ft^2/d	Coarse gravels along San Juan Animas and La Plata Rivers	Lyford (1979)
				≤1000 ft^2/d	Along ephemeral streams	

(1) Source: Lyford (1979)
(2) Source: Stone (1981)
(3) Source: Spinks (1982)
(4) Source: Cooper and John (1968)

A NOTE: Transmissivity ranges with varying degrees of secondary porosity in the San Andres LS and the degree of cementation in the Glorieta SS.

Stone, 1978). The Rio San Jose and Rio Salado (tributary to Jemez River) are the only perennial streams in the San Juan Structural Basin east of the continental divide and are also ground-water discharge areas.

Although all aforementioned aquifers are separated by shale and other fine-grained units, some inter-aquifer transfer of ground water may occur. Principal conduits for such vertical ground-water movement are: (1) the many discontinous faults of small displacement throughout the basin; (2) the Hogback Monocline in the northwest part of the basin; (3) the Rio Puerco fault belt at the edge of the Rio Grande Valley; and (4) direct leakage through the materials considered to have relatively low permeability (upward or downward).

4.C.4 Westwater Canyon Member Aquifer System

4.C.4.a Previous Work

Previous studies (Guyton and Associates, 1978; Camp Dresser & McKee, Inc., 1981) suggest that a ground-water system consisting of the Triassic, Jurassic, and Cretaceous formations between the Chinle Formation and the Mancos Shale can be considered hydraulically isolated from the geologic units below and above these major confining units (Figure 4-1). As noted in the stratigrapic summary (Table 4-1), the Chinle Formation and the Mancos Shale are regionally extensive and relatively thick (700 to 1500 feet and 800 to 2300 feet, respectively) units consisting generally of shale, siltstone and mudstone, with lesser amounts of limestone, sandstone, and conglomerate. The affected environment, which could conceivably be impacted by the well field proposed to be used as an alternative water supply for NMGS, is thus assumed to be limited to the aquifers lying between the Chinle Formation and the Mancos Shale (Entrada Sandstone, Westwater Canyon Member of the Morrison Formation, and Dakota

Sandstone). These aquifers and the confining units that lie between them are herein called the Westwater Canyon Member Aquifer System. This aquifer system is shown schematically in Figure 4-3.

Ground water occurs under confined conditions in the aquifers of the Westwater Canyon Member Aquifer System, except near the outcrop belt where recharge occurs.

4.C.4.b. Detailed Evaluation of the Westwater Canyon Member Aquifer System

A detailed investigation of the Westwater Canyon Member Aquifer System was performed for this study. This investigation included preparation of isopach, structure, and potentiometric maps for the various confining and water-bearing units, where possible, and a numerical ground-water model for the entire system (Section 4.D). The data for the maps discussed below have been compiled principally from Guyton and Associates (1978), Stone and Mizell (1978), Lyford (1979), and Lyford, Frenzel and Stone (1980). Data for defining the aquifer parameters (transmissivity, storage coefficient) of the various formations have been obtained mainly from uranium mining companies and their consultants, and are summarized in Table 4-3.

The form of the following discussion of data compiled for the Westwater Canyon Member Aquifer System is by each of the five layers of the system, as defined by the water-yielding properties of the formations.

Entrada Sandstone

Data for the Entrada Sandstone are limited. This scarcity of data is due to the formation depth (except at outcrop areas), which has historically made exploration for resources economically unfeasible.

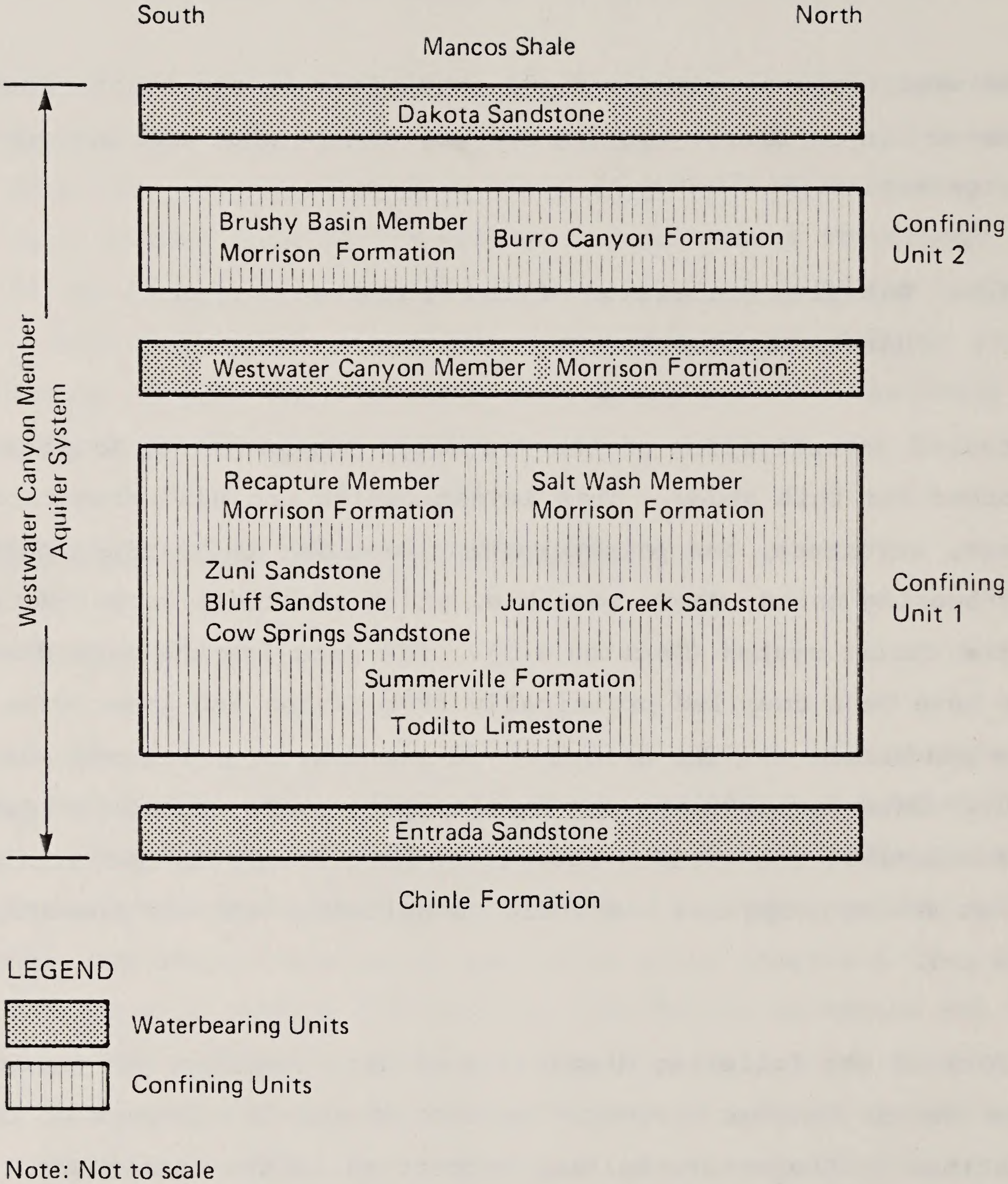


Figure 4-3. STRATIGRAPHIC SEQUENCE OF THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

TABLE 4-3
AQUIFER PARAMETERS OF THE WESTWATER CANYON MEMBER AQUIFER SYSTEM MEASURED BY PUMPING TESTS

Location T	R	Section	Owner	Well (Mine) Name	Formation	Transmissivity (ft^2/d)	Storage Coefficient	Type of Test	Reference	Comments
12N	4W	SE,NE,NE 5	EXXON	Marquez	Jmw Kd	324-555 86-183	1.2×10^{-4} to 2.9×10^{-4}	Time drawdown (72 hrs) Residual Recovery	Woodward-Clyde Consultants, 1977	leakance (Jmw) 1.0×10^{-5} to 2.1×10^{-5} day^{-1} leakance (Kd) 1.7×10^{-5} to 1.2×10^{-3} day^{-1}
12N	4W	NW,NW,SE 5	EXXON	West Marquez	Jmb, Kd	71-88	---	Time Drawdown (24 hrs)	Woodward Clyde Consultants, 1977	
12N	4W	SE,SW,SW 13	EXXON	Power Line	Jmw	211-338	7.1×10^{-5} to 2.1×10^{-4}	Time drawdown (72 hrs) Residual Recovery	Woodward-Clyde Consultants, 1977	leakance 0.0 to 1.3×10^{-3} day^{-1}
12N	4W	SE,SE,SW 15	EXXON	S.A. Valley Water Supply	Jmw (1)	219-245	---	Time Drawdown (24 hrs)	Woodward-Clyde Consultants, 1977	(1) partial penetration
12N	4W	NW,NW,NW 22	EXXON	San Antonio Valley	Jmw	77-132	1.3×10^{-4}	Time drawdown (50 hrs) Residual Recovery	Woodward-Clyde Consultants, 1977	leakance 3.1×10^{-5} to 4.3×10^{-5} day^{-1}
13N	8W	24	Gulf	Mt. Taylor	Jmw Jmb, Kd	492 27	---	Drill Stem	McGlothlin, 1972	
14N	10W	SE,SE,NW 22	Kermac Nuclear Fuels Corp.	Kermac Well No.1 and No.2	Jmw	400	---	Bailer	Jacob, 1957	
16N	10W		Cooooo (?)	Borrego Pass	Jmw	281	---	Time drawdown	Geohydrology Associates, 1977	
16N	10W	NE 2	Conoco (?)	Borrego Pass	Jmw, Kg, Kdca (1)	962	---	Time drawdown	Geohydrology Associates, 1977	(1) Most of production was from Kg and Kcda
17N	12W		Crownpoint	Crownpoint Well Field (2 wells)	Jmw	267-307	---	Time drawdown (24 hrs)	Geohydrology Associates, 1977	
17N	12W	SW 20	Crownpoint	Well No.6	Kd, Jmb, & Jmw	>360	---	Time drawdown (24 hrs) Residual Recovery	Earth Environmental Consultants, Inc. 1976	Test conducted in 1961
17N	12W	NW,NW, 20	Conoco	Crownpoint Project	Jmw	187 (avg) 166 to 205 (range)	2×10^{-4}	Time drawdown (9 days) Residual Recovery	Earth Environmental Consultants, Inc. 1976	Test conducted in 1975
17N	12W	SW 28	Mobil	Mobil Monument Project	Jmw	106 (avg) 92 to 131 (range)	5×10^{-5} (avg) 3×10^{-5} to 1×10^{-3} (range)	Time drawdown (5 day test)	Hargis and Montgomery, Inc. 1979	
17N	13W	4	Mobil (?)	?	Jmw	401 (avg)	1×10^{-4}	Time drawdown (5 day test)	Mobil, 1980	
17N	13W	SW 9	Mobil	Crownpoint Project	Jmw	187 (avg) 160-240 (range)	5×10^{-5} (avg) 1×10^{-5} to 3×10^{-4} (range)	Time drawdown (3 day test) Residual Recovery	Marshbarger and Associates, 1978	
17N	13W	15,16	Mobil	Crownpoint Property	Jmw	267 (avg) 170-360 (range)	1×10^{-4} (avg) 4×10^{-5} to 4×10^{-4} (range)	Time draw- (13 day test)	Mobil, 1980	
19N	11W	31	Phillips Petroleum Company	Nose Rock	Jmw, Kd	88-136	4.2×10^{-5}	Time drawdown Shut-in Recovery	Dames and Moore, 1977	
19N	11W	?	Phillips	Nose Rock	Kd	44	---		Camp, Dresser and McKee, 1981	
20N	6W	NW,SW,NE 31	Cherokee and Pittsburg Coal and Mining Company	No.1 Star Lake	Jmw	35	---	Time drawdown Shut-in Recovery	Shoemaker, 1977	
21N	9W	SW,NE 16	Cherokee and Pittsburg Coal and Mining Company	No.1 Gallo Wash Water Well	Jmw	88-130	---	Time drawdown Shut-in Recovery	Shoemaker 1977	
23N	13W	SE,NW 9	US. Bureau of Land Management	Apache-Foshay No. 1 (Bisti Well)	Jmw Je	355 (approx.) 175-460	10^{2} to 10^{-4} (1)	Time drawdown Shut-in Recovery	Shoemaker, 1974b	(1) undifferentiated Je, Jmw, Kg
23N	14W	SW,NW 3	Consolidation Coal Co.	El Paso-Burnham No. 1	Jmw	158-206	---	Time drawdown Shut-in Recovery	Shoemaker, 1977	

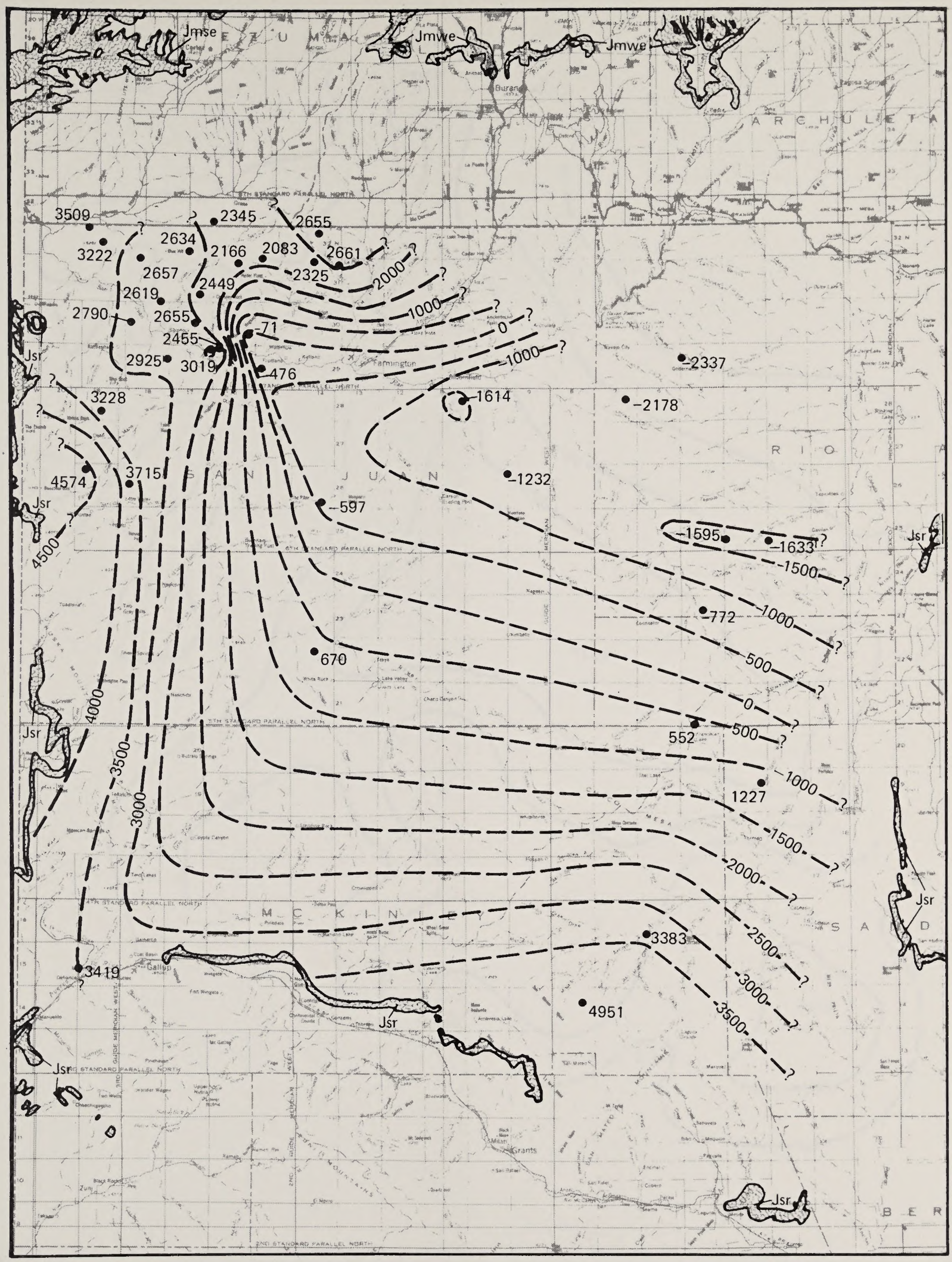
The Entrada Sandstone occurs over the entire San Juan Structural Basin and generally follows the structural trends of the basin (Map 4-3). Near the location of the well field for NMGS the Entrada Sandstone dips gently to the north and lies at a depth of approximately 6000 feet. The Entrada Sandstone contains an average of 100 to 150 feet of total porous sandstone (Map 4-4). Generally, the porous sandstone portion of the Entrada Sandstone decreases in thickness toward the northeast and is absent at the southern and eastern margins of the basin due to Cenozoic erosion. Table 4-1 contains a summary of the lithologic character of the Entrada Sandstone.

The hydrologic characteristics of the Entrada Sandstone are presented in Table 4-2. Cooley and others (1969) estimate that wells tapping this formation could discharge up to several gallons of water per minute; however, the Entrada Sandstone is considered to be a unit with relatively low permeability in the Gallup area (Mercer and Cooper, 1970). A transmissivity for the Entrada Sandstone of 175-460 ft^2/day has been estimated from one aquifer test in the vicinity of NMGS (Table 4-3).

Confining Unit 1

Confining Unit 1 consists of the Todilto Limestone, the Summerville Formation, the Cow Springs/Bluff/Zuni Sandstones, the Junction Creek Sandstone, and the Recapture and Salt Wash Members of the Morrison Formation (Figure 4-3). As discussed in the stratigraphic summary (Table 4-1), these formations are generally composed of limestone, sandstone, siltstone, and shale.

Data for defining the thickness and hydrologic parameters of this unit are sparse due to the depth of the formations, which has limited the development of resources. The thickness of this confining unit ranges from 400 to 700 feet but generally appears to be fairly uniform (Map 4-5).



LEGEND

• 2165 Well
Elevation (feet, MSL) on top of Entrada Sandstone

1500 Contour line of equal elevation (feet, MSL), on top of Entrada Sandstone, dashed where approximate

Outcrop

Jsr San Rafael Group (Bluff, Cowsprings, Zuni Sandstones; Summerville Formation; Todilto Limestone; Entrada Sandstone; Carmel Formation)

Jmse Morrison Formation, Summerville Formation, Entrada Sandstone

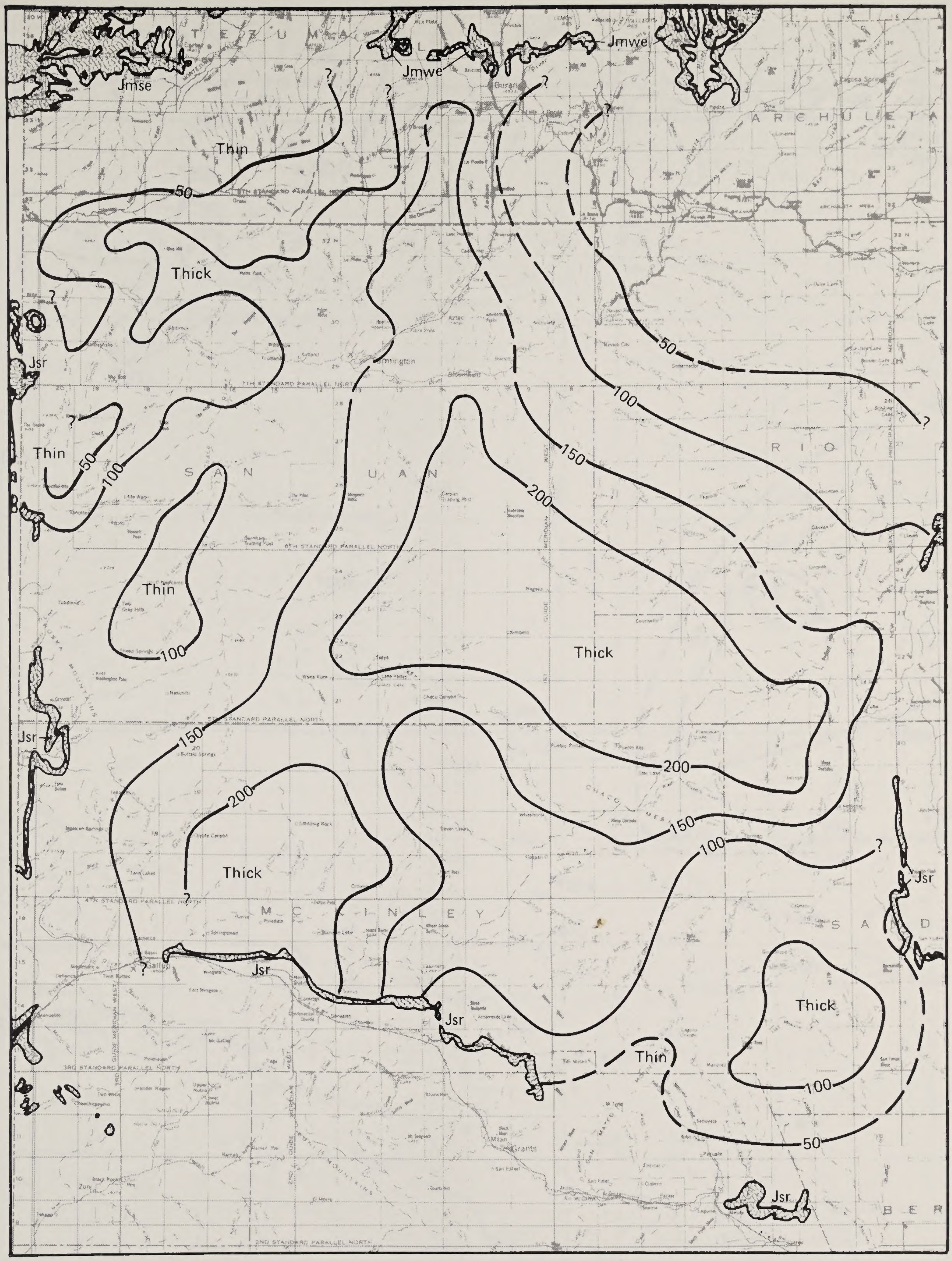
Jmwe Morrison Formation, Wanakah Formation, Entrada Sandstone

N

0 10 20 30
miles

Sources: Dane and Bachman (1965); Guyton and Associates (1978); Hintze (1981); Wilson, Moore, and Cooper (1969); and Tweto (1979).

Map 4-3. STRUCTURE OF ENTRADA SANDSTONE IN THE SAN JUAN BASIN



LEGEND

Isopach (feet), dashed where approximate

Jsr San Rafael Group (Bluff, Cow Springs, Zuni, Sandstones: Summerville Formation; Todilto Limestone; Entrada Sandstone; Carmel Formation)

Jmse Morrison Formation, Summerville Formation, Entrada Sandstone

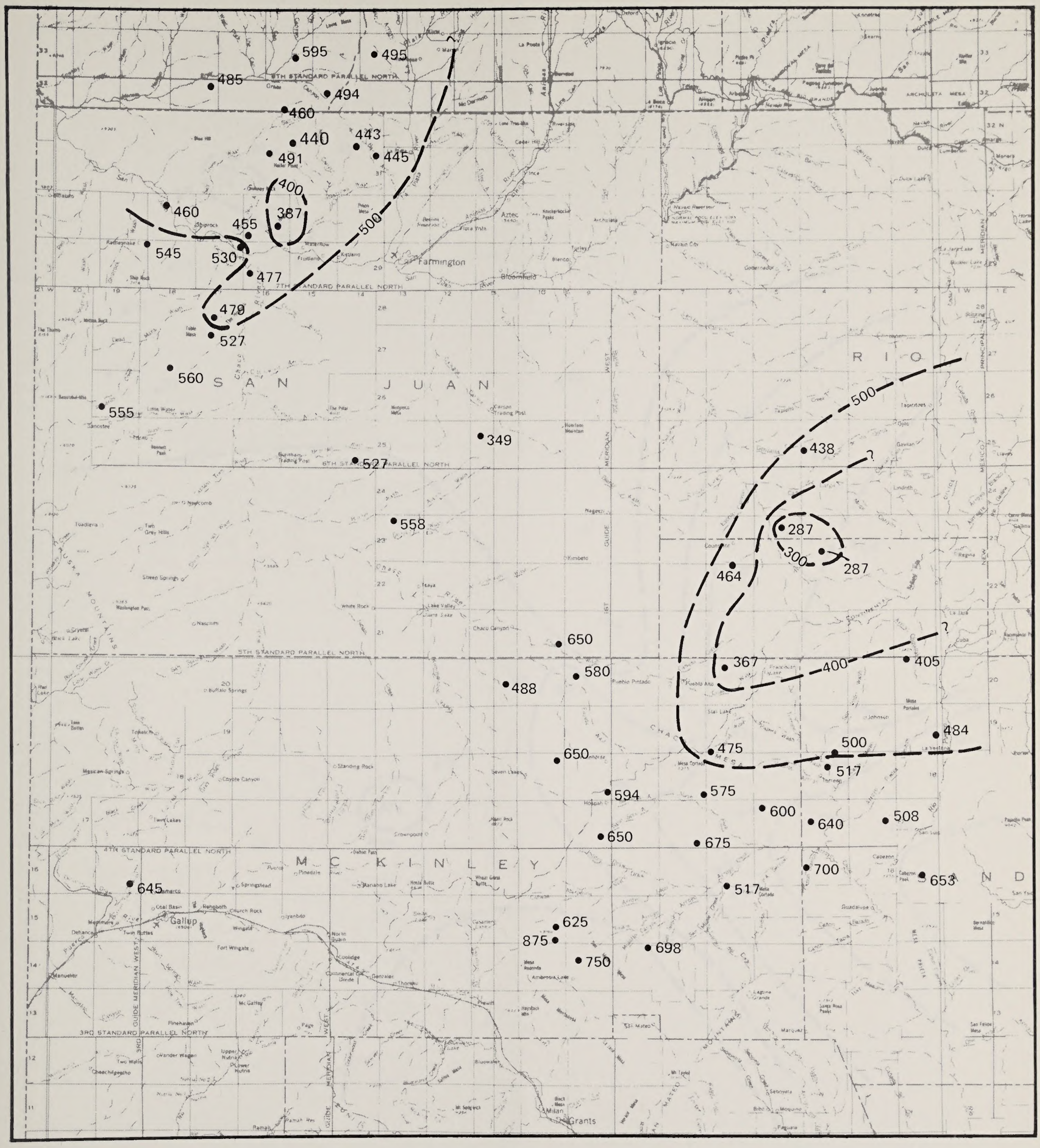
Jmwe Morrison Formation, Wanakah Formation, Entrada Sandstone

N

0 10 20 30
miles

Sources: Dane and Bachman (1965); Peterson et al. (1965); Hintze (1981); Wilson, Moore, and Cooper (1969); and Tweto (1979).

Map 4-4. TOTAL POROUS SANDSTONE PRESENT IN THE ENTRADA SANDSTONE



LEGEND

• 595 — Well
Thickness of Confining Unit 1 (feet)
(Confining Unit 1: Todilto Limestone; Summerville Formation; Cow Springs, Bluff, Zuni Sandstones; Junction Creek Sandstone; Recapture and Salt Wash Members of Morrison Formation).

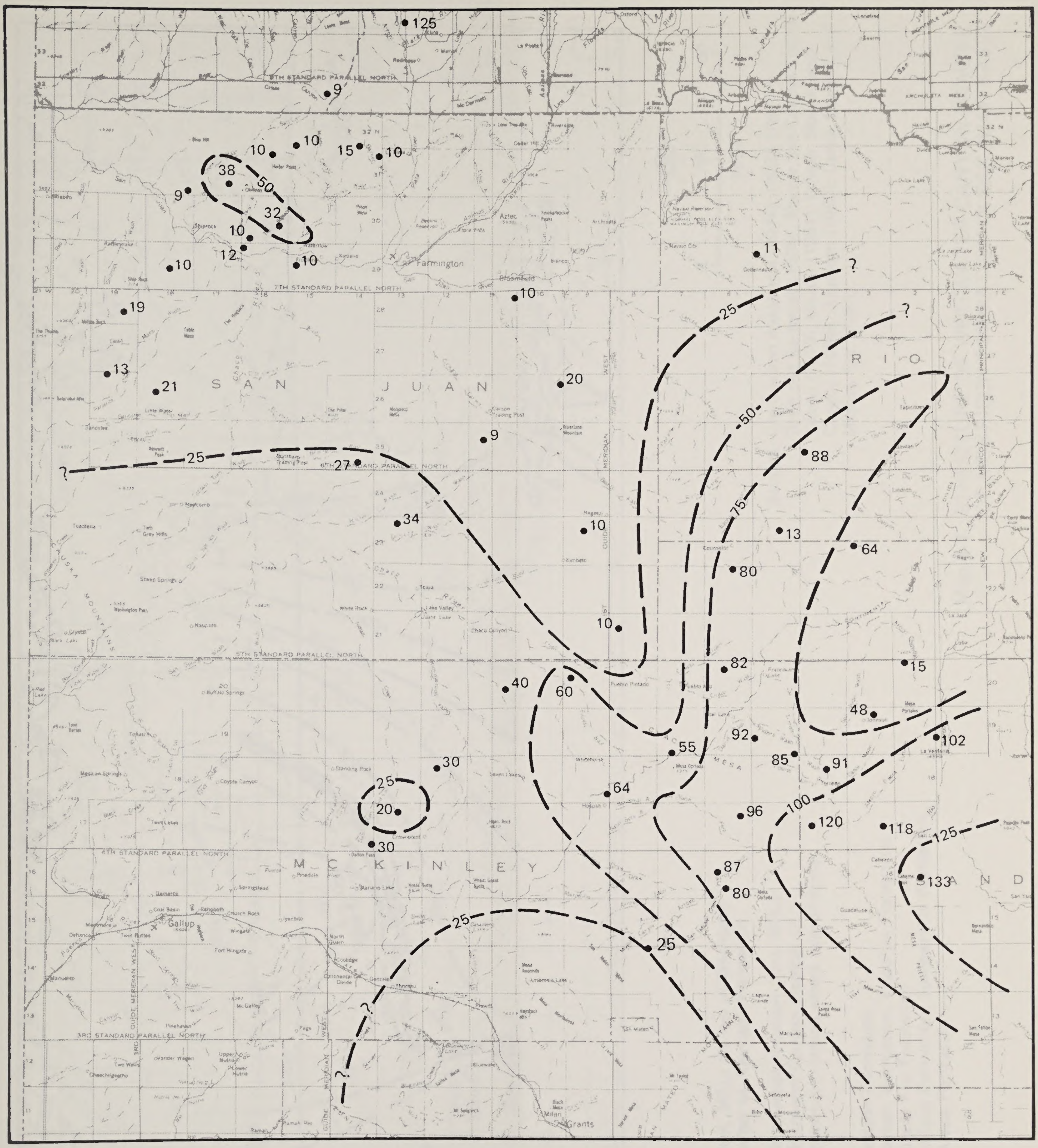
500 — Isopach (feet), dashed where approximate

N

0 10 20 30
miles

Sources: Guyton Associates (1978); New Mexico Bureau of Mines and Mineral Resources (1977); USGS (1981c); Cooper and John (1968); Camp, Dresser and McKee, Inc. (1981).

Map 4-5. THICKNESS OF CONFINING UNIT 1



LEGEND

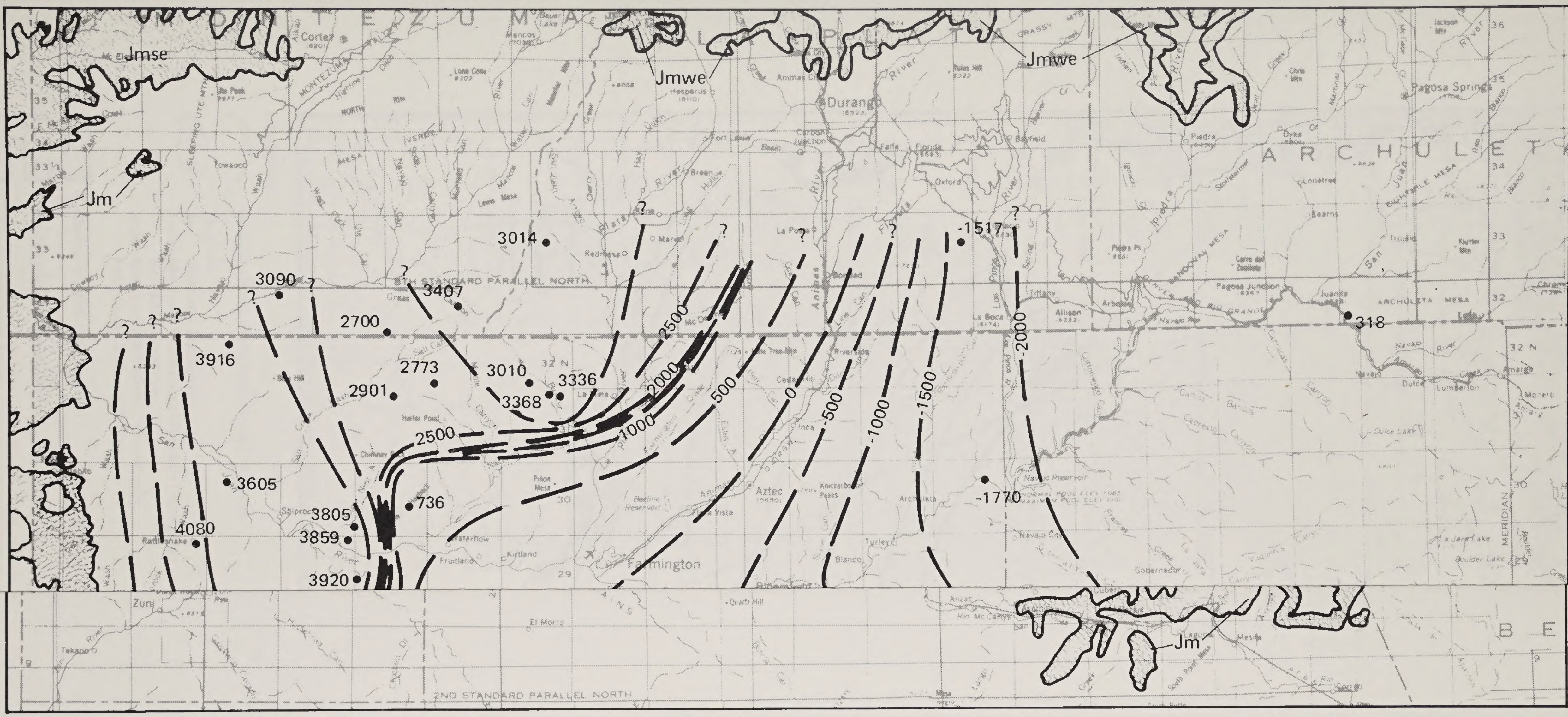
- • 85 Well — Thickness of Todilto Limestone (feet)
- —50— Isopach (feet), dashed where approximate

N

0 10 20 30 miles

Source: Camp, Dresser, and McKee, Inc. (1981) Guyton and Associates (1978); USGS (1981c); New Mexico Bureau of Mines and Mineral Resources (1977); Cooper and John (1968).

Map 4-6. THICKNESS OF TODILTO LIMESTONE



LEGEND

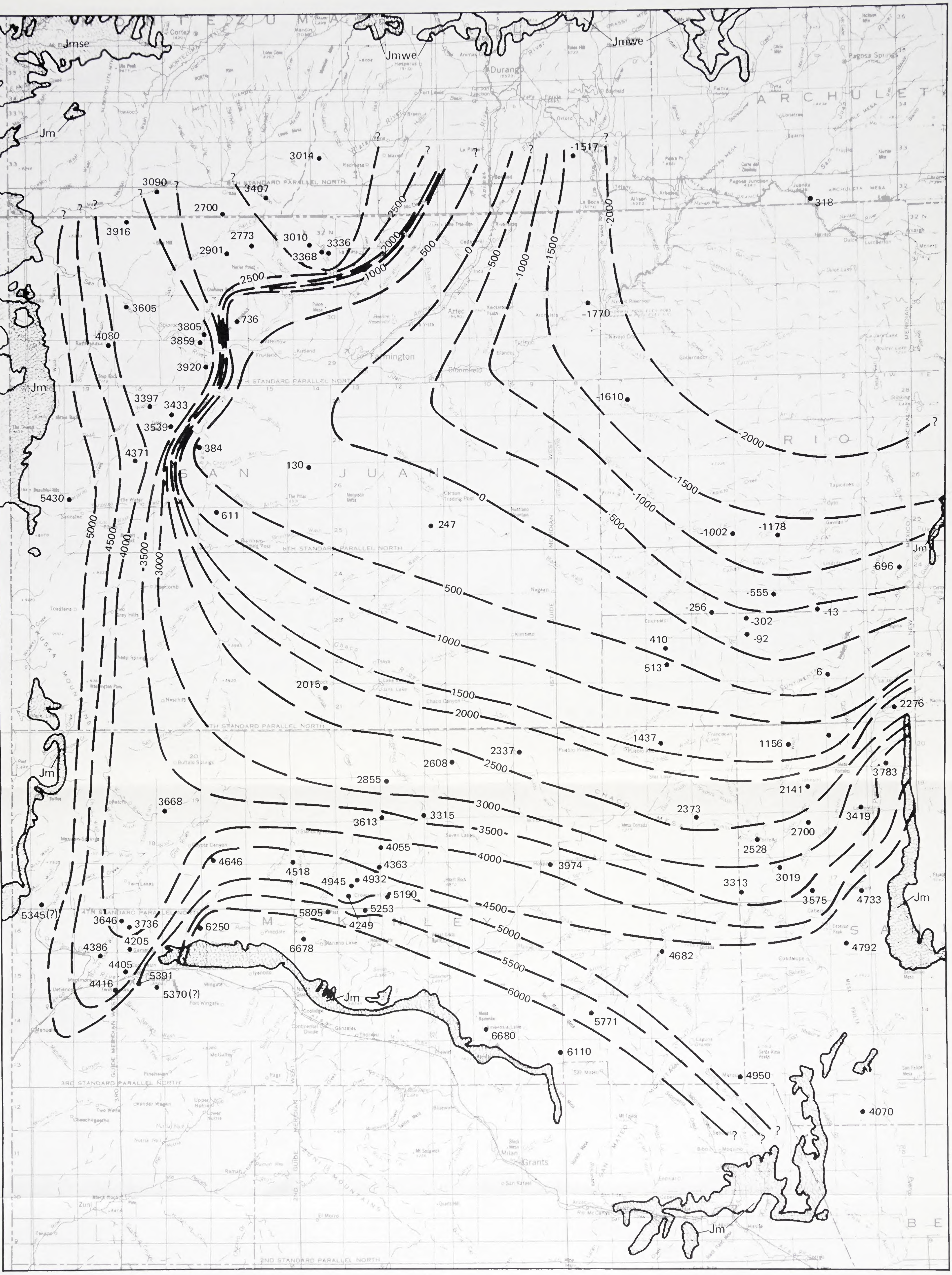
• 414	Well Elevation (feet, MSL) on top of Westwater Canyon Member of Morrison Formation
— —500— —	Contour line of equal elevation (feet, MSL) on top of Westwater Canyon Member of Morrison Formation, dashed where approximate
	Outcrop
Jm	Morrison Formation
Jmwe	Morrison Formation, Wanakah Formation, Entrada Fro Formation
Jmse	Morrison Formation, Summerville Formation, Entrada Formation

N

0 10 20
miles

Sources: Guyton and Associates (1978); USGS (1981c); Dane and Bachman (1965); Mercer and Cooper (1970); Tweto (1979); Hintze (1981); Wilson, Moore, and Cooper (1969); Rautman (1980); Camp, Dresser, and McKee, Inc. (1981).

Map 4-7. STRUCTURE OF WESTWATER CANYON MEMBER OF MORRISON FORMATION IN SAN JUAN BASIN



LEGEND

• 414 — Well; Elevation (feet, MSL) on top of Westwater Canyon Member of Morrison Formation

— 500 — — Contour line of equal elevation (feet, MSL) on top of Westwater Canyon Member of Morrison Formation, dashed where approximate

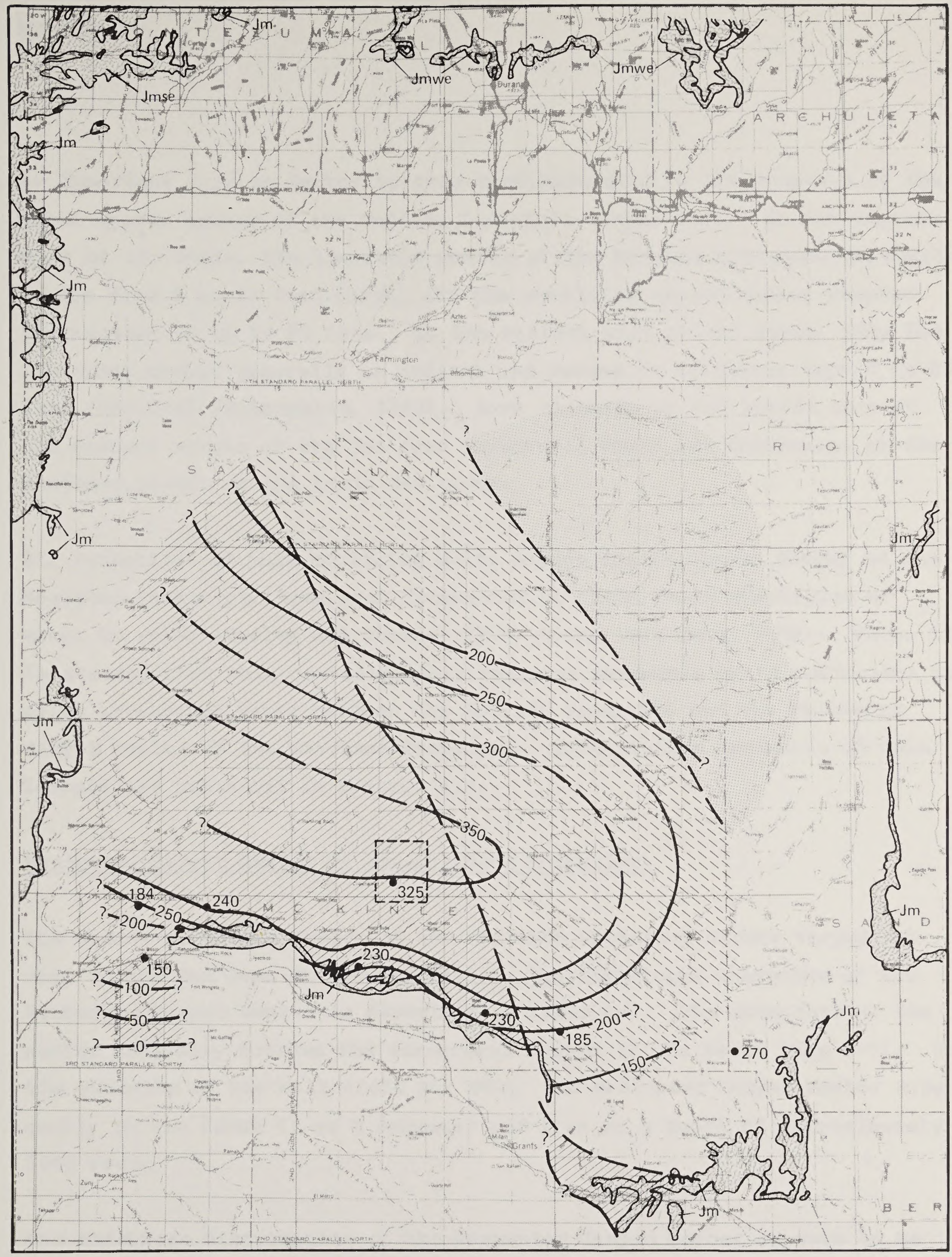
Outcrop
- Jm — Morrison Formation
- Jmwe — Morrison Formation, Wanakah Formation, Entrada Fro Formation
- Jmse — Morrison Formation, Summerville Formation, Entrada Formation

N

0 10 20
miles

Sources: Guyton and Associates (1978); USGS (1981c); Dane and Bachman (1965); Mercer and Cooper (1970); Tweto (1979); Hintze (1981); Wilson, Moore, and Cooper (1969); Rautman (1980); Camp, Dresser, and McKee, Inc. (1981).

Map 4-7. STRUCTURE OF WESTWATER CANYON MEMBER OF MORRISON FORMATION IN SAN JUAN BASIN



LEGEND

Isopach (feet), dashed where approximate

Outcrop
- Jm — Morrison Formation
- Jmwe — Morrison Formation, Wanakah Formation, Entrada Formation
- Jmse — Morrison Formation, Summerville Formation, Entrada Sandstone

Coarse-grained sand facies

Medium-grained sand facies

Fine-grained sand facies

Area shown in Map 4-9

N

0 10 20 30
miles

Sources: Guyton and Associates (1978); Rautman (1980); Dane and Bachman (1965); Kelly (1977); Mercer and Cooper (1970); Tweto (1979); Hintze (1980); Wilson, Moore, and Cooper (1969).

Map 4-8. LITHOFACIES AND THICKNESS OF WESTWATER CANYON MEMBER OF MORRISON FORMATION, SAN JUAN BASIN

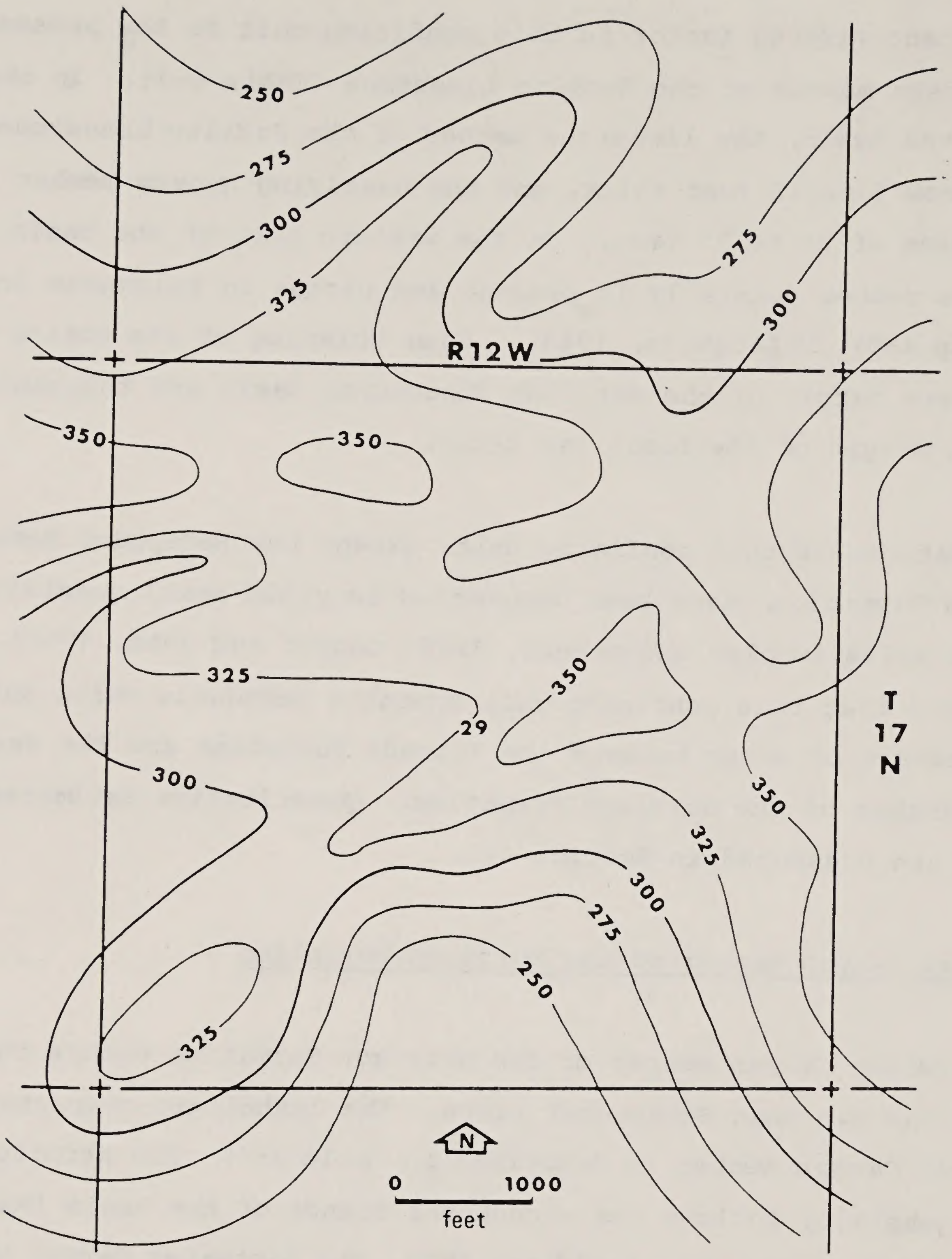
An important varying factor in this confining unit is the presence of the upper gypsum member of the Todilto Limestone (Table 4-1). In the eastern part of the basin, the limestone member of the Todilto Limestone generally ranges from 5 to 10 feet thick, and the overlying gypsum member reaches thicknesses of up to 95 feet. In the western part of the basin, only the limestone member generally is present and ranges in thickness from 0 to 25 feet (Map 4-6) (McLaughlin, 1963). Some thinning of the entire unit at the eastern margin of the San Juan Structural Basin and thickening at the southern margin of the basin may occur.

All formations of this confining unit, except the Recapture Member of the Morrison Formation, have been documented to yield small quantities of water to wells (Cooley and others, 1969; Cooper and John, 1968). Thus, it is assumed that this confining unit contains permeable units sufficient to allow leakage of water between the Entrada Sandstone and the Westwater Canyon Member of the Morrison Formation. Quantitative estimates of this leakage are presented in Section 4.D.

Westwater Canyon Member of the Morrison Formation

The Westwater Canyon Member of the Morrison Formation occurs throughout most of the San Juan Structural Basin. The lithologic character of the Westwater Canyon Member is described in Table 4-1. The structure of the member generally follows the structural trends of the basin (Map 4-7). In the vicinity of the well field for NMGS, the Westwater Canyon Member dips gently to the north (1 or 2 degrees) and lies at a depth of approximately 5000 feet.

The thickness distribution of the Westwater Canyon Member appears to be variable both on a local and a regional scale (Maps 4-8 and 4-9; Rautman, 1980; Kelly, 1977; Kelley 1963; and, Craig et. al, 1955). Most sources agree that the Westwater Canyon Member represents an alluvial fan that spread into northwestern New Mexico and adjacent parts of Arizona, Utah,



LEGEND

300 Isopach (feet)

Source: Wentworth and others (1980).

Note: Approximate location of above area within San Juan Basin is shown on Map 4-8.

Map 4-9. THICKNESS OF WESTWATER CANYON MEMBER IN SEC. 29, T. 17 N., R. 12 W.

and Colorado from an apex in west-central New Mexico. The thickness of the Westwater Cañyon Member generally ranges from about 50 feet along what is assumed to be the distal edges of the fan (northern and western margins of the basin) to over 300 feet in the more proximal areas, north of Gallup, New Mexico (Map 4-8). Southwest of Gallup, the Westwater Canyon Member thins rapidly to a pinchout resulting from pre-Dakota erosional truncation (Saucier, 1967).

The hydrologic characteristics of the Westwater Canyon Member of the Morrison Formation are presented in Table 4-2. Well tests conducted to estimate the aquifer parameters of this unit are presented in Table 4-3. The transmissivity estimated for the Westwater Canyon Member is based on the observed regional grain size distribution and results of aquifer pumping tests. As noted by Ridgely, et al. (1978):

> "In the southwestern part of the basin, the member consists of arkosic to arkosic conglomeratic sandstone, poorly sorted sandstone, and thin beds of light greenish-gray or grayish red siltstone, and claystone. Laterally to the north and east the conglomerate disappears and the Westwater Canyon Member consists of varying proportions of sandstone, siltstone, and claystone. The ratio of sandstone to claystone and the grain size decrease from south to north."

The transmissivity of the Westwater Canyon Member appears to be greatest in the southwestern part of the basin (>300 ft^2/day) and decreases to less than 50 ft^2/day in the northeastern part of the basin (Lyford, 1979). This variation probably is due mainly to changes in grain size and lithology as the distance from the provenance of the sediments increases. As illustrated by the aquifer test data (Table 4-3), there are other sources of variation in transmissivity, which may be related to: (1) fracture premeability due to presence of faulting (especially in Mount Taylor area--see Map 4-2); (2) differences in experimental procedures of aquifer tests; and (3) smaller scale variations in thickness and lithology of the Westwater Canyon Member. The average transmissivity of the Westwater Canyon Member is judged to be approximately 240 ft^2/day.

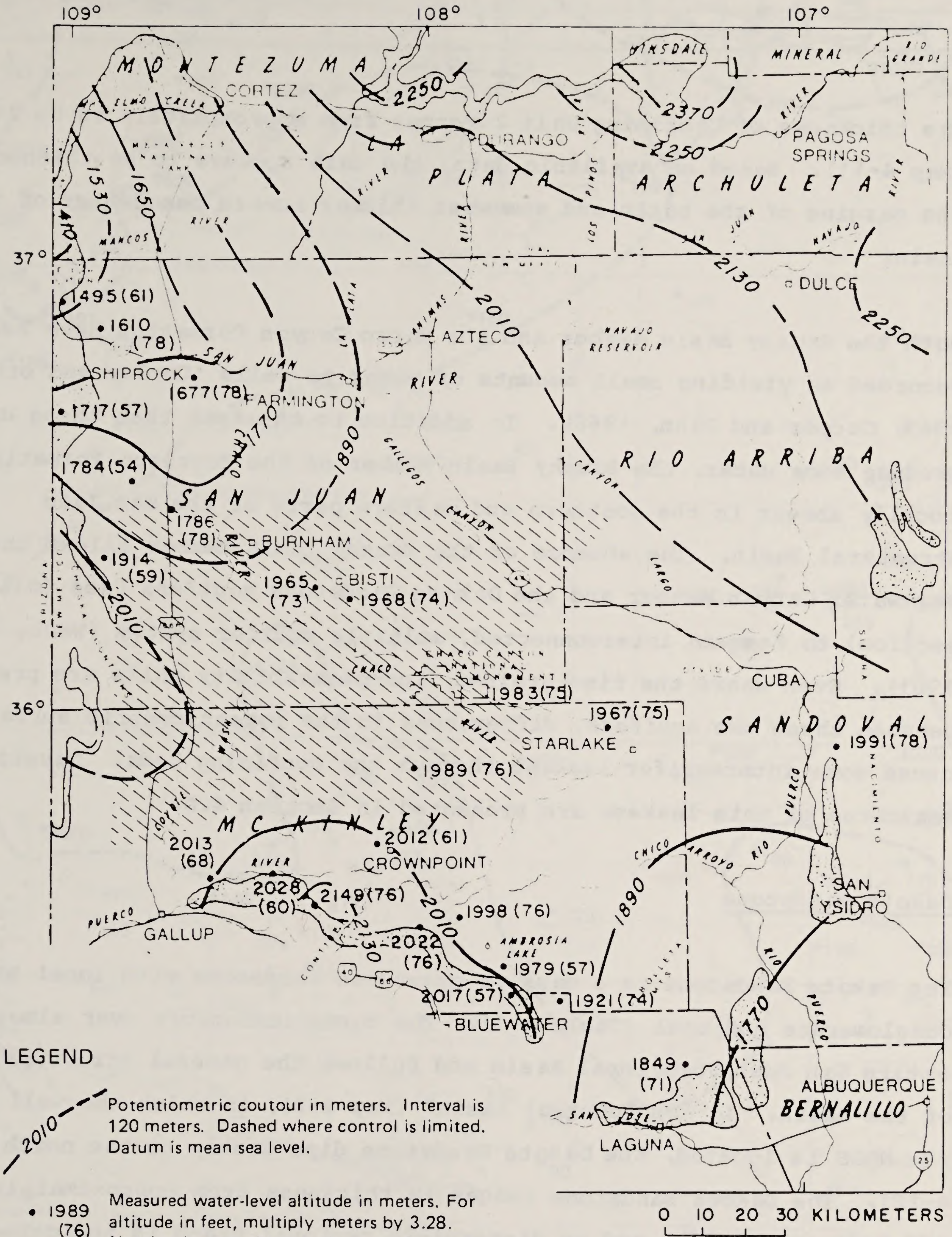
Values of storage coefficient calculated from aquifer tests generally range from 1×10^{-5} to 4×10^{-4} (Table 4-3). An average value of about 8×10^{-5} is indicated by the test results.

The potentiometric surface of the Morrison Formation, as compiled from water-level data and shut-in pressures of flowing wells for a period of over 20 years, is shown on Map 4-10. This figure is assumed to be representative of the potentiometric surface of the Westwater Canyon Member. Ground water in the Westwater Canyon Member appears to move from topographically high areas where the unit crops out to: (1) the center of the basin and then northwestward toward the San Juan River; (2) southeastward toward the Rio Puerco; and (3) southwestward toward the Puerco River (Map 4-10).

Wells that are completed in the Westwater Canyon Member, in a generalized area of approximately 2,500 square miles, are flowing (potentiometric surface above the ground surface) (Map 4-10). The western boundary of this zone of flowing wells coincides with the front of the Chuska Mountains (Kelly, 1977). Along the southern edge of the basin, the outcrop belt of the Point Lookout Sandstone (Mesaverde Group) generally coincides with the southern limit of flowing wells from the Westwater Canyon Member. The eastern boundary of the area of flowing-wells is roughly defined by the 6,500-foot elevation of the land surface (Kelly, 1977).

Confining Unit 2

Confining Unit 2 consists of the Brushy Basin Member of the Morrison Formation and, to the north, the Burro Canyon Formation (Figure 4-3). As discussed in Table 4-1, these formations generally consist of claystone and sandstone, and conglomerate and sandstone with some mudstone lenses, respectively.



LEGEND

Potentiometric coutour in meters. Interval is 120 meters. Dashed where control is limited. Datum is mean sea level.

• 1989 (76) Measured water-level altitude in meters. For altitude in feet, multiply meters by 3.28. Number in parentheses is the year of measurement.

Outcrop area.

Area of flowing wells

Source: Kelly (1977), Lyford, Frenzel, and Stone (1980).

Note: The water levels measured in wells that penetrate all or part of the Morrison Formation are assumed to be representative of the potentiometric surface in the Westwater Canyon Member.

Map 4-10. POTENTIOMETRIC SURFACE OF MORRISON FORMATION, 1954-1978

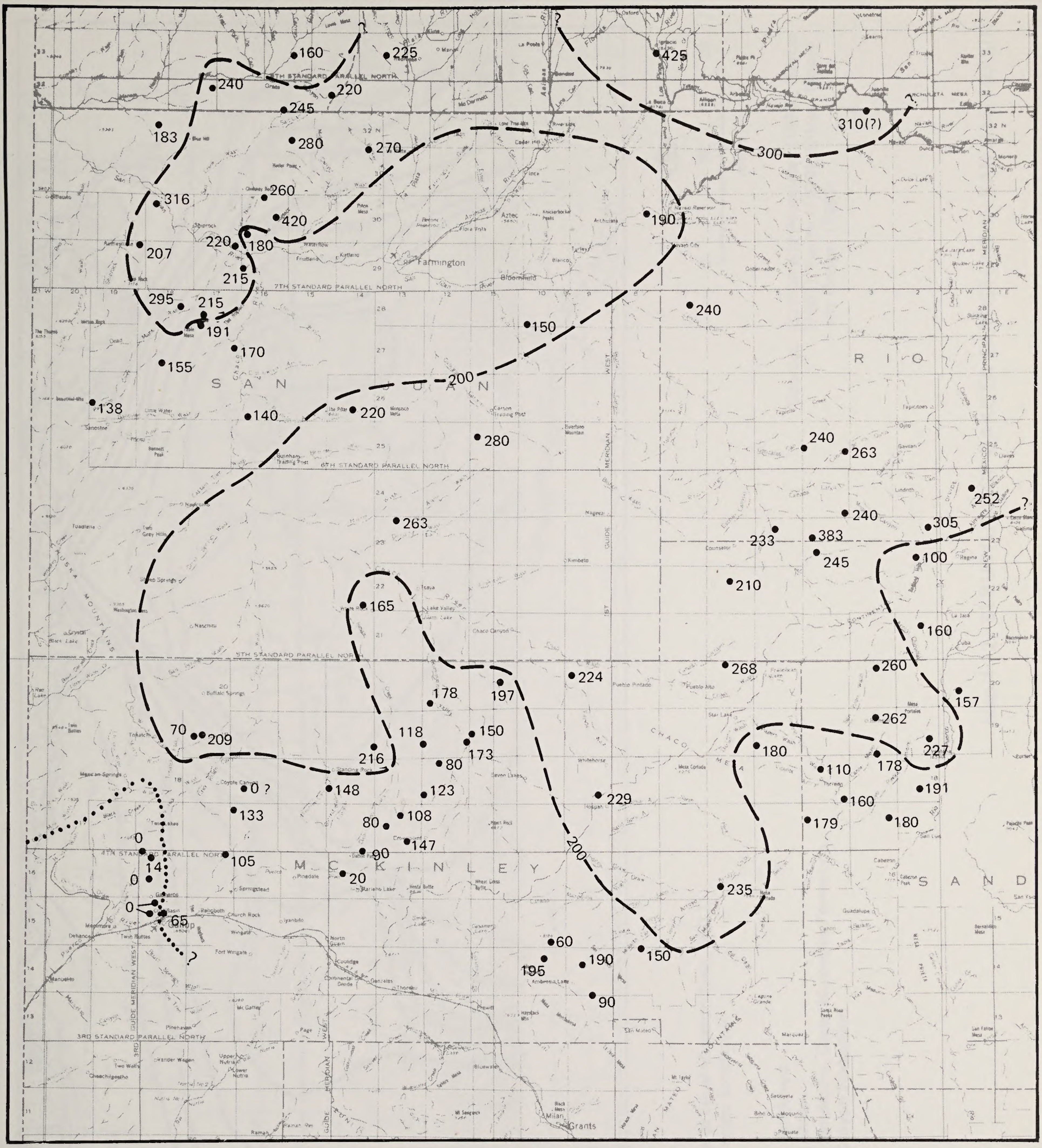
The thickness of Confining Unit 2 ranges from approximately 50 to 250 feet (Map 4-11). Based on available data, the unit appears to be thinner on the margins of the basin and somewhat thicker toward the center of the basin.

Both the Brushy Basin Member and the Burro Canyon Formation have been recorded as yielding small amounts of water to wells (Cooley and others, 1969; Cooper and John, 1968). In addition to the fact that these units produce some water, the Brushy Basin Member of the Morrison Formation is locally absent in the southern and western parts of the San Juan Structural Basin. The absence of the Brushy Basin Member allows the Westwater Canyon Member and the Dakota Sandstone aquifers (see following section) to form an interconnected, multiple aquifer system (West, 1961). Even where the fine-grained, low-permeability units are present between these two aquifers, differences in the potentiometric surfaces cause some interaquifer leakage through the confining beds. Quantitative estimates of this leakage are presented in Section 4.D.

Dakota Sandstone

The Dakota Sandstone is a massive quartzose sandstone with local beds of conglomerate and coal (Table 4-1). The formation occurs over almost the entire San Juan Structural Basin and follows the general structural trends of the basin. In the "central basin" (Map 4-2), in which the well field for NMGS is located, the Dakota Sandstone dips gently to the north (Map 4-12). The Dakota Sandstone ranges in thickness from approximately 150 to 350 feet (Map 4-13), and no discernible regional trend is indicated by available data.

The hydrologic characteristics of the Dakota Sandstone are presented in Table 4-2. Well tests conducted to estimate the aquifer parameters of this unit are presented in Table 4-3.



LEGEND

•287 Well
Thickness of Confining Unit 2 (feet)
(Confining Unit 2: Brushy Basin Member of Morrison Formation; Burro Canyon Formation)

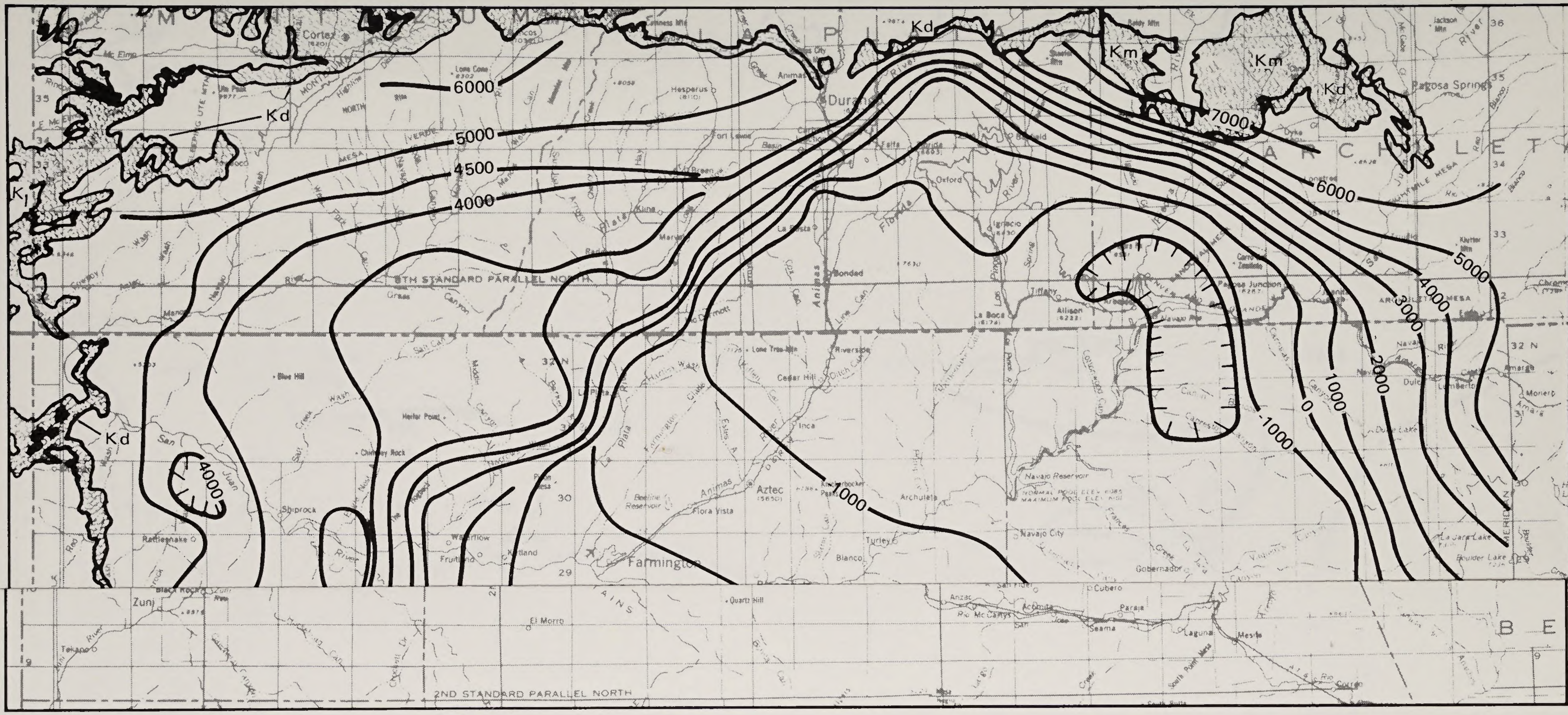
300 Isopach (feet), dashed where approximate

Approximate line of zero foot thickness of Brushy Basin Member of Morrison Formation

N
0 10 20 30
miles

Sources: Camp, Dresser and Mckee, Inc. (1981); Guyton and Associates (1978); USGS (1981c); Mercer and Cooper (1970); Mobil (1980); Rautman (1980); Cooper and John (1968); Stone and Mizell (1978).

Map 4-11. THICKNESS OF CONFINING UNIT 2



LEGEND

500 — Contour line of equal elevation (feet, MSL), on top of Dakota Sandstone

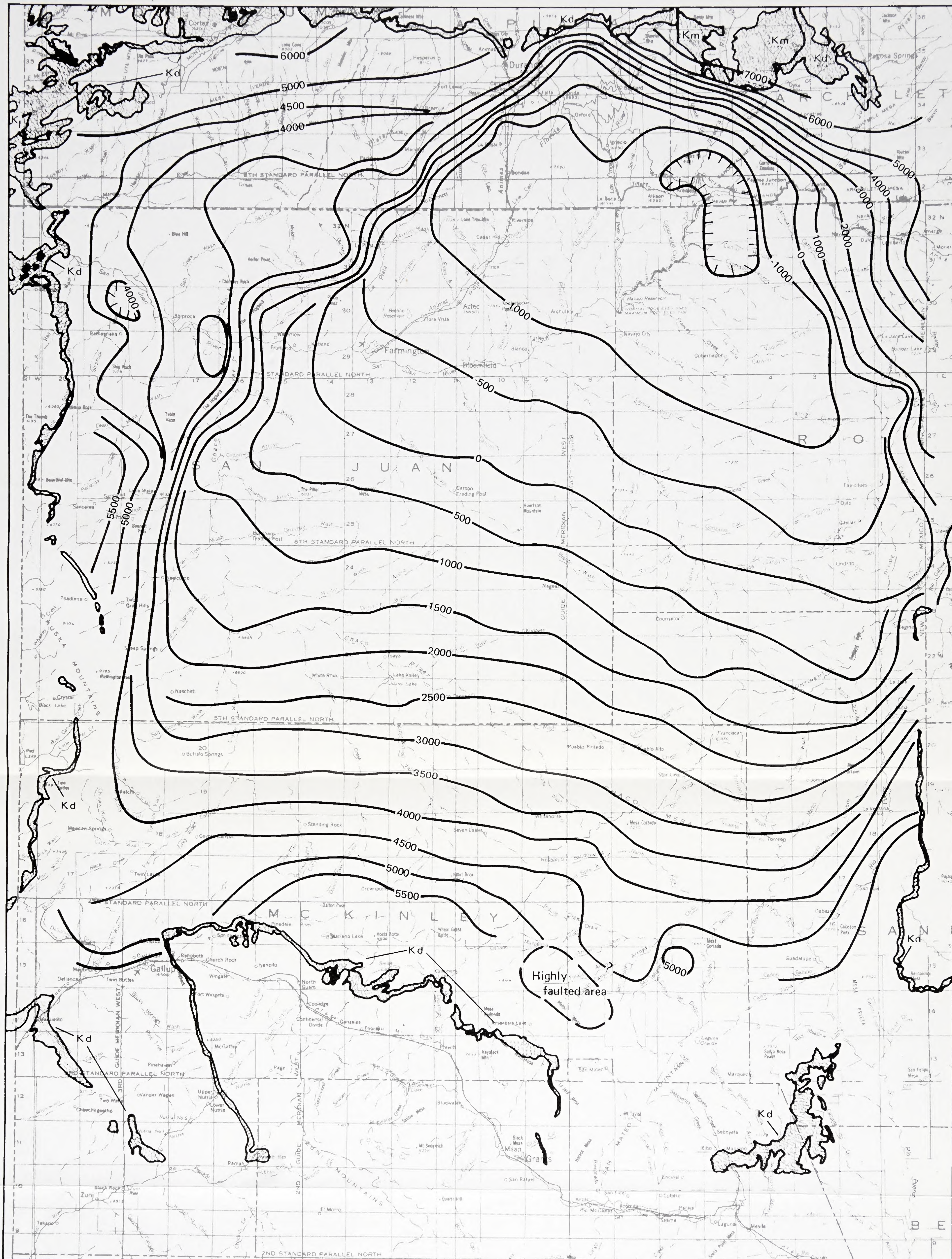
Outcrop
Kd Dakota Sandstone
Km Mancos Shale
K_l Dakota Sandstone, Cedar Mountain Formation, Burro Canyon Formation

N

0 10 20
miles

Sources: Guyton and Associates (1978); Hintze (1981); Tweto (1979); Wilson, Moore, and Cooper (1969).

Map 4-12. STRUCTURE OF DAKOTA SANDSTONE IN SAN JUAN BASIN



LEGEND

500 — Contour line of equal elevation (feet, MSL), on top of Dakota Sandstone

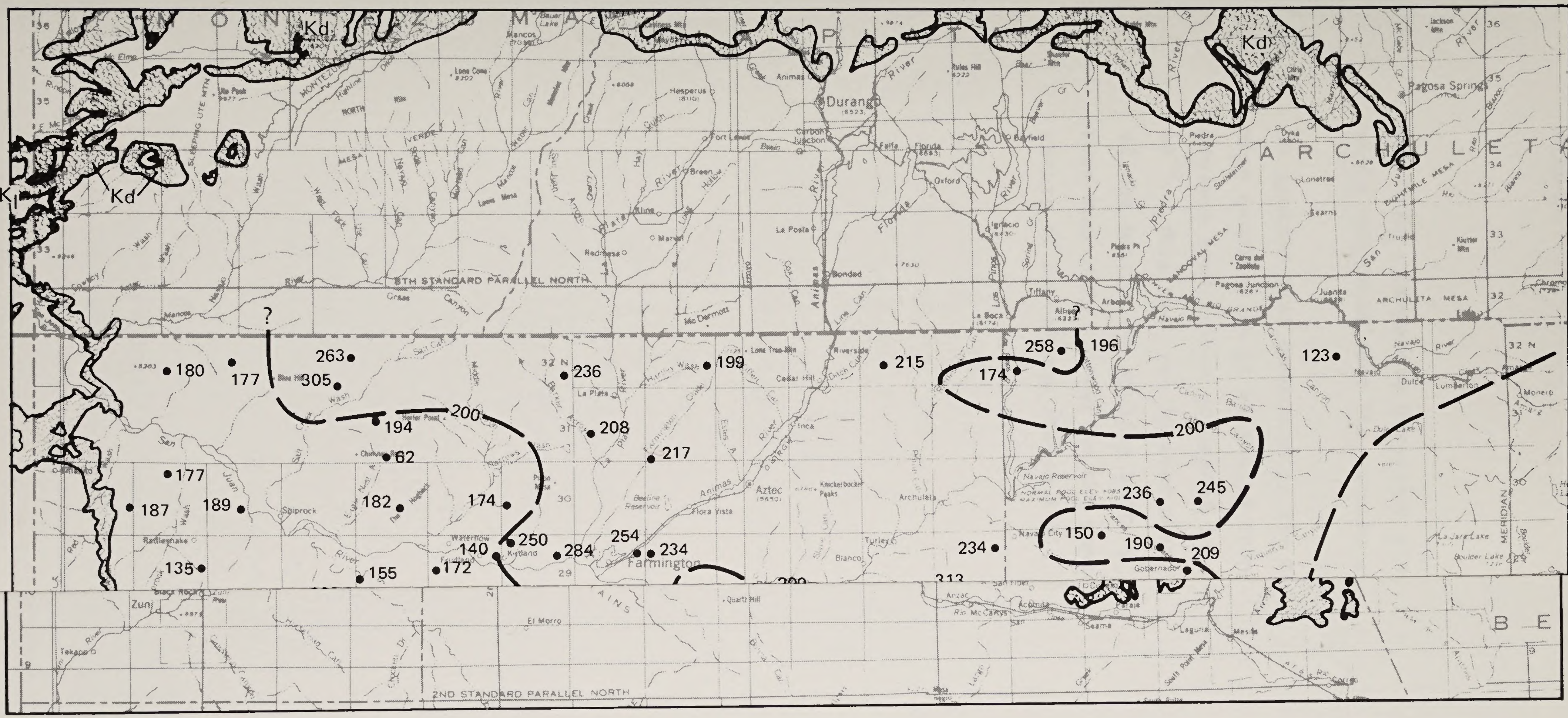
Outcrop
Kd Dakota Sandstone
Km Mancos Shale
K_l Dakota Sandstone, Cedar Mountain Formation, Burro Canyon Formation

N

0 10 20
miles

Sources: Guyton and Associates (1978); Hintze (1981); Tweto (1979); Wilson, Moore, and Cooper (1969).

Map 4-12. STRUCTURE OF DAKOTA SANDSTONE IN SAN JUAN BASIN



LEGEND

Well
210 Thickness of Dakota Sandstone (feet)

100 Isopach (feet), dashed where approximate

Outcrop
Kd Dakota Sandstone
K_l Dakota Sandstone, Cedar Mountain Formation, Burro Canyon Formation

0 10 20
miles

Sources: Dane and Bachman (1965); Mercer and Cooper (1975); Rautman (1980); Stone and Mizell (1978); Tweto (1979); Hintze (1981); Wilson, Moore, and Cooper (1969).

Map 4-13. THICKNESS OF DAKOTA SANDSTONE

LEGEND

• 210 Well
Thickness of Dakota Sandstone (feet)

—100— — Isopach (feet), dashed where approximate

Outcrop
Kd Dakota Sandstone
K_l Dakota Sandstone, Cedar Mountain Formation, Burro Canyon Formation

0 10 20
miles

Sources: Dane and Bachman (1965); Mercer and Cooper (1975); Rautman (1980); Stone and Mizell (1978); Tweto (1979); Hintze (1981); Wilson, Moore, and Cooper (1969).

Map 4-13. THICKNESS OF DAKOTA SANDSTONE

The Dakota Sandstone generally yields less than 10 gallons per minute to wells completed near the outcrop area (Cooper and John, 1968).

An aquifer test conducted in the Dakota Sandstone at the Exxon Marquez Mine resulted in an estimated transmissivity of 85-185 ft^2/day. The storage coefficient estimated in the test ranged from 8×10^{-5} to 1×10^{-4}. This test was located near Mount Taylor in the southeastern portion of the basin. An aquifer test of the Dakota Sandstone at the Phillips Nose Rock Mine, closer to the center of the basin, yielded a transmissivity of 44 ft^2/day (Table 4-3).

4.C.4.c Historic, Present and Projected Uses. Historic consumptive uses of ground water in the San Juan River Basin in New Mexico (corresponds to geographic area of San Juan Underground Water Basin) are summarized in Table 4-4. The largest historical use of ground water has been for mining, most of which represents mine dewatering and milling of uranium. The next largest historical use of ground water has been for rural domestic water supply, followed in importance by livestock watering. The total historical use of ground water in the San Juan Underground Water Basin has been relatively small, and is only about 1 percent of the historic consumptive surface-water use in the same area (see Table 3-3).

Historic, present, and projected uses of ground water from the Westwater Canyon Member aquifer system in the San Juan Structural Basin is of particular significance for estimating the effects of the well field for NMGS on other ground-water users. A compilation of these ground-water uses was prepared based on many sources of available information. This compilation was divided into four categories that are required for the impact analysis:

(1) Historic users (through 1980)
(2) Prior users (users who have filed water rights applications prior to Paragon Resources, Inc., or declarations (see Section 4.B.2)
(3) PNM (New Mexico Generating Station)
(4) Water users (projects) in the BLM Future 1 and Future 2 baselines.

Water uses for these four categories are presented in Tables E-1, E-2, E-3, and E-4, respectively (see Appendix E). Only ground-water users who produce from the Dakota Sandstone, Westwater Canyon Member of the Morrison Formation, and Entrada Sandstone (Westwater Canyon Member aquifer system) were tabulated, because the effects of these uses were judged not to extend to other overlying or underlying aquifers (see Section 4.C.4.a). A further restriction was that only users who produce more than 100 AFY were considered as significant for the impact analysis. Smaller users (less than 100 AFY) were not tabulated because it was judged that the cumulative effect of such smaller users, on drawdown of the potentiometric surface of aquifers in the Westwater Canyon Member aquifer system, would not be recognized. There are probably

Table 4-4. HISTORIC GROUND-WATER USES
SAN JUAN RIVER BASIN, NEW MEXICO

Water User	CONSUMPTIVE USE (acre-feet per year) 1970[a]	1975[b]
Irrigated Agriculture	0	0
Municipal (urban)[c]	0	0
Domestic (rural)[d]	700	700
Mining	800	1,100
Livestock Watering	400	500
Manufacturing	200	100
Power Production	0	0
TOTAL	2,100	2,400

[a] Source: U.S. Bureau of Reclamation 1976a.

[b] Source: Sorensen 1977.

[c] Does not include pumpage for City of Gallup, which lies in Puerco River Basin. This pumpage estimated to be 2,500 acre-feet per year in 1970 and 3,200 acre-feet per year in 1975 (Sorensen 1977; Umshler 1979).

[d] Includes use by community of Crownpoint.

on the order of 100 of these users in the less than 100 AFY category. All users of ground water from the Westwater Canyon Member aquifer system could conceivably be affected by the relatively large users. Therefore all known wells and springs in the aquifer system that would be significantly affected by pumping from the well field for NMGS are tabulated in Appendix G.

The historical water uses in Table E-1 are based on the best available information. In several cases there are gaps in the years in which water use was reported. In other cases, values of water use reported by two different authors are not in agreement. Interpolation of the available data, therefore, is required to construct a continuous estimate of historical ground-water use by a particular user.

The projected future water uses presented in Tables E-2, E-3, and E-4 are based on planned intentions of various water users, which were compiled from water rights files, environmental impact statements, permit applications, and information from the New Mexico Energy and Minerals Department. Information on these intended uses included: (1) the aquifer to be developed; (2) the rate of ground-water production; and (3) the time schedule of use.

Information on certain proposed uranium mining projects was relatively uncertain, because of the present slowdown in the uranium mining industry in the San Juan Basin and other poorly known factors such as ore reserves and future prices of uranium. Unless information on the intended life of uranium mines was available, all mines were assumed to have a 30-year life. Uranium mines that had historical ore production or had mine development underway, but were shut down in November 1981, have been assumed to start up again in 1990. Assumptions that are specific to a particular mine are identified in Tables E-2 and E-4.

Pumping of ground water from the Westwater Canyon Member for uranium mine dewatering in the Church Rock and Ambrosia Lake areas has been the largest historical use of ground water from the Westwater Canyon Member aquifer system. Municipal supplies have been developed from the aquifer system for the city of Gallup and the community of Crownpoint. A flowing well near

Tohatchi (well 14T-515) has historically produced a significant quantity of water from the Westwater Canyon Member aquifer system (Table E-1).

Production of ground water from the Westwater Canyon Member for uranium mine dewatering and milling is projected to be the dominant future use of the aquifer system (Tables E-2, E-3, and E-4). Other projected future uses of the aquifer system include municipal supply, surface coal mining and reclamation, and powerplant cooling.

Use of the well field for NMGS is projected to be in three steps that correspond to the four units of NMGS coming on- and going off-line (Table E-3). Production from the well field from 1995 to 1997, inclusive, and from 2031 to 2033, inclusive, would be 6250 AFY. Production from 1998 to 2030, inclusive, would be 15,000 AFY. In year 2010, production of 15,000 AFY for NMGS would represent approximately 15 percent of the projected future pumpage of ground water from the Westwater Canyon Member in that year. The projected water uses from the Westwater Canyon Member in year 2010 are summarized in Table 4-5.

Most of the information on historic and projected future uses of ground water for municipal supply, surface coal mining, reclamation, stock watering and power plant cooling (Tables E-1, E-2, E-3, and E-4) was used directly as the basis for simulating pumpage from the Westwater Canyon Member Aquifer System in the numerical model described in Section 4.D. It should be noted that the historic and projected future uses of ground water for uranium mine dewatering (Tables E-1, E-2, and E-4) were used only as preliminary estimates of pumpage from the aquifer system. Because historic pumpage data from uranium mines generally were not well documented, and future pumpage would not be constant but would depend in part on other ground-water users, a physical basis was required for estimating ground-water production from uranium mines. Therefore, in the numerical model of the Westwater Canyon Member Aquifer System, constant-head values were used to simulate the influence of most of the uranium mines (see Section 4.D.6). In general, the mine dewatering as simulated by the numerical model was considerably less than the projected future uses shown in Tables E-2 and E-4.

Table 4-5. PROJECTED FUTURE USES OF GROUND WATER FROM THE WESTWATER CANYON MEMBER IN YEAR 2010[a]

User	Projected Water Use - Year 2010 (acre-feet per year)	
PNM (for NMGS)	15,000	
City of Gallup	2,800	
Crownpoint	640	
Gallup-Gamerco Coal Co.	150	
Navajo Well 14T-515	720	
BLM Bisti Well	325	
Plains Electric (Escalante	20,000	
Generating Station)	—	
Phillips Uranium Co. (Nose Rock)	32,250	(maximum by State Engineer order)
CONOCO (Crownpoint and	15,000	
Borrego Pass projects)	—	
Mobil Oil Corp. (Crownpoint	3,088	
and Monument projects)	—	
Chaco Energy Co.	—	
South Hospah Mine	650	
Star Lake Mine	1,300	
Alamito Coal Co. (Gallo Wash)	650	
Consolidation Coal Co.	—	
(ConPaso-Burnham Mine)	540	
Sohio L-Bar Mill	1,305	
Bokum Resources Co.	—	
Marquez Mine	2,560	
Marquez Mill	1,912	
Kerr-McGee Corp.	—	
Lee Mine	2,593	
Rio Puerco Mine	965	
TOTAL	102,450[b]	

[a]Compiled from information presented in Tables E-2, E-3, and E-4.

[b]Equivalent to 141.5 cubic feet per second.

The projected future uses of water for the Plains Escalante Generating Station (Table E-4) also did not appear to be realistic. The ground-water production for this project was also simulated in the numerical model by constant heads. The numerical model indicates that projected future uses of the Westwater Canyon Member aquifer for this project probably would be less than the uses estimated in Table E-4 (see Table 4-10).

4.D NUMERICAL MODEL OF THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

4.D.1 Introduction

The impacts that would occur as a result of pumping 15,000 acre-feet per year from the Westwater Canyon Member aquifer by the proposed NMGS well field were calculated by a numerical model that simulates the Westwater Canyon Member Aquifer System as a multilayer aquifer system. The program by Trescott and Larson (1976) for simulation of three dimensional ground-water systems was used to model the well field, which is located in T.23N, R.12W; T.23N, R.13W; and T.22N, R.12W (see Section 4.A.1.)

The development of the numerical model consisted of the following steps:

- development of a conceptual model of the Westwater Canyon Member Aquifer System,
- design of a finite difference grid,
- estimation of parameters,
- use of model to simulate historical stresses, and adjustment of model parameters to provide a match between calculated and observed historical responses; and
- prediction of future changes in the potentiometric surface and future changes in discharges from the aquifer system.

This modeling effort was designed to calculate the impacts of both the proposed withdrawals for NMGS, and the additive impacts of development in the San Juan Structural Basin. Specifically, four cases of ground-water development in the San Juan Structural Basin were simulated.

- Case 1: future pumping by existing users and proposed users with water rights prior to those for NMGS;

- Case 2: Case 1 pumping plus pumping for NMGS;

- Case 3: Case 1 pumping plus pumping by projects included in BLM's Baseline 1 and Baseline 2;

- Case 4: Case 3 pumping plus pumping for NMGS

The impacts that the model was designed to identify were drawdowns exceeding twenty-five feet in any aquifer, and any reductions in natural discharges from aquifers in excess of 0.01 cubic foot per second (cfs). Smaller impacts cannot be accurately calculated with the method used in this study because of model error introduced by uncertainty in the estimates of model parameters and boundary conditions.

4.D.2 Conceptual Model of the Westwater Canyon Member Aquifer System

The Westwater Canyon Member Aquifer System, was modeled in this study as five layers (Figure 4-4):

- the Entrada Sandstone aquifer layer defined as the Jurassic-aged Entrada Sandstone (layer 1);

- the Westwater Canyon Member to Entrada Sandstone confining layer, defined to consist of the Recapture Member of the Morrison Formation, the Summerville Formation, the Bluff Sandstone and the Todilto Limestone (layer 2);

- the Westwater Canyon Member aquifer, defined as the Jurassic-aged Westwater Canyon Member of the Morrison Formation (layer 3);

- the Dakota Sandstone to Westwater Canyon Member confining layer, defined as the Brushy Basin Member of the Morrison Formation (layer 4); and

GEOLOGY			LAYER	PARAMETER
LOWER CRETACEOUS		Dakota Sandstone	Dakota Sandstone Aquifer (Layer 5)	T_5, S_5
JURASSIC	MORRISON FORMATION	Brushy Basin Member	Confining Unit 2 (Layer 4)	S_4, Kv_4, b_4
JURASSIC	MORRISON FORMATION	Westwater Canyon Member	Westwater Canyon Member Aquifer (Layer 3)	T_3, S_3
JURASSIC	MORRISON FORMATION	Recapture Member	Confining Unit 1 (Layer 2)	S_2, Kv_2, b_2
JURASSIC		Summerville Formation Todilto Limestone		
JURASSIC		Entrada Sandstone	Entrada Sandstone Aquifer (Layer 1)	T_1, S_1

S_n = Storage coefficient
T_n = Transmissivity
Kv_n = Vertical hydraulic conductivity
b_n = Saturated thickness

Figure 4-4. CONCEPTUAL MODEL OF THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

- the Dakota Sandstone aquifer layer defined as the Lower Cretaceous-aged Dakota Sandstone (layer 5).

The Westwater Canyon Member Aquifer System was defined after a careful review of available information on the geologic and hydrogeologic characteristics of the strata in the study area (see Section 4.C.4). The aquifer system was characterized explicitly for calculating the impacts of proposed pumping for NMGS. The five layers were chosen so that interformational movement of water could be analyzed, and so that effects in the Dakota Sandstone and Entrada Sandstone, as well as the Westwater Canyon Member, could be calculated.

The Westwater Canyon Member Aquifer System, as defined for this study, is bounded below by the Chinle Formation and above by the Mancos Shale. These boundaries were defined on the basis of calculations which showed that drawdowns in the aquifers above the Lower Mancos Shale and below the Chinle Formation would probably be less than twenty-five feet as a result of pumping for NMGS. These calculations, made during development of the Westwater Canyon Member Aquifer System model, showed that if the leakage coefficient (K'/b) in units overlying or underlying the Westwater Canyon Member aquifer was less than about 8.6×10^{-10} day^{-1}, drawdowns in aquifers above or below the Westwater Canyon Member aquifer would be less than 25 feet. The ubiquitous Lower Mancos Shale, which has a fairly uniform thickness of about 600 feet over much of the study area, probably has an effective vertical hydraulic conductivity of less than 8.6×10^{-7} ft/day ($K'/b = 1.3 \times 10^{-10}$ day^{-1}). Based upon lithologic considerations alone, the estimated leakage coefficient for the Chinle Formation is much less than 8.6×10^{-10} day^{-1}. The leakage coefficients for the Westwater to Entrada confining unit, and the Dakota to Westwater confining unit are probably greater than 8.6×10^{-10} day^{-1} (Lyford, 1978; Camp, Dresser and McKee, 1981). Therefore, the Entrada Sandstone and Dakota Sandstone aquifers were included in the conceptual model of the Westwater Canyon Member Aquifer System.

The confining layers were modeled as distinct units to represent storage releases from the confining beds and to represent response lags to system stresses. Explicit representation of the confining layers also permitted a sensitivity analysis on the effect of varying the specific storage assigned to the confining beds. These benefits outweigh the added complexity created by the inclusion of these units in the model and the increased computation time.

The Westwater Canyon Member, Dakota Sandstone, and the Entrada Sandstone were represented as explicit aquifer layers because these units are generally recognized as aquifers in the San Juan Basin. The Entrada Sandstone is tapped by only a few wells, but many stock wells are completed in the Dakota Sandstone in the vicinity of the proposed NMGS well field. The Westwater Canyon Member is the major aquifer for much of the San Juan Structural Basin and is the proposed source of water for the NMGS well field.

Several models have previously been developed to calculate impacts of pumping from the Westwater Canyon Member aquifer in the San Juan Structural Basin. The models, which have been published in the open literature or described in documents in the files of the New Mexico State Engineer, include:

- model developed by Guyton and Associates (1978) to calculate dewatering requirements and to predict impacts of the Phillips Uranium Co.'s Nose Rock mine on other ground-water users;
- model developed by Science Applications, Inc. (SAI, 1981) to predict impacts of the Conoco Crownpoint Project;
- model developed by Camp, Dresser and McKee, Inc. (CDM, 1981) to predict impacts of the Mobil Crownpoint and Monument Projects;

- model developed by the U.S. Geological Survey (Lyford, Frenzel and Stone, 1980) to estimate regional impacts of ground-water development in the San Juan Structural Basin.

None of these models was judged to be adequate for estimating the impacts of the proposed pumping for NMGS. The models by Guyton & Associates (1978), Science Applications, Inc. (1981) and Lyford, et al. (1980) were not constructed to allow calculations of drawdowns in the Dakota Sandstone and Entrada Sandstone.

The Guyton & Associates (1978) and Science Applications, Inc. (1981) models represented only the Westwater Canyon Member aquifer; the model by Lyford, et al. (1980) represented only the Westwater Canyon Member aquifer and the Brushy Basin Member of the Morrison Formation. The Brushy Basin Member was modeled explicitly by Lyford, et al. (1980) so that storage release from the confining beds could be more realistically represented. The model by Camp, Dresser and McKee, Inc. (1981) was an 11-layer aquifer model representing units from the Entrada Sandstone through the Tertiary-aged rocks in the San Juan Structural Basin. Because calculated drawdowns in the upper six layers of this model were less than twenty feet for the stresses applied to the Westwater Canyon Member aquifer, this model was judged to be unnecessarily complex for the present study.

4.D.3 Numerical Methods

The USGS finite-difference computer model for simulation of three-dimensional ground-water flow was used to model the Westwater Canyon Member Aquifer System (Trescott, 1975; Trescott and Larson, 1976). This model allows for variable grid spacing and uses the strongly implicit procedure for simultaneous solution of the difference equations. The program is utilized by dividing the region of interest into three-dimensional blocks (nodes). Values of transmissivity and storage coefficient are assigned to each block representing an aquifer; values of vertical hydraulic conductivity, storage coefficient, and thickness are assigned to each block representing a confining unit. The finite-difference grid used for each aquifer in the aquifer system model is shown in Maps 4-14, 4-15, and 4-16. A variable spaced grid was used, with 2-mile square blocks near the NMGS well field and in the uranium mining districts to accurately calculate mine inflows and drawdowns, and larger spacing elsewhere to prevent computation costs from becoming exorbitant.

The program by Trescott (1975) and Trescott and Larson (1976) was modified slightly for this study. The input and output routines were modified to allow greater flexibility in data input and output. The program was modified to allow constant heads to be changed at each time step. The mass balance routines were modified to include a routine that computes a mass balance for each layer at each time step, a routine that prints out vertical flows by grid blocks, and a routine that calculates changes in storage in each outcrop block at each time step.

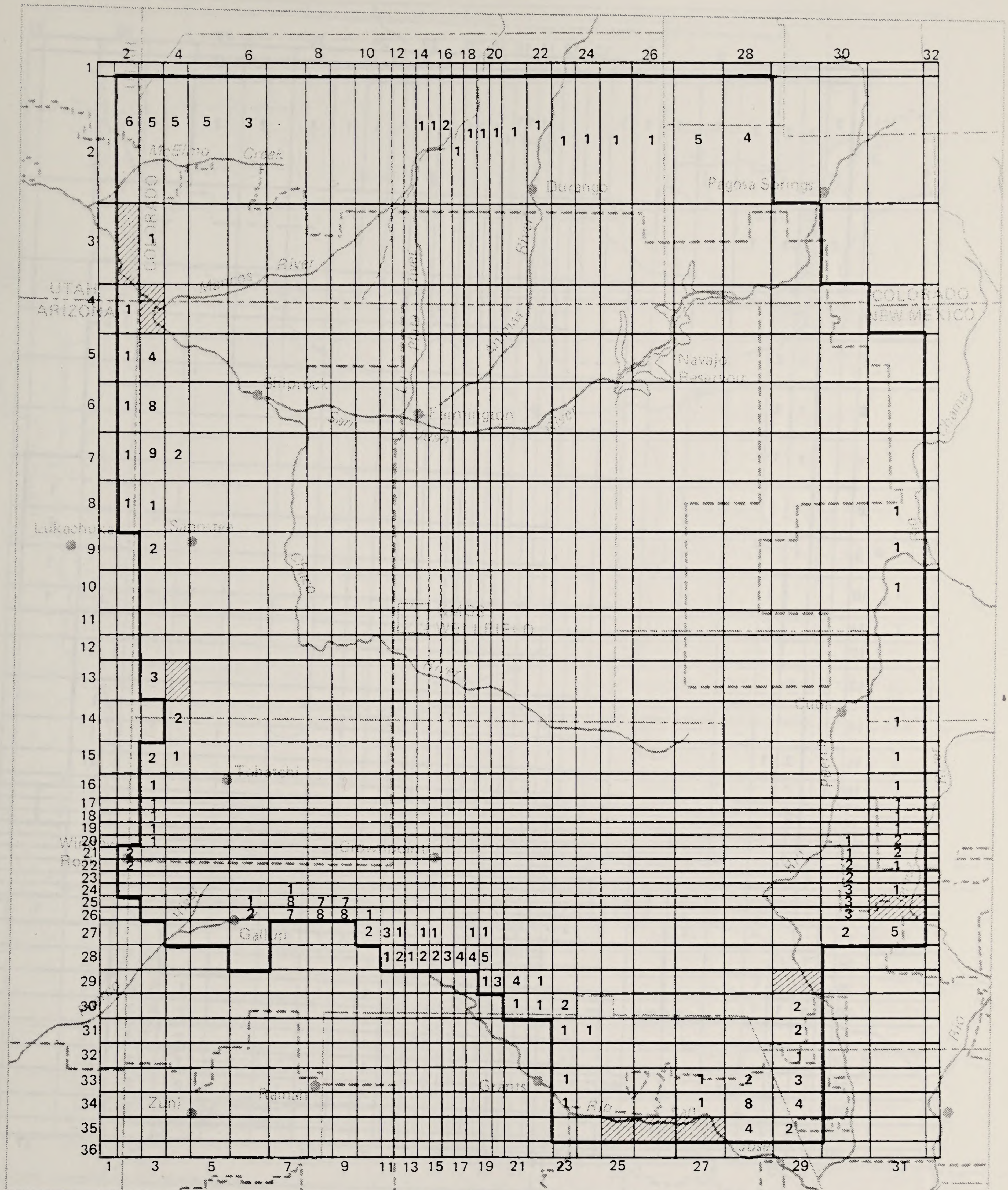
4.D.4 Parameter Estimates

The numerical model used to simulate the Westwater Canyon Member Aquifer System required as input data the following parameters at each grid block:

- storage coefficient and transmissivity for the Westwater Canyon Member, Dakota Sandstone, and Entrada Sandstone layers;

- storage coefficient, vertical hydraulic conductivity and thickness for each of the confining layers.

Vertical hydraulic conductivity was not specified in the aquifer layers of this model because vertical flow is controlled by vertical hydraulic conductivity in the confining beds rather than in the aquifer layers. Transmissivity was not specified in the confining layers because horizontal flow of water in the confining beds was assumed to be negligible. The estimated values of the aquifer parameters used to characterize the Westwater Canyon Member Aquifer System within the San



N

0 10 20 30
miles

Indian Reservations

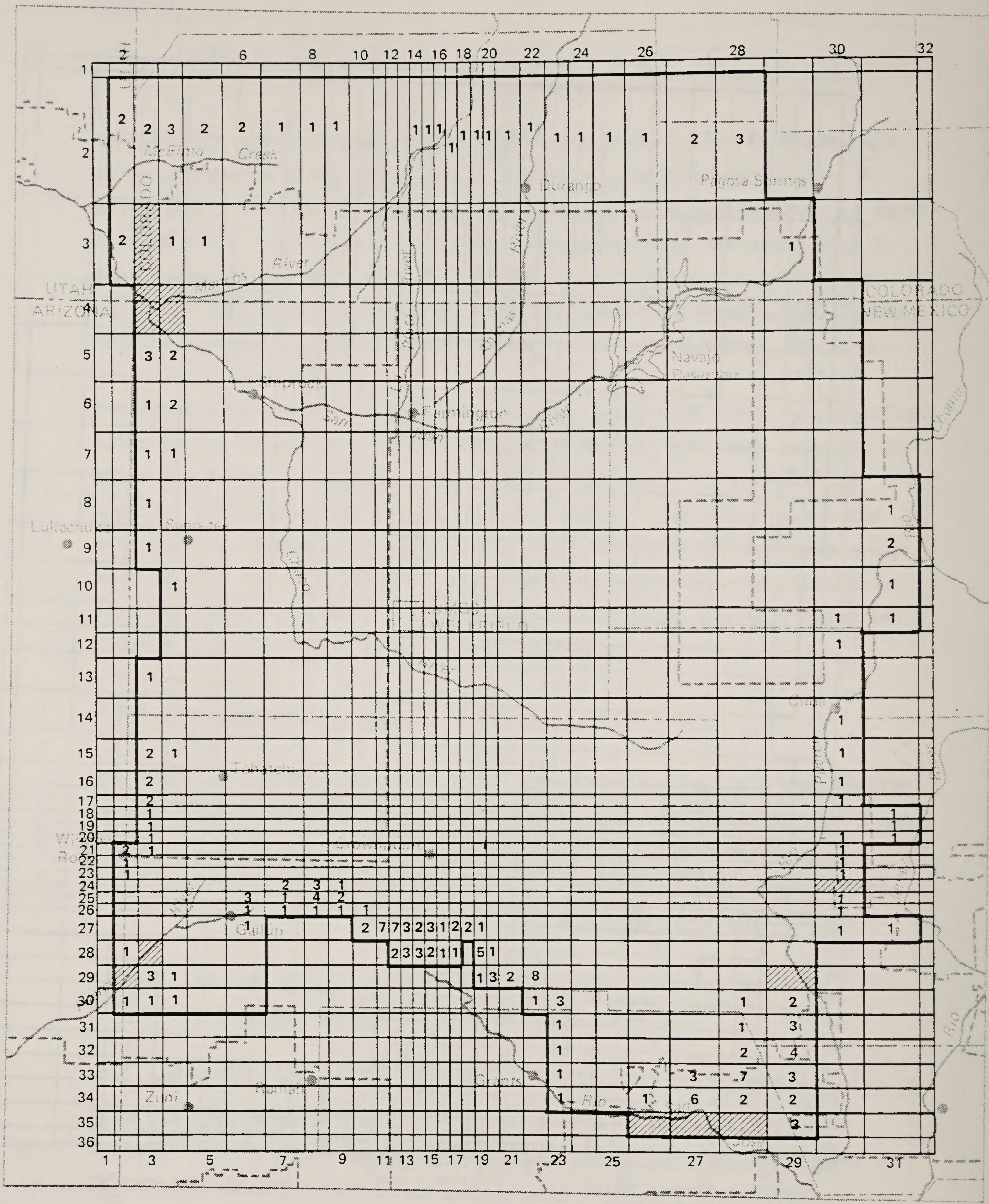
LEGEND

Layer boundary

Constant head node

1-9 Percent of outcrop area within the node (% = value x 10)

Map 4-14. THE FINITE DIFFERENCE GRID USED TO MODEL THE WESTWATER CANYON AQUIFER IN THE SAN JUAN STRUCTURAL BASIN



miles 0 10 20 30

Indian Reservations

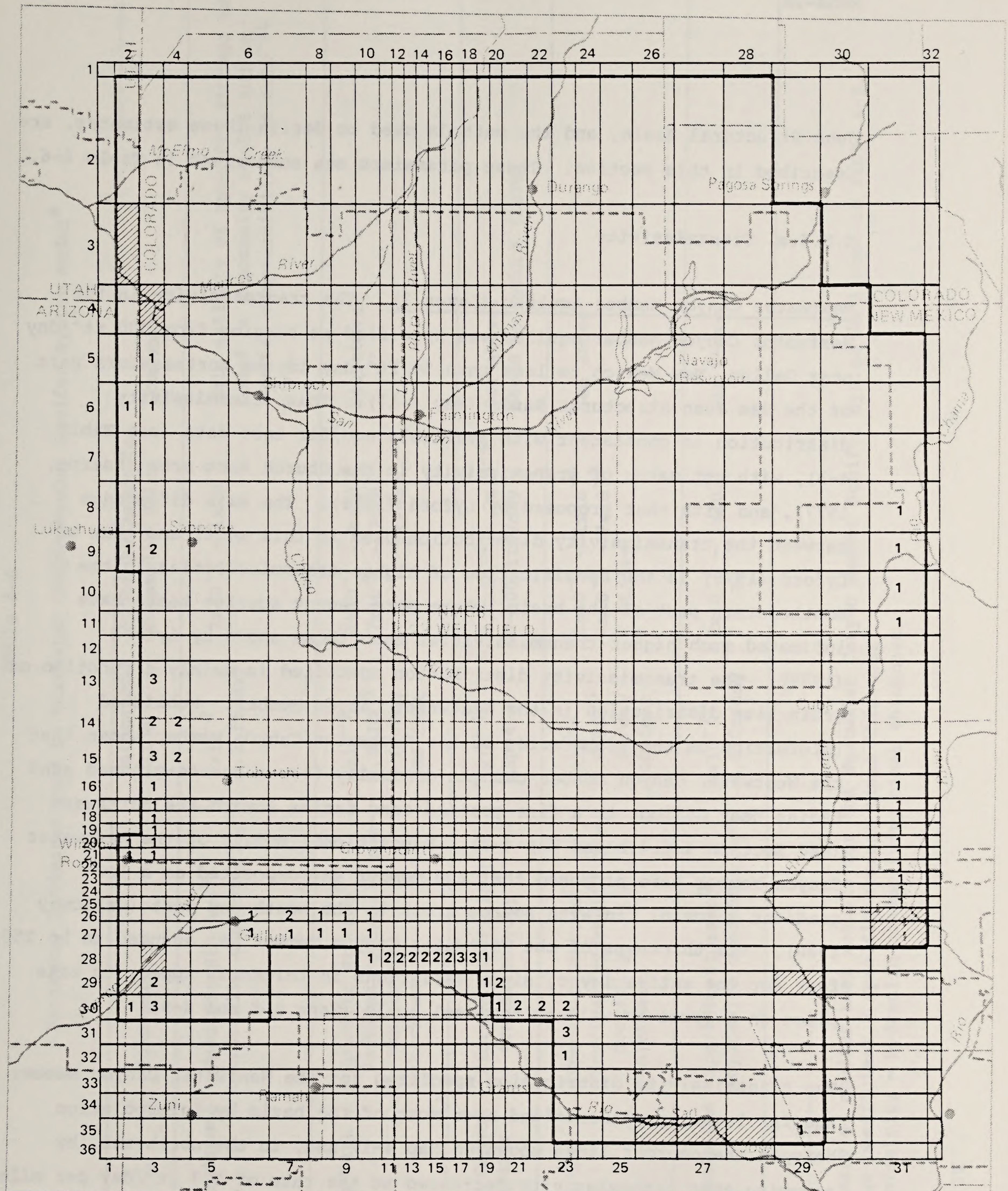
LEGEND

Layer boundary

Constant head node

1-9 Percent of outcrop area within the node (% = value x 10)

Map 4-15. THE FINITE DIFFERENCE GRID USED TO MODEL THE DAKOTA SANDSTONE AQUIFER IN THE SAN JUAN STRUCTURAL BASIN



LEGEND

Layer boundary

Constant head node

1-9 Percent of outcrop area within the node (% = value x 10)

Indian Reservations

0 10 20 30 miles

Map 4-16. THE FINITE DIFFERENCE GRID USED TO MODEL THE ENTRADA SANDSTONE AQUIFER IN THE SAN JUAN STRUCTURAL BASIN

Juan Structural Basin, and the methods used to derive these estimates, are described in this section. These parameters are summarized in Table 4-6.

4.D.4.a Transmissivity

Westwater Canyon Member Aquifer (Layer 3). The transmissivity in the Westwater Canyon Member aquifer was specified as ranging from 300 ft^2/day near Gallup, New Mexico to less than 50 ft^2/day in the northeastern part of the San Juan Structural Basin (Map 4-17). This transmissivity distribution is consistent with available aquifer test data (see Table 4-3), with estimates of transmissivity in the Church Rock area (Hearne, 1977), and with that proposed by Lyford (1979). The main difference between the transmissivity distribution used in this model and that of Lyford (1979) is the specification of higher transmissivities in the southeastern part of the basin, where more recent aquifer tests have indicated much higher transmissivities than those shown by Lyford (1979). The transmissivity distribution specified is mainly a function of grain size distribution in the Westwater Canyon Member. Published information on the lithofacies of the Westwater Canyon Member shows that the Westwater Canyon Member changes gradually from a coarse-grained sand facies near Gallup, to a fine-grained sand facies toward the northeast (see Section 4.C.4.b and Map 4-8). Depositional models of the Westwater Canyon Member have proposed that the member was deposited as a low-gradient alluvial fan with source areas to the south and west (Galloway 1980). The thickness of the Westwater Canyon Member was assumed to be 250 feet for the entire layer, since variations in thickness appear to take place on a local as well as regional scale (Maps 4-8 and 4-9).

The transmissivity distribution specified for the Westwater Canyon Member Aquifer layer was discretized over most of the basin by interpolation between the contour lines shown on Map 4-17 and, in the northeast, by assuming that transmissivity decreased at the rate of 0.7 ft^2/day per mile toward the northeast.

Table 4-6

Parameter Estimates Used in Westwater Canyon Member Aquifer System Model[a]

Layer	Parameter	Estimated Value	Probable Range in Parameter Value	Comments
Dakota Sandstone Aquifer	Specific Storage[b] hydraulic conductivity[c]	$4x10^{-7}$ 0.2 ft/day	$2x10^{-7}$ - $1x10^{-6}$?	This estimate of specific storage is based on a porosity of 20% and an aquifer compressibility of $6x10^{-11}$ m^2/N.
Confining Unit	Specific Storage[b] Vertical hydraulic conductivity thickness	$4x10^{-7}$ $2.8x10^{-6}$ ft/day 200 feet	$2x10^{-7}$ - $1x10^{-6}$ $7x10^{-6}$ - $7x10^{-7}$ ft/day	See above.
Westwater Canyon Member Aquifer	Storage Coefficient transmissivity	$1x10^{-4}$ Map 4-7	$0.6x10^{-4}$ - $2x10^{-4}$ 0-500 ft^2/day	See above. based on Lyford (1979)
Confining Unit	Specific Storage[b] Vertical hydraulic conductivity thickness	$4x10^{-2}$ $2.8x10^{-6}$ ft/day 600 feet	$2x10^{-7}$ - $1x10^{-6}$ $7x10^{-6}$ - $7x10^{-7}$ ft/day	See above.
Entrada Sandstone Aquifer	Specific Storage[b] hydraulic conductivity[c]	$4x10^{-7}$ 0.6 ft/day	$2x10^{-7}$ - $1x10^{-6}$?	See above.

a. A summary of aquifer test results for the Westwater Canyon Member Aquifer System is listed in Table 4-3.
b. Storage coefficient = specific storage times thickness.
c. Transmissivity = hydraulic conductivity times thickness.

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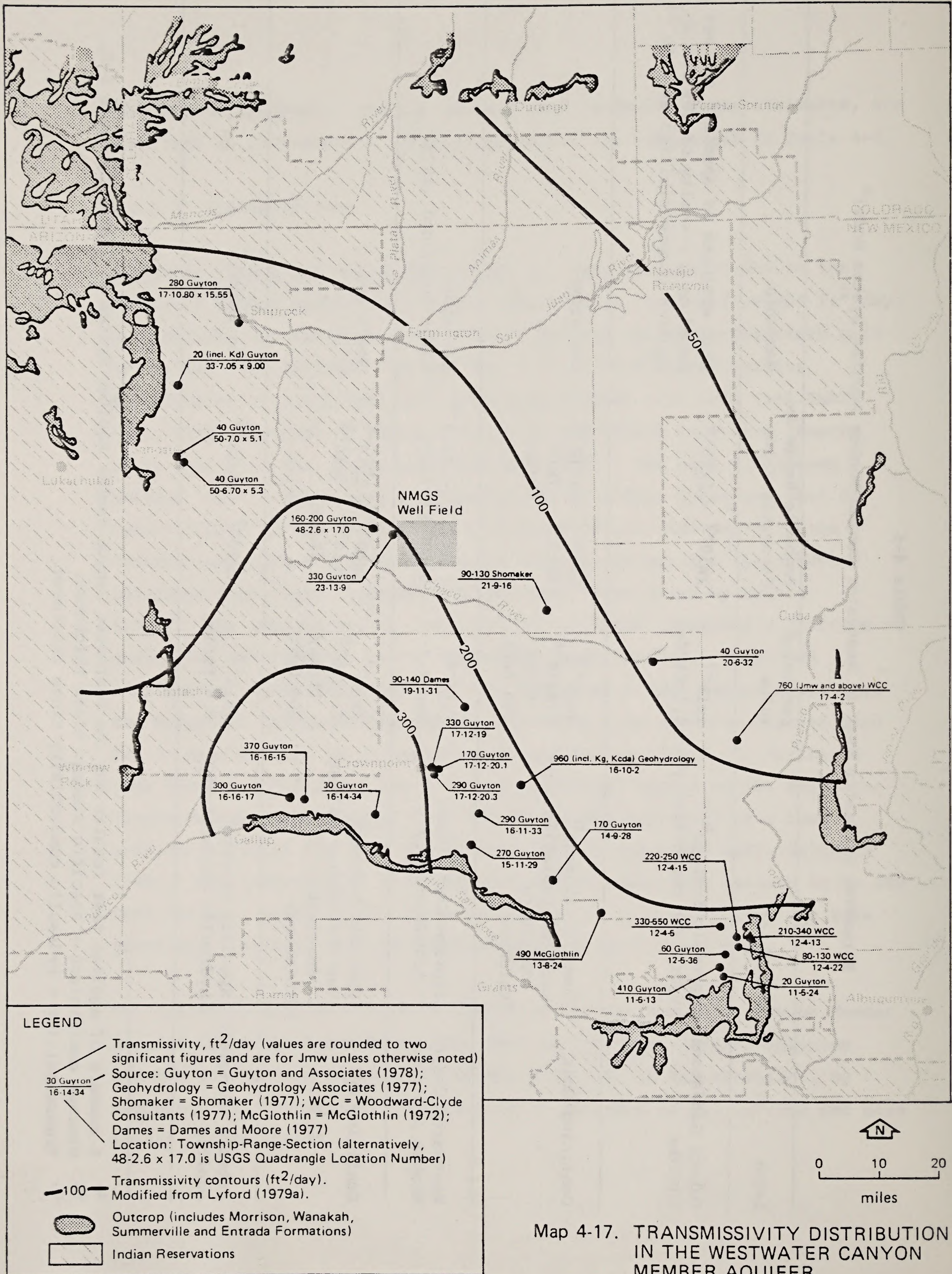


Map 4-17. TRANSMISSIVITY DISTRIBUTION IN THE WESTWATER CANYON MEMBER AQUIFER

Dakota Sandstone Aquifer (Layer 5). The transmissivity of the Dakota Sandstone was specified as being equal to 0.22 ft/day (hydraulic conductivity) times the thickness of the layer as determined from the map of thickness (Map 4-13). This estimate was based solely on the results of one aquifer test run at the site of the proposed Phillips Nose Rock Mine, where a transmissivity of 44 ft^2/day was reported with an approximate thickness of 200 feet (CDM, 1981). Other data on the hydraulic properties of the Dakota Sandstone in the San Juan Structural Basin exist only in the Mount Taylor area (Table 4-3). Sensitivity runs described in Section 4.E.2 demonstrate that calculated drawdowns are not very sensitive to the transmissivity specified for the Dakota Sandstone aquifer.

Entrada Sandstone Aquifer (Layer 1). The transmissivity of the Entrada Sandstone was specified as being equal to 0.59 ft/day (hydraulic conductivity) times the thickness of the unit as determined from the thickness map (Map 4-4). The transmissivity of the Entrada Sandstone has been measured as 100 to 300 ft^2/day near Chaco Canyon and as 50 ft^2/day near outcrop areas in the southeast part of the San Juan Structural Basin (Table 4-2). As the thickness of the Entrada Sandstone is about 3 to 4 times larger near Chaco Canyon than in the southeast (Map 4-4), similar hydraulic conductivities are calculated for the Entrada Sandstone at both locations. The method used in this model to estimate transmissivity yields a distribution that is consistent with available data. In his initial model of the San Juan Basin, Lyford (personal communication, 1978) specified a hydraulic conductivity in the Entrada Sandstone of 0.34 ft/day west of Ambrosia Lake and 0.17 ft/day east of Ambrosia Lake. Higher values were specified west of Ambrosia Lake because of the presence of the Wingate Sandstone. Because the areal distribution of the Wingate Sandstone is poorly known and is probably very limited, this unit was neglected in the model.

4.D.4.b Vertical Hydraulic Conductivity

The vertical hydraulic conductivity in both confining layers (layers 2 and 4) was specified as being equal to 2.85×10^{-6} ft/day with two exceptions:

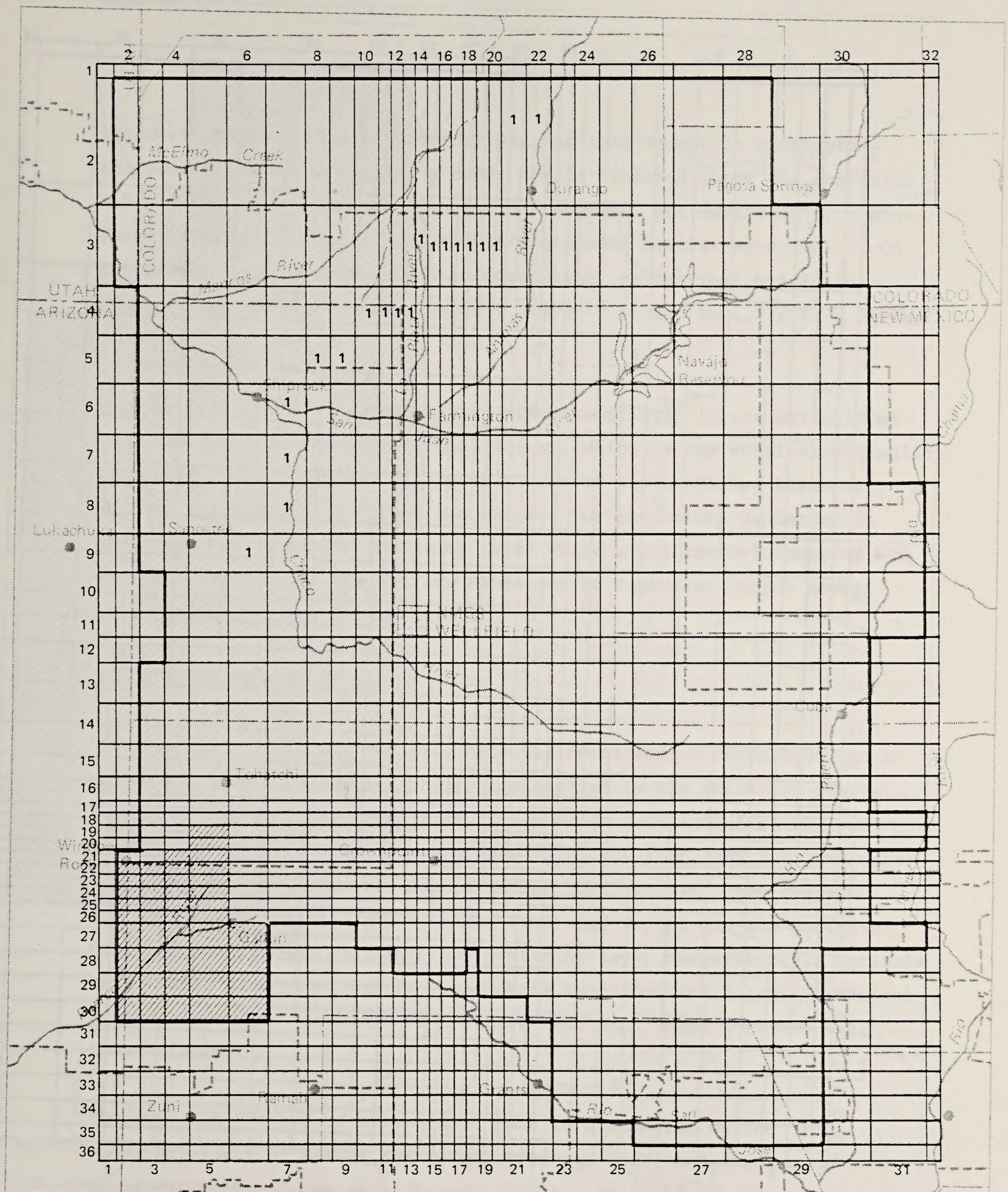
- the vertical hydraulic conductivity was specified at 2.85 x 10^{-4} ft/day along the Hogback Monocline (see Map 4-2) where jointing is assumed to have increased the effective vertical hydraulic conductivity (Maps 4-18 and 4-19); and

- the vertical hydraulic conductivity of the Entrada Sandstone to Westwater Canyon Member confining layer (layer 2) was specified as 2.85 x 10^{-7} ft/day in the eastern part of the modeled area where the Todilto Limestone is composed of more than 25 feet of gypsum (Maps 4-6 and 4-19).

The vertical hydraulic conductivity of 2.85 x 10^{-6} ft/day was specified because use of this value in the model of historical production from the Westwater Canyon Member aquifer produced calculated drawdowns at Crownpoint similar to recorded drawdowns (see Section 4.D.7). Higher values of vertical hydraulic conductivity were specified along the Hogback Monocline because Lyford (1978) suggested that such values helped produce a better fit of the potentiometric surface in his steady-state model of the San Juan Structural Basin aquifer systems.

In previous modeling studies of the Westwater Canyon Member Aquifer System in the San Juan Structural Basin, several values of vertical hydraulic conductivity were used: a value of 8.64 x 10^{-8} ft/day was used by Lyford, et.al. (1980) and a value of 6.68 x 10^{-7} ft/day was used by CDM (1981). Hearne (1977), though, in his model of the Westwater Canyon Member in the Church Rock area, used a vertical hydraulic conductivity of about 1.3 x 10^{-5} ft/day. Lyford (1978) stated that vertical hydraulic conductivities in the confining beds were likely in the range of 8.6 x 10^{-6} to 8.6 x 10^{-8} ft/day, and CDM (1981) stated that the probable range was 6.8 x 10^{-6} to 6.8 x 10^{-8} ft/day.

Short term aquifer test results have been analyzed to estimate the vertical hydraulic conductivity of the confining beds (Harshbarger and Associates, 1977; Hargis and Montgomery, 1979; CDM 1981). Unfortunately,



N

0 10 20 30
miles

Indian Reservations

LEGEND

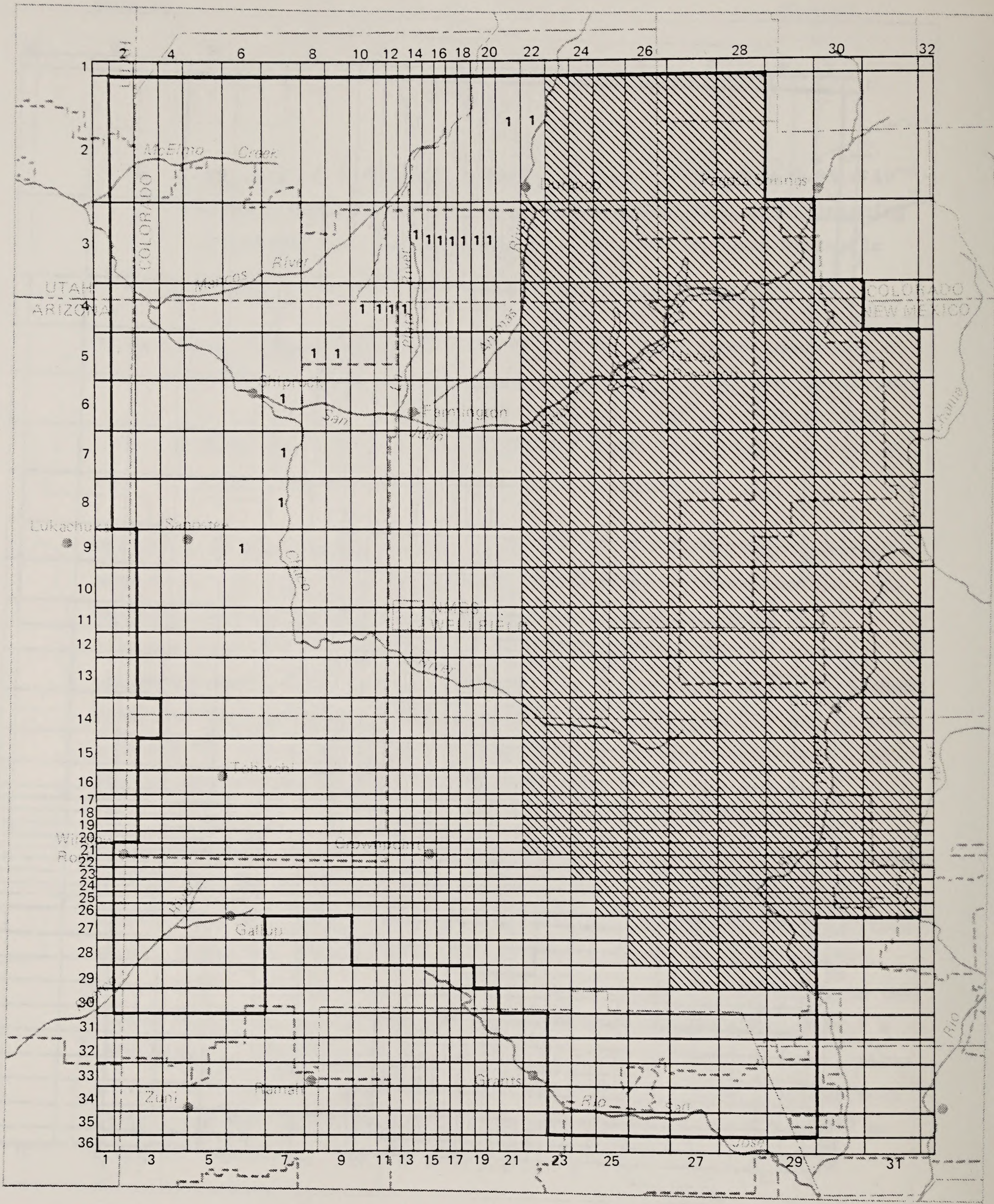
Layer boundary

1 Hogback feature present

Confining Unit 2 absent

Confining Unit 2:
Brushy Basin Member of Morrison Formation;
Burro Canyon Formation

Map 4-18. VERTICAL HYDRAULIC CONDUCTIVITY DISTRIBUTION IN CONFINING UNIT 2



N

0 10 20 30
miles

Indian Reservations

LEGEND

Layer boundary

1 Hogback feature present

Confining unit not gypsiferous

Confining unit gypsiferous

Confining Unit 1: Todilto Limestone; Summerville Formation; Cow Springs Bluff, Zuni Sandstones; Junction Creek Sandstone; Recapture and Salt Wash Members of Morrison Formation

Map 4-19. VERTICAL HYDRAULIC CONDUCTIVITY DISTRIBUTION IN CONFINING UNIT 1 the duration of the tests probably was not long enough to propagate stresses through the confining beds. Wells finished above the confining beds in the Dakota Sandstone showed no response, and deviation from non-leaky behavior in wells completed in the pumped aquifer were small. On the basis of these tests alone an upper limit on vertical hydraulic conductivity was estimated: about 5.3×10^{-4} ft/day to 1.3×10^{-5} ft/day (CDM, 1981).

The vertical hydraulic conductivity of the confining layers was entered into the model as the leakage coefficient, which is the vertical hydraulic conductivity (K') divided by the thickness of the confining layer (b). A uniform thickness of 200 feet was assumed for the Dakota Sandstone to Westwater Canyon Member confining layer while a uniform thickness of 600 feet was assumed for the Entrada Sandstone to Westwater Canyon Member confining layer (see Section 4.C.4).

4.D.4.c Storage Coefficent

The storage coefficient for all units was specified as being equal to a specific storage of 4×10^{-7} $feet^{-1}$ multiplied by the thickness of the layer, except in outcrop areas where a storage coefficient of 0.1 was specified. Uniform thicknesses of 250 feet, 200 feet, and 600 feet were specified for the Westwater Canyon Member aquifer layer, the Dakota Sandstone to Westwater Canyon Member confining layer, and the Westwater Canyon Member to Entrada Sandstone confining layer respectively. Variable thicknesses were specified for the Dakota Sandstone and Entrada Sandstone aquifer layers on the basis of the thickness maps (Maps 4-13 and 4-4, respectively).

The specific storage of a saturated rock is a function of the compressibility of water, the porosity of the rock, and the compressibility of the rock (Lohman, 1972). If it is assumed that the Westwater Canyon Sandstone has a porosity of 20 percent, and no rock compressibility, a specific storage of 2.6×10^{-7} $feet^{-1}$ is calculated. Since 20 percent porosity is a reasonable value for the aquifers and confining layers under consideration (Mobil, 1980), 2.6 x 10^{-7} $feet^{-1}$ would be a lower limit for the specific storage in these layers.

Storage coefficients estimated for the Westwater Canyon Member from aquifer test data have been in the range of 1 x 10^{-3} to 1 x 10^{-5} (specific storage of 4 x 10^{-6} to 4 x 10^{-8}) (see Table 4-3). Some of these estimates may be in error, most likely because of the test procedures. Detailed aquifer tests of the Westwater Canyon Member run by Mobil (1980) at their Crownpoint area properties suggested that average values of the storage coefficient estimated from several observation wells were in the range of 8 x 10^{-5} to 2 x 10^{-4} (specific storage of about 3 x 10^{-7} to 8 x 10^{-7}). Harshbarger (1978) concluded on the basis of one of the Mobil tests with 7 observation wells that a storage coefficient of 5 x 10^{-5} was appropriate.

Several previous models of the Westwater Canyon Member aquifer have used specific storages of 1 x 10^{-6} ft^{-1} (Guyton and Associates, 1978; Lyford et al., 1980; CDM, 1981), though Hearne (1977) used a value of 6 x 10^{-7}. The basis for these estimates is a statement by Lohman (1972, p.8): "The storage coefficient of most confined aquifers...is about 10^{-6} per foot of thickness." Based on theoretical considerations alone, this value is most likely too high for the units under consideration. In order for a sandstone aquifer with 20 percent porosity to have a specific storage of 1 x 10^{-6} ft^{-1}, the rock compressibility must be 2.7 x 10^{-10} m^2/Newton. According to Freeze and Cherry (1979) the range of compressibilities for solid rock is 10^{-9} to 10^{-11} m^2/Newton (4.8 x 10^{-8} to 4.8 x 10^{-10} ft^2/lb). The rocks in the Westwater Canyon Member Aquifer System are more likely to be less compressible than average because of the depth of burial.

After weighing all the available data, a specific storage in the range of 3 x 10^{-7} to 8 x 10^{-7} ft^{-1} was judged to be appropriate for the Westwater Canyon Member, and the best estimate was judged to be 4 x 10^{-7} ft^{-1}. All other units were assigned the same specific storage because no information was available to allow for differentiation among units. The range of values of specific storage was tested in the sensitivity analyses discussed in Section 4.E.2.

A storage coefficient of 0.1 was specified in outcrop areas because several sources have reported that the specific yield of the Westwater Canyon Member is about 10 percent (Guyton and Associates, 1978; Mobil, 1980; Lyford et al., 1980). In grid blocks where the outcrop area of the aquifer unit did not cover the entire block, the storage coefficient was set equal to the percent of outcrop area in the block multiplied by 0.001.

4.D.5 Initial and Boundary Conditions

In the model, the initial potentiometric heads in all layers in the Westwater Canyon Member Aquifer System were assigned a value of zero. Modeled changes in the potentiometric surface may be superimposed on the pre-development potentiometric surface (Map 4-10) to calculate the potentiometric surface at later dates.

Boundary conditions specified in the model of the aquifer system were no-flow and constant-head type conditions. No flow boundaries were specified around the periphery of each of the aquifer units in the study area (Maps 4-14, 4-15, and 4-16). The areal extent of each of the aquifer units was defined on the basis of available geologic data (Section 4.C.4). The boundaries of the Dakota and Entrada aquifers in the Gallup Basin area (see Map 4-2) were defined arbitrarily to exist just south of the Puerco River. In the northeastern part of the San Juan Structural Basin, the areal extent of the Westwater Canyon Member aquifer was defined the same as it was by Lyford, et al. (1980). In most of the rest of the region, the areal extent of the aquifer layers was defined by outcrops.

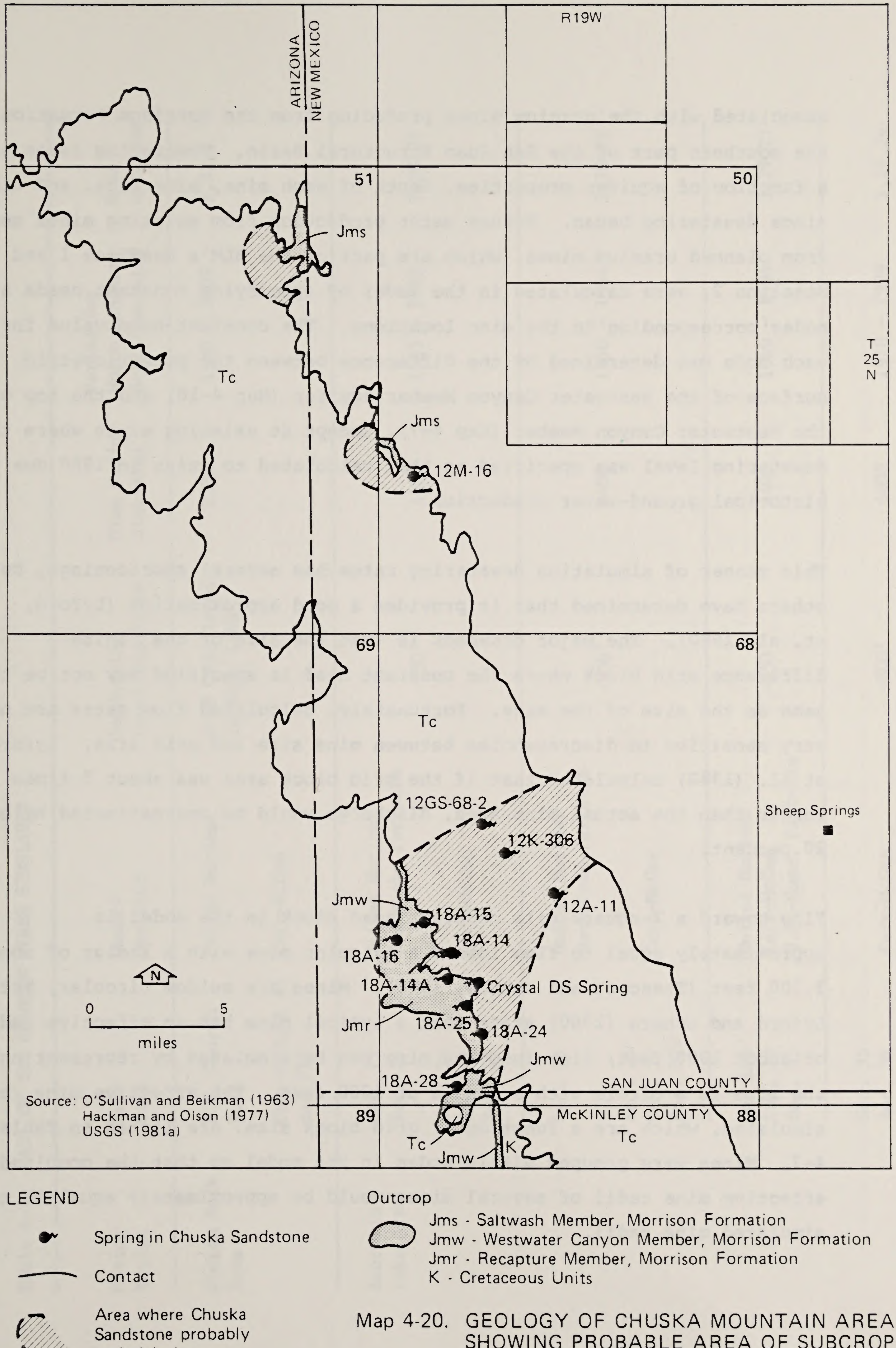
Constant-head type boundary conditions were used to simulate the effects that ground-water production from the Westwater Canyon Member Aquifer System would have on natural discharge. Constant heads were specified where outcrop areas of the aquifer layers are crossed by perennial streams: the San Juan River, the Rio San Jose, and the Rio Salado (tributary to Jemez River) (Maps 4-14, 4-15, and 4-16). These areas are the natural discharge points for ground water in the Westwater Canyon Member Aquifer System (Map 4-10 and Table 4-2). Constant heads were specified where the Dakota Sandstone and Entrada Sandstone cross the Puerco River, and where all three aquifers cross the Rio Puerco. Elevations of the land surface in these locations suggest that natural ground-water discharge from the Westwater Canyon Member Aquifer System also takes place there.

Constant-head type boundary conditions were also used to simulate potential inflow to the Westwater Canyon Member aquifer from the Tertiary-aged Chuska Sandstone in the Chuska Mountains (Map 4-14). In this region, the Chuska Sandstone directly overlies the Westwater Canyon Member of the Morrison Formation and flow from the Chuska Sanstone could be expected to increase with head declines in the Westwater Canyon Member. Presently many springs issue from outcrops of the coarse-grained Chuska Formation. Lyford, et.al. (1980) also used constant-head type boundary conditions to simulate inflow from the Chuska Mountains. A hydrogeologic map of the Chuska Mountains showing the probable area underlain by the Morrison Formation and location of these springs is presented in Map 4-20. The sensitivity of predictions of potential inflow to this constant-head assumption is discussed in Section 4.E.2.c.

Recharge to the Westwater Canyon Member Aquifer System was assumed <u>not</u> to be a function of hydraulic heads in the Westwater Canyon Aquifer System at other locations in the modeled area. Therefore, recharge was not simulated with boundary conditions.

4.D.6 Aquifer Stresses

Historical and proposed future uses of water from the Westwater Canyon Member Aquifer System are discussed in Section 4.C.4.c. This information is the basis for specifying the production of water (stresses) that is simulated in the model. Most historical water production from the Westwater Canyon Member Aquifer System has come from dewatering operations



Map 4-20. GEOLOGY OF CHUSKA MOUNTAIN AREA SHOWING PROBABLE AREA OF SUBCROP OF MORRISON FORMATION (Jm) OVERLAIN BY CHUSKA SANDSTONE (Tc)

associated with the uranium mines producing from the Morrison Formation in the southern part of the San Juan Structural Basin. Dewatering rates are a function of aquifer properties, depth of each mine, mine size, and time since dewatering began. Future water production from existing mines and from planned uranium mines, which are part of the BLM's Baseline 1 and Baseline 2, were calculated in the model by specifying constant heads at nodes corresponding to the mine locations. The constant-head value for each node was determined by the difference between the potentiometric surface of the Westwater Canyon Member aquifer (Map 4-10) and the top of the Westwater Canyon Member (Map 4-7), except at existing mines where the dewatering level was specified as that calculated to exist in 1980 due to historical ground-water production.

This manner of simulating dewatering rates has several shortcomings, but others have determined that it provides a good approximation (Lyford, et. al. 1980). The major drawback is that the size of the finite-difference grid block where the constant head is specified may not be the same as the size of the mine. Fortunately, calculated flow rates are not very sensitive to discrepancies between mine size and grid size. Lyford, et al. (1980) calculated that if the grid block area was about 5 times larger than the actual mine area, discharge would be overestimated by only 20 percent.

Flow toward a 2-square mile constant head block in the model is approximately equal to flow toward a circular mine with a radius of about 2,200 feet (Trescott and others, 1976). Mines are seldom circular, but Lyford and others (1980) state that a typical mine has an effective radius of about 1000 feet; flow into the mine can be simulated by representing the mine as a circle with a radius of 1000 feet. The effective mine radii simulated, which are a function of grid block size, are listed in Table 4-7. Mines were grouped within nodes in the model so that the combined effective mine radii of several mines would be approximately equal to the simulated mine radii.

Table 4-7. DATA ON THE URANIUM MINES SIMULATED

Mining Region	Mine Name	Owner/ Operator	Dewatering Level Simulated	Mine Radius Simulated[a]	Period for Which Constant Head Simulated	Node Location[b]
Church Rock Area	N.E. Church Rock	United Nuclear	Head Calculated in Year 1980	2200	1980 - 2009	3,22,8
	Church Rock #1 and #1E	Kerr-McGee				
Ambrosia Lake Area	Sec. 13	United Nuclear				
	Sec. 23	Homestake Partners	-350'	4400	1955 - 1989	3,28,22
	Sec. 22					
	Sec. 17	Kerr-McGee				
	Sec. 19					
	Sec. 25	United Nuclear Homestake Partners	-350'	4400	1960 - 1994	3,29,22
	Sec. 24					
	Sec. 30	Kerr-McGee				
	Sec. 30W					
	Ann Lee	United Nuclear				
	Sec. 33	Kerr-McGee	-350'	4400	1960 - 1994	3,29,23
	Sec. 32	U.N.-Home. Partners				
	Sec. 35					
	Sec. 36	Kerr-McGee	-800'	4400	1970 - 1999	3,29,24

Table 4-7. DATA ON THE URANIUM MINES SIMULATED (concluded)

Mining Region	Mine Name	Owner/ Operator	Dewatering Level Simulated	Mine Radius Simulated[a]	Period for Which Constant Head Simulated	Node Location[b]
Ambrosia Lake Area (concluded)	Johnnie M Lee Mine	Ranchers Explor. & Development Kerr-McGee	-750'	4400	1975 - 2004	3,30,24
	Mt. Taylor Mine	Gulf Mineral	-800'	4400	1980 - 2009	3,30,25
Crownpoint	#8 #9 #10	Phillips	-3350	2200	2000 - 2014	3,18,19
	#5 #6 #7	Phillips	-3350	2200	1995 - 2009	3,18,18
	#1 #2 #3	Phillips	-3350	2200	1990 - 2004	3,19,18
	#4 #11 #12	Phillips	-3350	2200	2005 - 2019	3,19,17
	Crownpoint Project	Conoco Oil	-1500	2200	1990 - 2009	3,21,14
	Borrego Pass	Conoco Oil	-1750	2200	2000 - 2019	3,23,21

Sources: See Tables E-1, E-2, and E-3.

[a] A typical mine has an actual effective radius of about 1000 feet (Lyford et al. 1980).

[b] Node numbers referenced as (layer, row, column).

Another source of error due to the simulation of dewatering at mines with constant heads is the implicit assumption that the strata at and in the vicinity of the mine remain saturated. The model does not simulate dewatering of the aquifer. Calculations made for the Phillips Nose Rock mine (Guyton & Assoc., 1978) showed that at the mine, where the potentiometric surface is about 3300 feet above the top of the Westwater Canyon Member, dewatering of the aquifer would account for about 10 percent of the water produced. Aquifer dewatering would account for a greater percentage of total pumpage where mine depths are shallower, and in outcrop areas where all discharges would come from aquifer dewatering.

The uranium mines simulated with constant heads are listed in Table 4-7. The effective mine size and the mining period that were simulated are also listed in the table. All uranium mines were assumed to have a life of 30 years, unless documentation to the contrary was obtained (see Tables E-1, E-2, and E-3). The Phillips Nose Rock mine and the Conoco Crownpoint project were assumed to commence in 1990, and the Conoco Borrego Pass project was assumed to commence in year 2000.

Constant flux nodes were used to simulate: (1) water production from uranium mines for the period 1940 to 1980; (2) water production from municipal, stock, industrial, and coal-mining activities; and (3) water production from proposed uranium mines about which very little is known. Ground-water pumping rates used for simulating the period 1940 to 1980 are listed in Table 4-8; pumping rates used for simulating the period 1980 to 2188 for existing uses and planned future users with water rights prior to those assumed for NMGS are listed in Table 4-9; pumping rates used for simulating projects on BLM's Baseline 1 and Baseline 2 are listed in Table 4-10; and pumping rates used for simulating production from the proposed NMGS well field are listed in Table 4-11.

Table 4-8. HISTORICAL PUMPAGE FROM THE WESTWATER CANYON MEMBER AQUIFER

	Pumping Rate (cfs)[1]							Model Node Number[2]	Data Source[3]
	1940-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1980		
Crownpoint	0.1	0.125	0.125	.167	.167	.240	.240	3,21,15	a
Navajo Tract Well 14T-515			1.07	1.07	1.07	1.07	1.07		b
Church Rock Mines					.70	6.85	10.81	3,22,8	c
Old Church Rock Mines				.35			.07	3,24,7	c
Gallup-Gamerco Coal Co.				.1	.13	.13	.18	3,25,5	b
Mariano Lake Mine							.22	3,26,7	d
Ambrosia Lake[4] Area Mines			11.1	25.7	20.1	17.8	16.0	3,28,22 3,29,23 3,30,24	a

[1]Only users pumping more than 0.1 cfs are listed (1 cfs = 724 AFY).

[2]Node numbers referenced as (layer, row, column). Locations are shown on Map 4-14.

[3]Sources of data: See Table E-1.

[4]In the historical simulation, a constant head of -350 feet was specified at node (3,28,22) from 1955-1980, a constant head of -350 feet was specified at node (3,29,23) from 1960 to 1980, a constant head of -850 feet was specified at node (3,29,24) from 1970 to 1980, and a constant head of -700 feet was specified at node (3,30,24) from 1975 to 1980.

Table 4-9. GROUND WATER PUMPING[a] SIMULATED FOR THE PERIOD 1980 TO 2184 FROM EXISTING USERS AND USERS WITH WATER RIGHTS PRIOR TO THOSE FOR NMGS

	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	2020-2029	2030-2180	Node Number[b]
Existing Users											
Crownpoint	0.34	0.44	0.54	0.64	0.74	0.84	0.88	0.88	0.88	0.88	3,21,15
City of Gallup	1.84	1.90	2.06	2.22	2.44	2.58	2.58	2.58	2.58	2.58	3,26,6 3,27,6
Navajo Tract Well 14T-515	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	3,16,6
Gallup-Gamerco Coal Company	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	3,25,5
Mariana Lake Mine	0.48										3,26,17
Prior Water Rights											
Mobil - Crownpoint Project				1.47	3.29	3.85	3.78	2.10			3,22,16 3,20,12 3,20,13 3,20,14 3,21,12 3,21,13 3,21,14
Mobil - Monument Project				0.17	0.38	0.45	0.45	0.25			3,20,11
Star Lake Mine					1.66 1.1	1.66 1.1	1.66 1.1	1.66 1.1	1.66 1.1		1,15,26 3,15,26
South Hospah Mine		0.9	0.9	0.9	0.9	0.9	0.9				3,23,22 3,23,22
Gallo Wash Mine (Alamito Coal Co.)		0.9	0.9	0.9	0.9	0.9	0.9	0.9			3,13,23 3,14,23
BLM Bisti Well		0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	3,11,13

[a]All values in cubic feet per second (cfs) (1 cfs = 724 AFY).

[b]Node numbers are referenced as (layer, row, column). Locations of nodes are shown on Map 4-14.

Table 4-10. PUMPING RATES SIMULATED FOR PROJECTS IN BLM'S BASELINES 1 AND 2

	Pump Rates Simulated (cfs)[a]							
	1980-1984	1985-1989	1990-1999	2000-2009	2110-2019	2020-2029	2030-2184	Node No.[b]
Future Projects								
Plains Electric[c]	0.3	7.3	4.2	0.61	0.50			3,25,21
Consol. Coal (El Paso-Burnham Mine)[d]		.75	.75	.75	.75			3,25,22
Star Lake Bisti[d]								3,29,22
L-Bar Mill and JJ #1 Mine[d]			1.8	1.8	1.8			3,33,28
Star Lake Mine[d]				1.4 0.7	1.4 0.7	1.4 0.7		1,13,23 3,15,26
Marquez Mill[d]			2.6	2.6	2.6	2.6		3,32,25
Marquez Mine[d]			1.2	1.2	1.2	1.2		3,30,28
Rio Puerco Mine[d]			1.2	1.2	1.2	1.2		3,21,28

[a]1 cfs = 724 AFY.

[b]See Map 4-14 for locations of nodes. Node numbers are referenced as (layer, row, column).

[c]The water rights and water rights applications for the Plains Electric Escalante Generating Stations (SJ-886 and RG-32002) imply a pumping rate of about 20,000 AFY from the Westwater Canyon Member aquifer. This rate is physically not obtainable for the life of the project. The rates listed in the table were calculated by simulating the Plains Electric withdrawals with a constant head of -1000', which is about the present distance from the potentiometric surface to the top of the Westwater Canyon Member at the Plains Electric well field.

[d]The pump rates for these projects were derived from information contained in water rights applications for the respective projects. Refer to Table E-4 for more detail.

Table 4-11. SIMULATED PUMPING RATES FOR PUBLIC SERVICE COMPANY OF NEW MEXICO'S NEW MEXICO GENERATING STATION

Node Number[a]	Pumping Rates Simulated (cfs)[b] 1995-1997	1998-2029	2030-2032
3,11,14	1.08	2.59	1.08
3,11,15	1.08	2.59	1.08
3,11,16	1.08	2.59	1.08
3,11,18	1.08	2.59	1.08
3,11,17	0.54	1.29	0.54
3,12,13	0.54	1.29	0.54
3,12,14	0.54	1.29	0.54
3,12,15	0.54	1.29	0.54
3,12,16	1.08	2.59	1.08
3,12,17	1.08	2.59	1.08
Total (acre-ft/yr)	6250	15,000	6250

[a]Node numbers are referenced as (layer, row, column). Locations of nodes are shown on Map 4-14.

[b]1 cfs = 724 AFY.

4.D.7 Simulation of Historical Production From the Westwater Canyon Aquifer

Ground-water pumpage from the Westwater Canyon Member aquifer has been limited, in the past, mainly to the Church Rock and Ambrosia Lake uranium mining areas, where large quantities of water have been produced from dewatering operations. Small quantities of water have been produced at other uranium mining areas, by the towns of Crownpoint and Gallup for municipal supplies, and at various wells for stock watering (see Section 4.C.4.c). Estimates of historical rates of production from the Westwater Canyon Member aquifer are listed in Table 4-8.

The response of the potentiometric surface of the Westwater Canyon Member aquifer to historical pumping has been monitored at only two points, the Old Church Rock mine where water levels have been monitored from 1969 to 1978 (Hearne, 1977 and CDM, 1981), and in the Crownpoint area where water levels have been monitored from 1960 to the present (Guyton & Assoc., 1978.) The model of the Westwater Canyon Member Aquifer System was used to simulate the effects of historic pumpage to verify that the model could reproduce the observed responses in the potentiometric surface.

The first historical simulation of the Westwater Canyon Member Aquifer System was made using the pumping stresses listed in Table 4-8, and the parameter values listed in Table 4-12. The calculated drawdowns at Crownpoint and the Old Church Rock mine were nearly identical to the observed drawdowns at these locations. Calculated drawdowns in the Ambrosia Lake area, however, were below the base of the Westwater Canyon Member aquifer. Drawdowns in excess of 2000 feet were calculated in year 1965 for the northwestern part of the Ambrosia Lake area, whereas actual drawdowns were in the range of 300 to 400 feet (Kelly, et al., 1980). The pumping rates listed in Table 4-8 for the Ambrosia Lake area were derived from Guyton & Assoc. (1978), who based their estimates on sketchy data. Recent pumping rates in the Ambrosia Lake area estimated by others are considerably smaller than those estimated by Guyton & Assoc. The 1978 pumping rates were estimated to be 12 cfs (Lyford et al., 1980), and Kelly

Table 4-12. INITIAL PARAMETERS USED IN MODEL FOR SIMULATION OF HISTORICAL STRESSES

	Transmissivity (ft^2/day)	Specific Storage[a] (/ft)	Vertical Hydraulic Conductivity (ft/day)
Layer 3 Westwater Canyon Member Aquifer	Distribution Shown on Figure 4-17	4×10^{-7}	-
Layer 1 Entrada Sandstone	0.59 * b[b]	4×10^{-7}	-
Layer 5 Dakota Sandstone	0.22 * b[b]	4×10^{-7}	-
Confining Units (Layers 2 and 4)	-	4×10^{-7}	8.6×10^{-6}

[a]Specific storage was multiplied by the layer thicknesses shown on Maps 4-4 and 4-13. A uniform thickness of 600 feet was used in layer 2, a uniform thickness of 250 feet was used for layer 3, and a uniform thickness of 200 feet was used for layer 4.

[b]Thickness estimates were derived from values shown in Maps 4-4 and 4-13.

(1980) estimated pumping rates in the 1975 to 1978 period to be 10 cfs. In addition, the estimates of total withdrawal overstate actual net discharge from the Westwater Canyon Member in the Ambrosia Lake area, according to Kelly, et al. (1980) and Guyton & Assoc. (1978), because much of the pumped water is discharged to streams, which lose much of their flow when crossing a zone of intense faulting downstream from the mine areas. Water percolating downward within this fault zone is likely to recharge the Westwater Canyon Member aquifer.

Because pumping rates in the Ambrosia Lake area are poorly known, constant heads were used to simulate the historical stresses in the Ambrosia Lake area in the second historical simulation of the Westwater Canyon Member Aquifer System. The constant head levels for the various mines in the Ambrosia Lake area were calculated from data presented in Kelly, et al. (1980). Calculated dewatering rates using this approach are much lower than those estimated by Guyton & Assoc. (1978) (Figure 4-5). However, dewatering rates calculated for the period 1975-1979 agree closely with estimates by Lyford, et al. (1980) and Kelly, et al. (1980).

As a result of the decreased production rates simulated in the Ambrosia Lake area in the second historical simulation, calculated water level declines in the Crownpoint area were about 25 percent less than observed declines. The vertical hydraulic conductivity in the confining beds was decreased to 2.8×10^{-6} ft/day in order to reproduce closely, the observed declines in the potentiometric surface at Crownpoint (Figure 4-6) and at the Old Church Rock mine. Calculated and observed drawdowns at the Old Church Rock Mine were about 190 feet in 1975.

This process of adjusting parameters and stresses in the model has assured that the model subsequently used for predictions is at least consistent with observed aquifer responses. This procedure is not calibration in a formal sense, though, because there are not enough observed responses to estimate all of the parameters in the model.

Figure 4-5. GROUND-WATER DISCHARGE IN THE AMBROSIA LAKE AREA (a) FROM MINE DEWATERING ESTIMATED BY GUYTON AND ASSOCIATES (1978) AND (b) CALCULATED USING CONSTANT HEADS TO SIMULATE MINE DEWATERING WITH THE AQUIFER MODEL

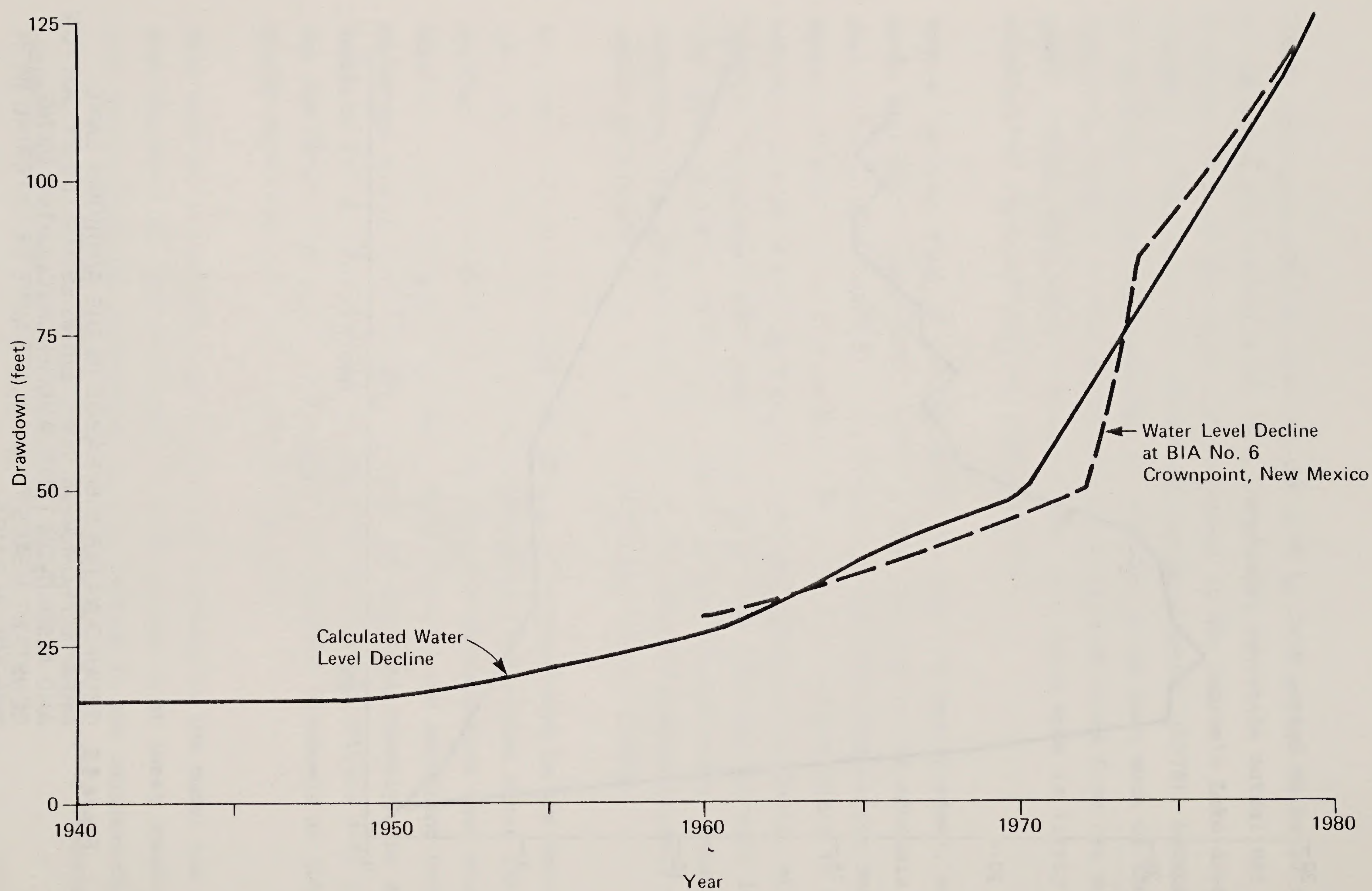


Figure 4-6. REPORTED AND CALCULATED WATER LEVEL DECLINES AT BIA WELL NO. 6, CROWNPOINT, NEW MEXICO

The calculated historical water-level changes in the Crownpoint area are a function of the stresses applied to the system and of aquifer parameters. Historical stresses at both the Ambrosia Lake area and in the Crownpoint area are poorly known. Estimates of current pumping rates in the Crownpoint area vary from 0.2 to 0.5 cfs (see Table E-1). Therefore, the estimates of parameters derived by fitting observed drawdown data at Crownpoint have a high variance. The vertical hydraulic conductivity of the confining beds, rather than the transmissivity and storage coefficient for the Westwater Canyon Member aquifer, was adjusted to produce a reasonable match of computed and observed water-level data at Crownpoint, because this parameter cannot be estimated very well from a priori information. Also drawdowns at Crownpoint are very sensitive to the value of vertical hydraulic conductivity (Figure 4-7).

A sensitivity analysis of a Church Rock area model developed informally for this report has shown that when model parameters were varied within reasonable bounds, the observed water level response at the Old Church Rock mine after the first year of pumping was essentially a function of only the transmissivity specified for the Westwater Canyon Member aquifer. This result is due to the proximity of the Old Church Rock Mine to the outcrop area. Water level responses at the Old Church Rock mine were not recorded during the first year of pumping at the nearby United Nuclear Church Rock mine. Therefore, the Old Church Rock data are useful only for estimating aquifer transmissivity in the vicinity of the Church Rock mine. This has previously been done in a formal manner by Hearne (1977).

Regardless of the limited information that can be obtained from the observed water-level changes in the Westwater Canyon Member at Crownpoint and the Old Church Rock mine, no aquifer responses have been recorded in the Dakota Sandstone and Entrada Sandstone aquifers, or in the Westwater Canyon Member aquifer over most of the area modeled. A priori assumptions that cannot be tested, except in short-term aquifer tests, therefore must

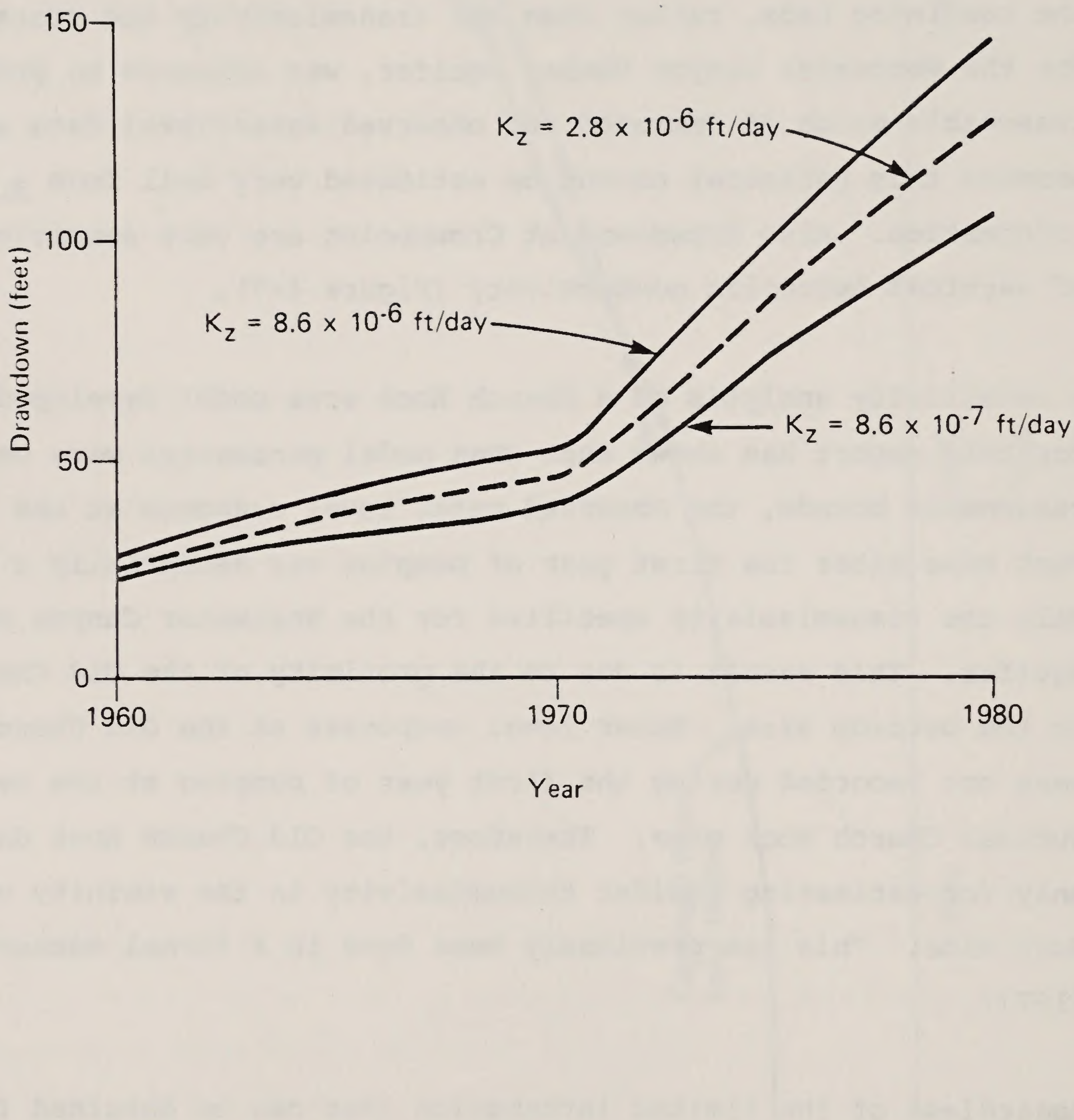


Figure 4-7. SENSITIVITY OF CALCULATED DRAWDOWNS AT CROWNPOINT (BIA WELL NO. 6) TO CHANGES IN VERTICAL HYDRAULIC CONDUCTIVITY IN CONFINING BEDS

be relied upon to estimate aquifer parameters in most of the study area. These assumptions have been discussed in Section 4.D.4 and estimates of aquifer parameters are presented in Table 4-6.

4.E IMPACTS CAUSED BY PUMPING FROM THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

4.E.1 Present and Proposed Future Users

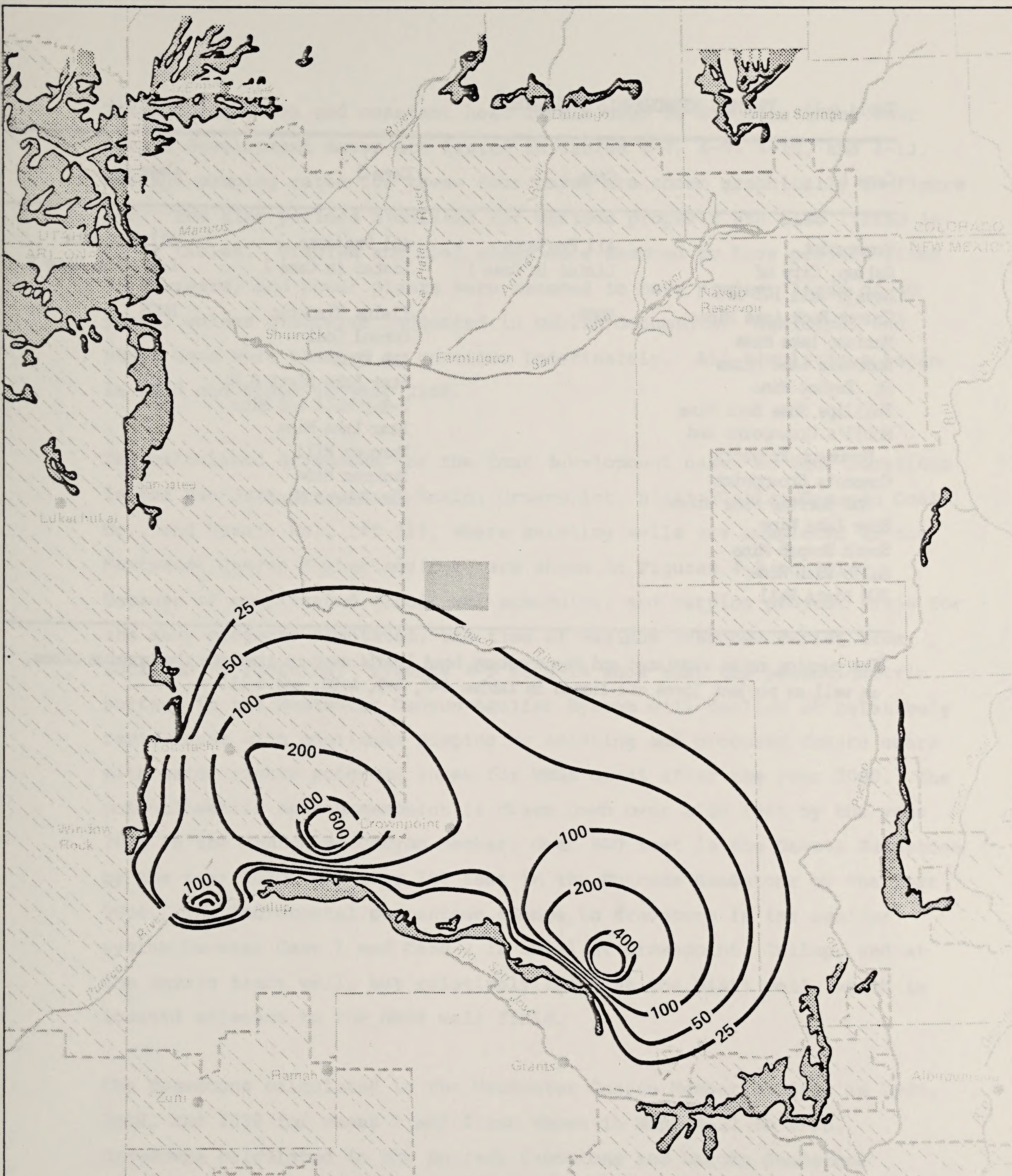
4.E.1.a. Historical Users

Calculated drawdowns in the Westwater Canyon Member aquifer in 1980 are shown in Map 4-21. These drawdowns were calculated using the stresses listed in Table 4-8 and the parameter estimates listed in Table 4-6. Calculated drawdowns in the Dakota Sandstone aquifer are shown in Appendix F. Drawdowns in the Entrada Sandstone were less than 25 feet. These drawdowns mainly reflect the ground-water production associated with uranium mining in the Church Rock and Ambrosia Lake areas.

4.E.1.b Future Effects (Cases 1 through 4)

Future declines in the potentiometric surface of aquifers in the Westwater Canyon Member Aquifer System and in natural discharges from the aquifers that would occur as a result of ground-water pumping were calculated using the model of the Westwater Canyon Member Aquifer System for four development cases. These development cases (Table 4-13) are:

- Case 1: continued pumping by existing users, and pumping by proposed users with water rights prior to those rights assumed for New Mexico Generating Station;
- Case 2: Case 1 plus pumping for NMGS;
- Case 3: Case 1 plus pumping by proposed users on BLM's Baseline 1 and Baseline 2;
- Case 4: Case 3 plus pumping for NMGS.



LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

NMGS Well Field

Outcrop includes Morrison, Wanakah, Summerville and Entrada Formations

N

0 10 20
miles

Map 4-21. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 1980

Table 4-13. PROJECT WITHDRAWALS SIMULATED[a]

Case 1	Case 2	Case 3	Case 4
Crownpoint Gallup, City of Navajo Well 14T-515	All Projects Listed in Case 1	All Projects Listed in Case 1	All Projects Listed in Case 3
Church Rock Area Mines	NMGS	Plains Electric	NMGS
Mariano Lake Mine		Consol Coal	
Ambrosia Lake Mines		Lee Mine	
Mt. Taylor Mine		Star Lake Bisti R.R.	
Phillips Nose Rock Mine		L-Bar Mill and Mine	
Mobil's Crownpoint and Monument Projects		Star Lake Mine Marquez Mill	
Conoco's Crownpoint and Borrego Pass Mines		Marquez Mine Rio Puerco Mine	
Star Lake Mine			
South Hospah Mine			
Gallo Wash Mine			
BLM Bisti Well			

[a]The pumping rates simulated and the constant head levels used to simulate the uranium mines, as well as project lives are listed in Tables 4-7, 4-9, 4-10, and 4-11.

The pumping rates and constant head levels used to simulate these four future development cases are listed in Tables 4-7, 4-9, 4-10, and 4-11. Average pumping rates for these four cases are shown graphically in Figure 4-8. The time periods simulated for various projects are also listed in these tables. Uranium and coal mines were assumed to have project lives of 30 years, and power plants were assumed to have project lives of 40 years, unless otherwise indicated in public documents. Municipal and stock uses were assumed to continue indefinately. All simulations began in 1940 and ended in year 2188.

The calculated drawdowns for the four development cases at four locations in the San Juan Structural Basin, Crownpoint, Bisti, Gallup-Gamerco Coal Co., and Navajo Well 14T-515, where existing wells are completed in the Westwater Canyon Member aquifer, are shown in Figures 4-9 to 4-14. Because of complicated withdrawal schedules, and varying project lives for the many projects simulated, the time of maximum drawdown varies from location to location. Figures 4-9 to 4-14 show that the potentiometric surface in the Westwater Canyon Aquifer System will decline at relatively rapid rates with continued pumping by existing and proposed future users with water rights prior to those for NMGS until after the year 2000. The potentiometric near Crownpoint is drawn down over 1700 feet by the year 2015 in the Westwater Canyon Member, over 600 feet in the Dakota Sandstone by the year 2020, and over 100 feet in the Entrada Sandstone by the year 2030. The incremental percentage change in drawdowns in the aquifer system between Case 1 and Case 2 is small at Crownpoint, Gallup, and at the Navajo tract well, but relatively large at the Bisti well, which is located adjacent to the NMGS well field.

The drawdowns calculated in the Westwater Canyon Member aquifer in 1995, 2010, and 2030 for cases 1 and 2 are shown in Maps 4-22 to 4-26. Drawdowns calculated in the Entrada Sandstone and Dakota Sandstone aquifers in 1995, 2010, and 2030 are shown in Appendix F. These dates were selected because 1995 is the year pumping by NMGS is scheduled to begin, 2030 is the last year of heavy pumping by NMGS (see Table 4-11), and 2010 is about the midpoint of the project life.

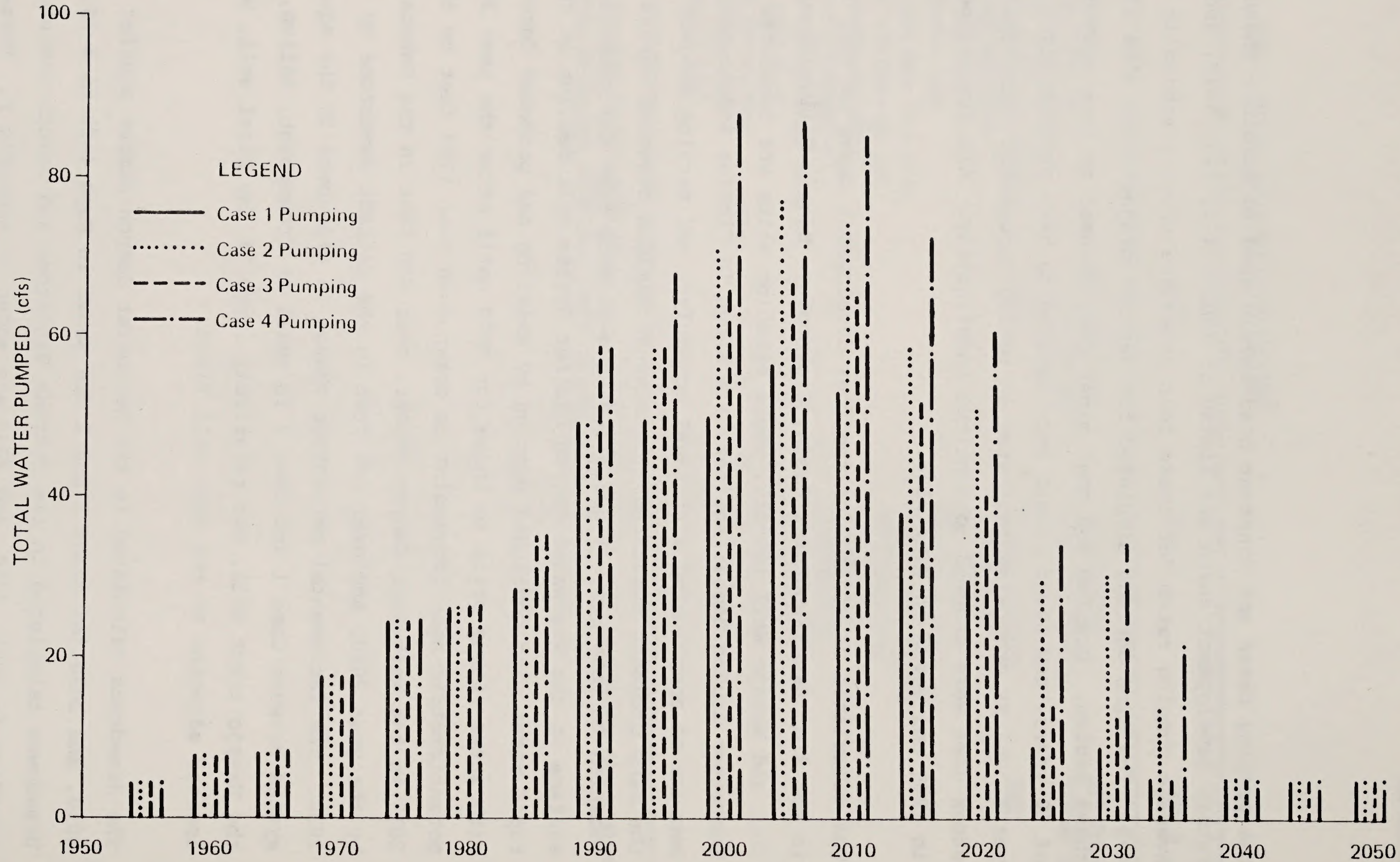


Figure 4-8. SIMULATED GROUNDWATER PUMPAGE FROM THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

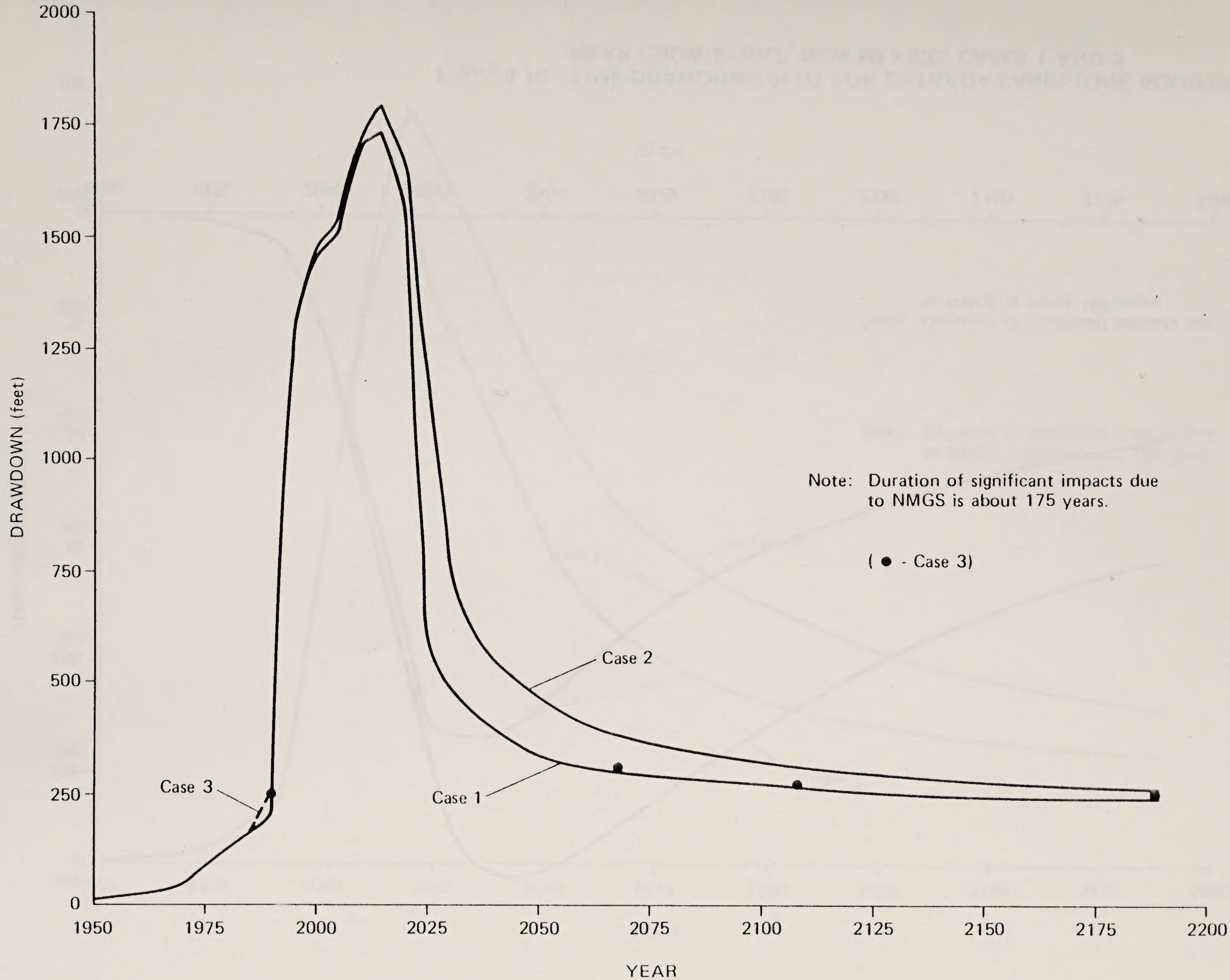


Figure 4-9. TIME-DRAWDOWN PLOT FOR THE WESTWATER CANYON AQUIFER NEAR CROWNPOINT, NEW MEXICO; CASES 1 AND 2

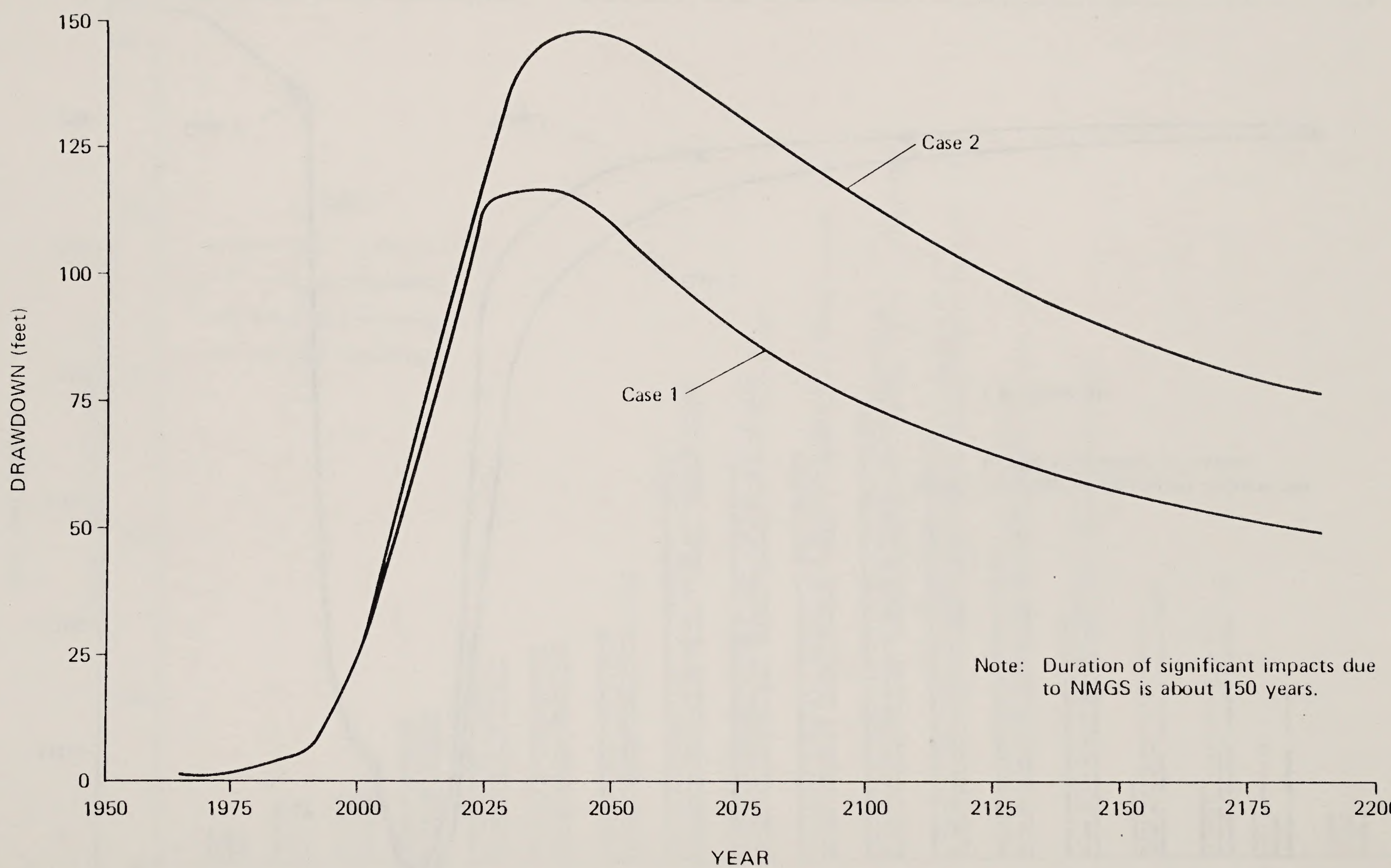


Figure 4-10. TIME-DRAWDOWN PLOT FOR ENTRADA SANDSTONE AQUIFER NEAR CROWNPOINT, NEW MEXICO; CASES 1 AND 2

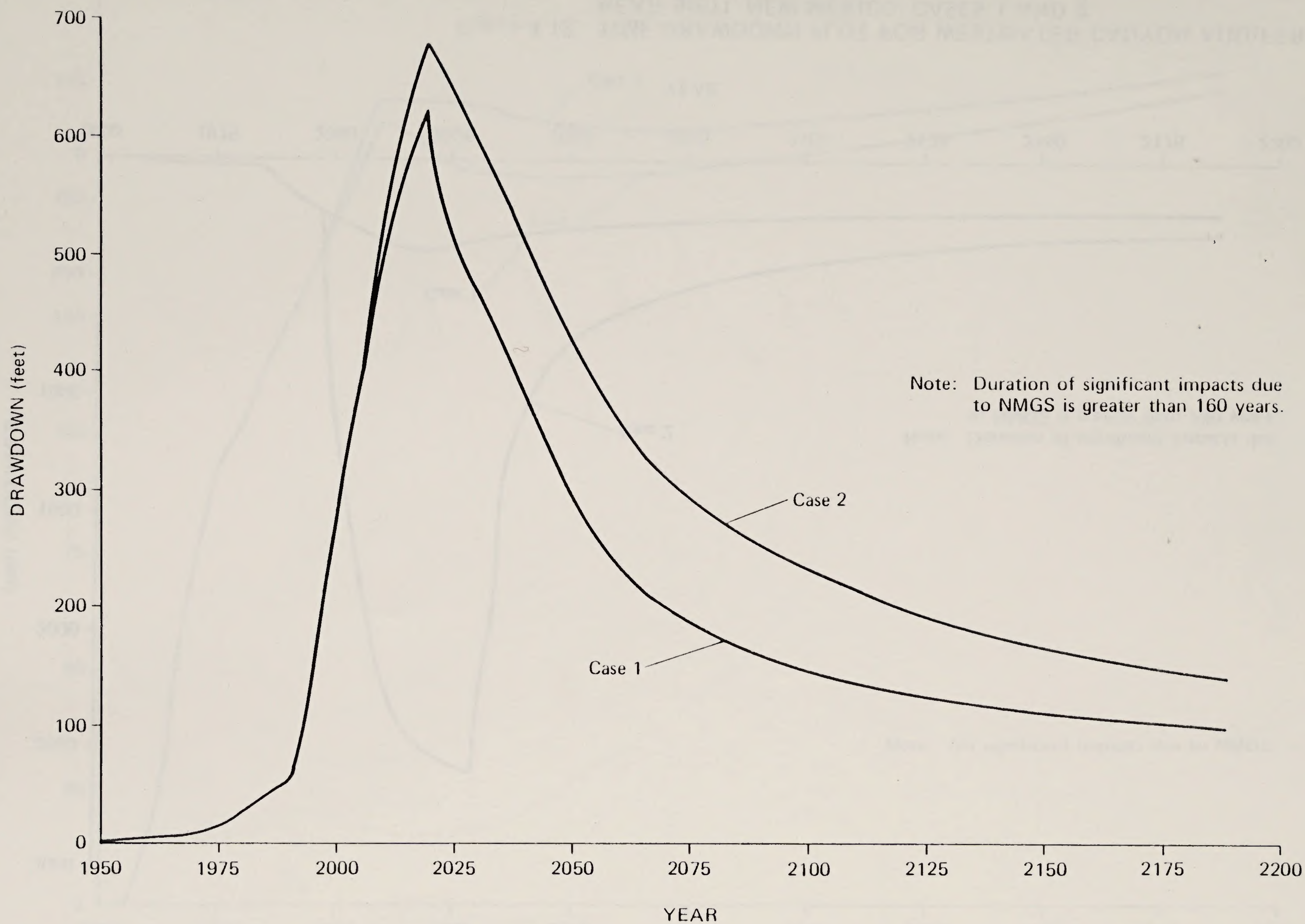


Figure 4-11. TIME-DRAWDOWN PLOT FOR DAKOTA SANDSTONE AQUIFER NEAR CROWNPOINT, NEW MEXICO; CASES 1 AND 2

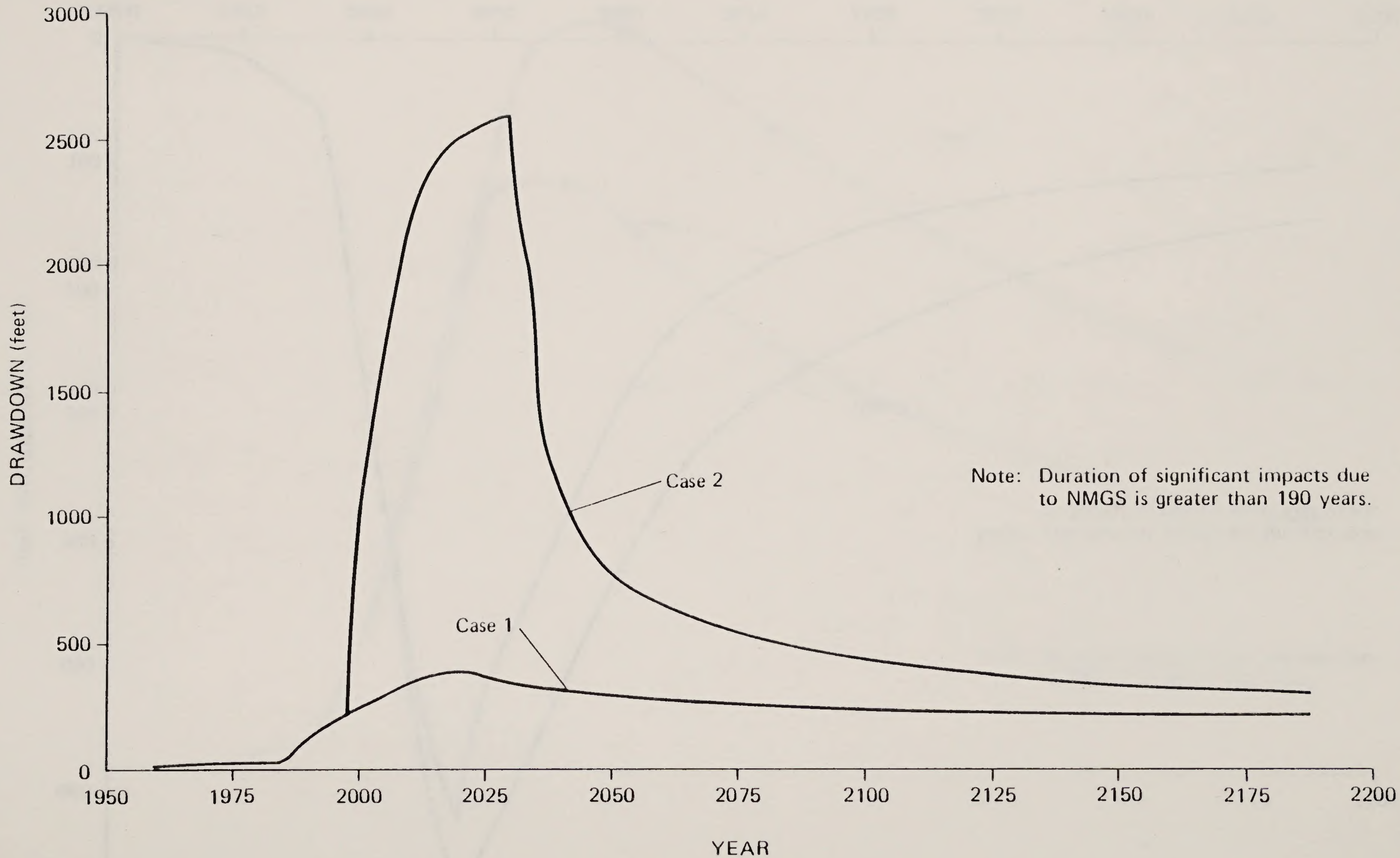


Figure 4-12. TIME-DRAWDOWN PLOT FOR WESTWATER CANYON AQUIFER NEAR BISTI, NEW MEXICO; CASES 1 AND 2

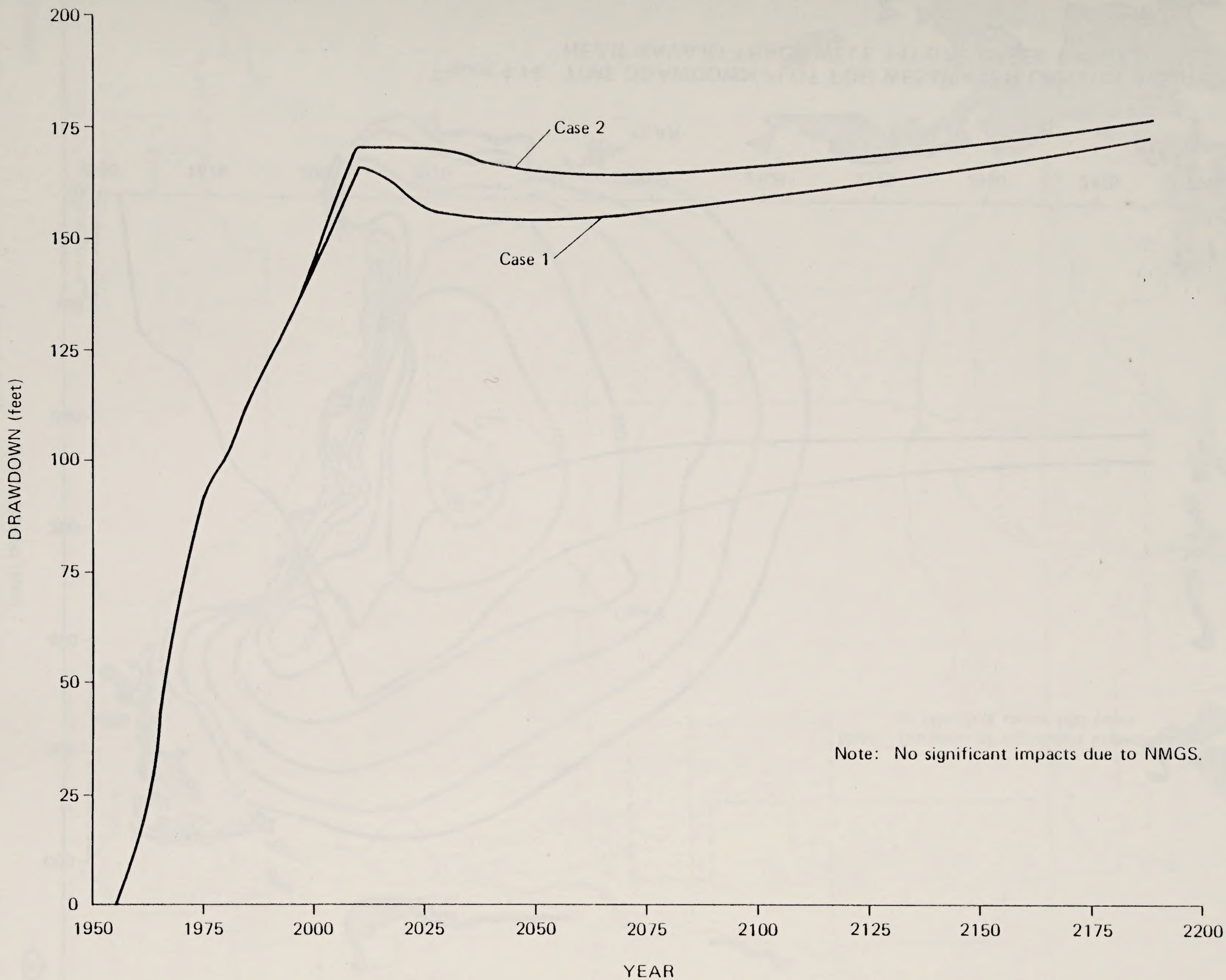


Figure 4-13. TIME-DRAWDOWN PLOT FOR WESTWATER CANYON AQUIFER NEAR GALLUP, NEW MEXICO; CASES 1 AND 2

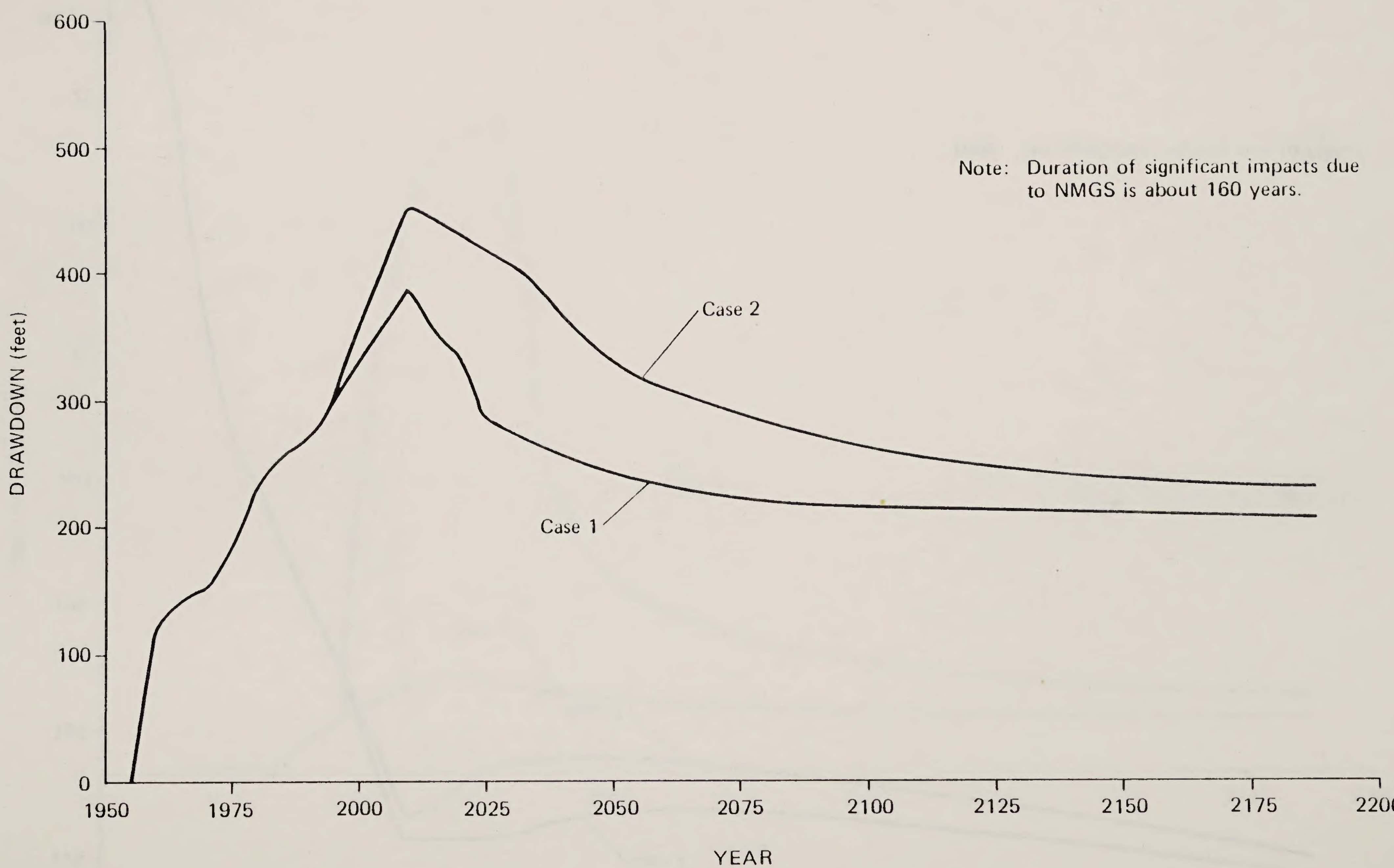
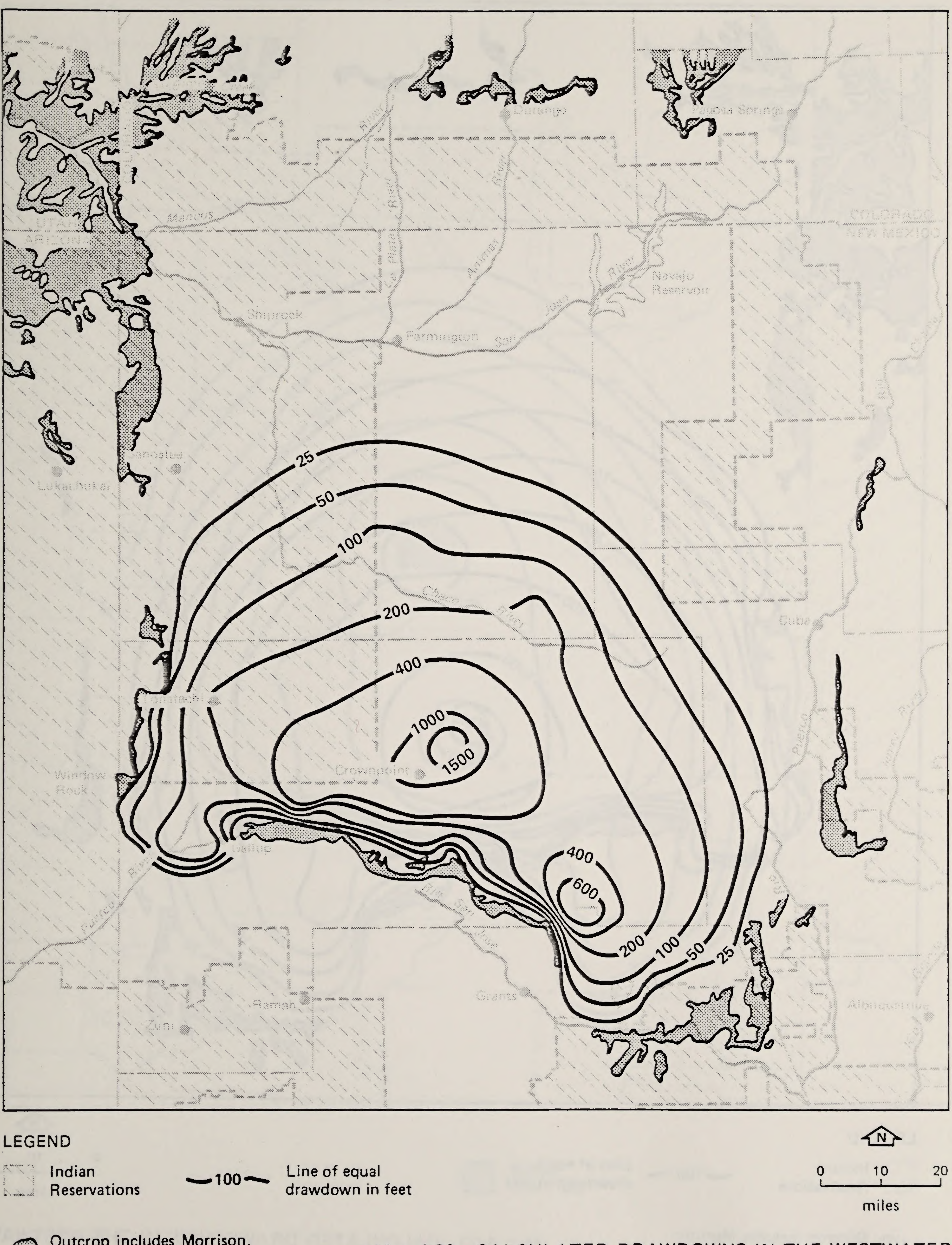
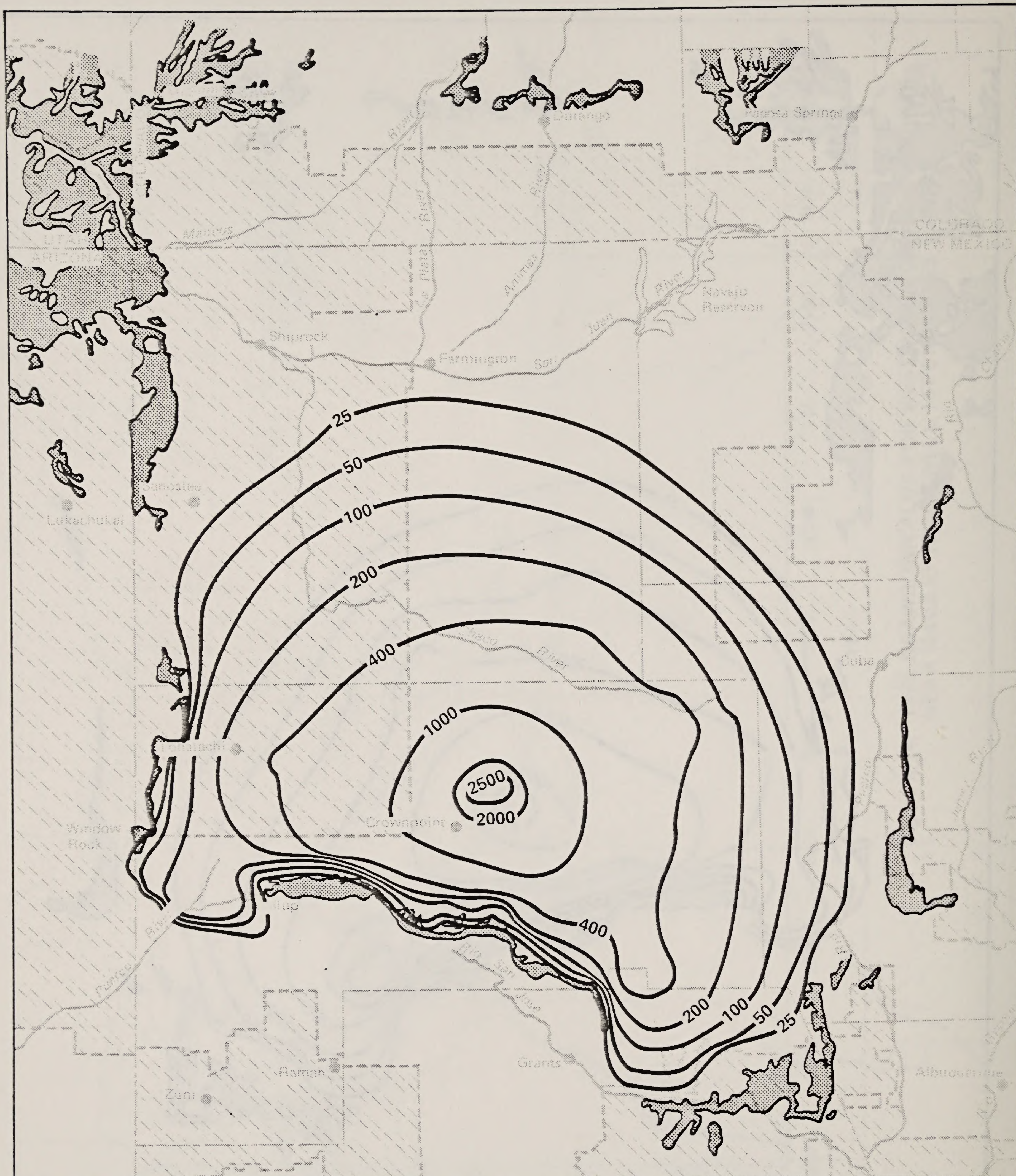


Figure 4-14. TIME-DRAWDOWN PLOT FOR WESTWATER CANYON AQUIFER NEAR NAVAJO TRACT WELL 14T-515; CASES 1 AND 2



Map 4-22. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 1995, CASE 1



LEGEND

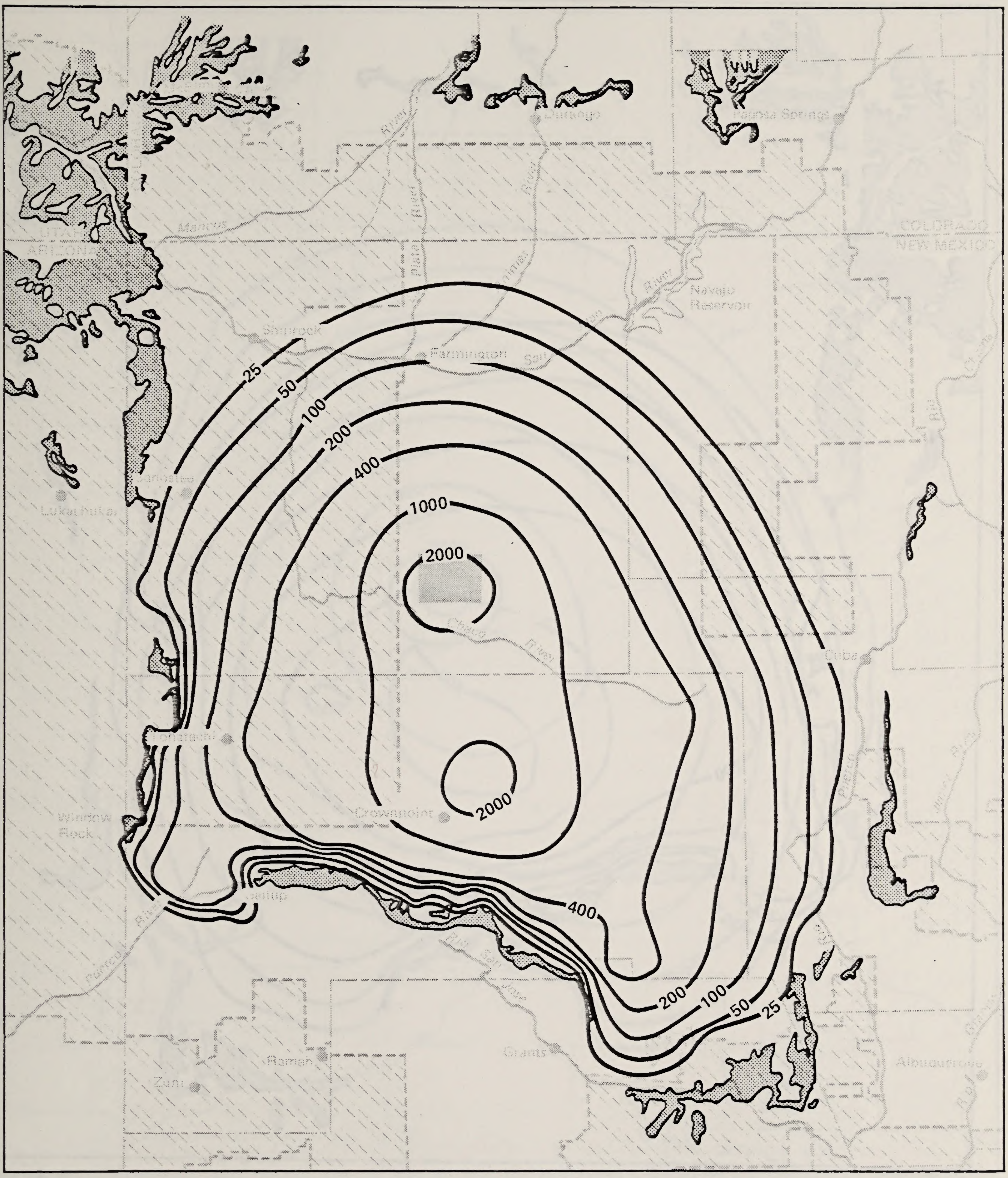
Indian Reservations

—100— Line of equal drawdown in feet

Outcrop includes Morrison, Wanakah, Summerville and Entrada Formations

0 10 20 miles

Map 4-23. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 2010, CASE 1



LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

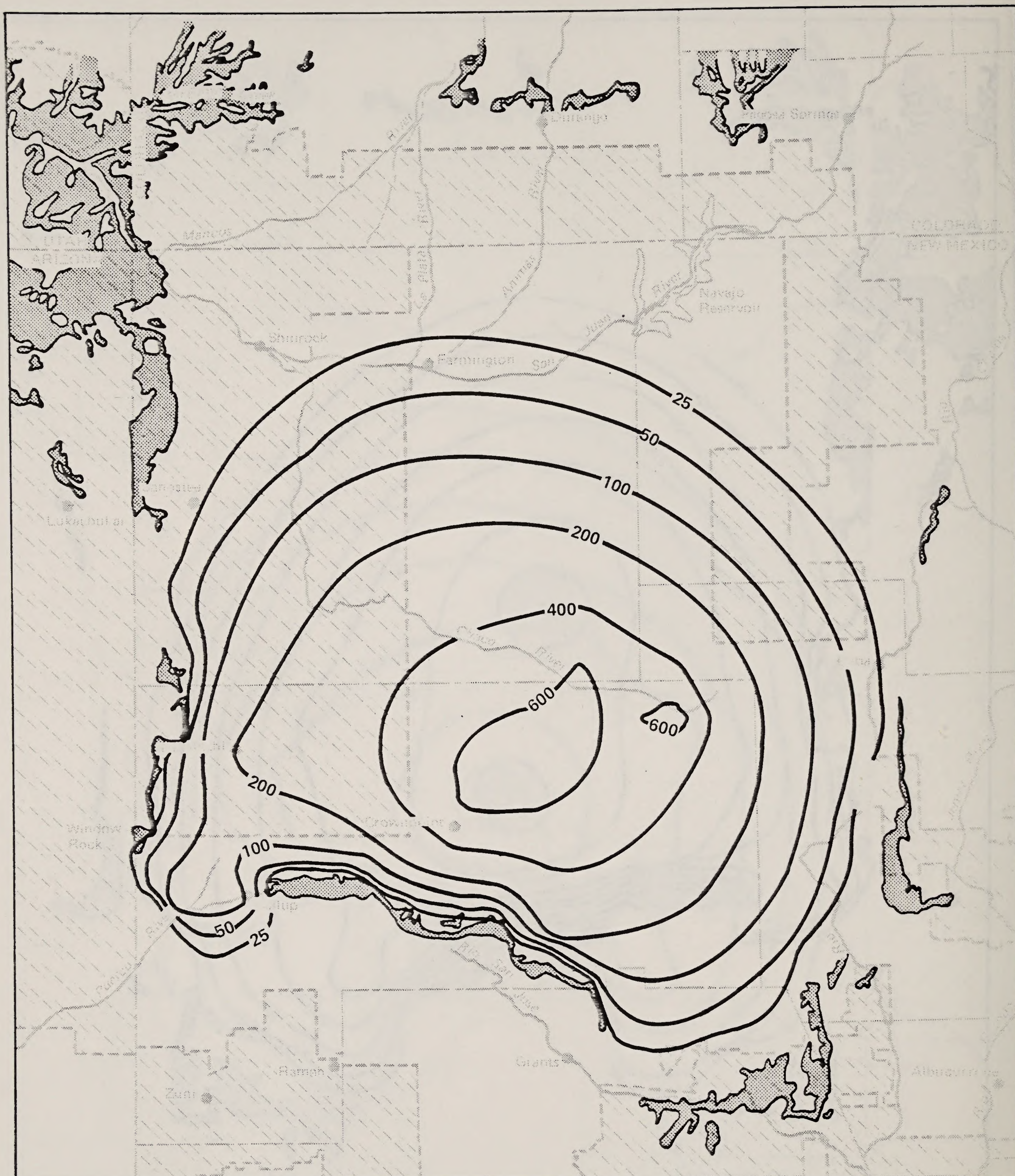
NMGS Well Field

Outcrop includes Morrison, Wanakah, Summerville and Entrada Formations

N

0 10 20
miles

Map 4-24. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 2010, CASE 2



LEGEND

Indian Reservations

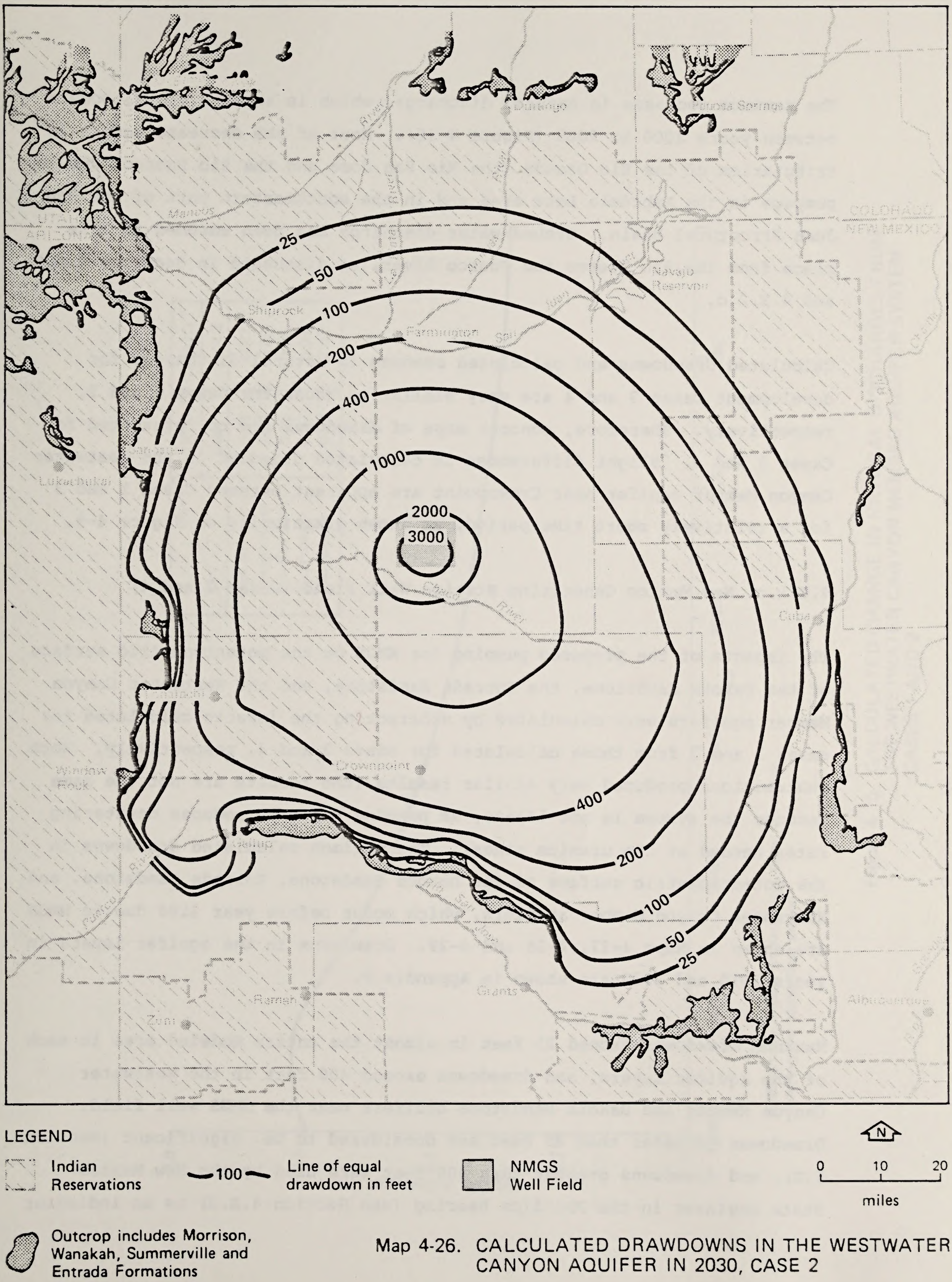
—100— Line of equal drawdown in feet

Outcrop includes Morrison, Wanakah, Summerville and Entrada Formations

N

0 10 20
miles

Map 4-25. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 2030, CASE 1



Map 4-26. CALCULATED DRAWDOWNS IN THE WESTWATER CANYON AQUIFER IN 2030, CASE 2

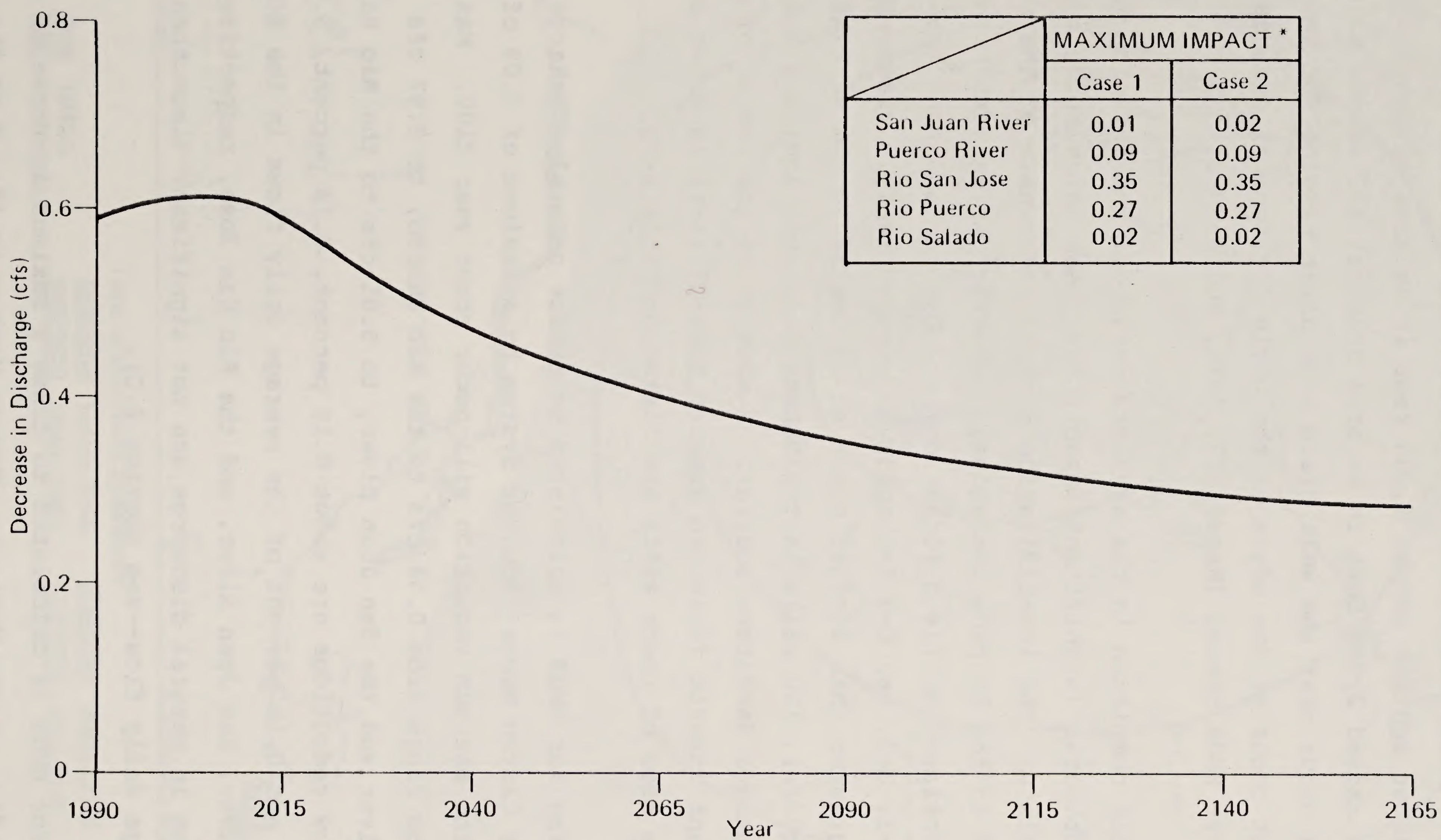
The maximum decrease in natural discharge, which is about 0.6 cfs, occurs between years 2000 to 2005 (Figure 4-15). Most of the decrease occurs in tributaries of the Rio Grande (the Rio San Jose and the Rio Puerco) due to pumpage in the Ambrosia Lake area and in the southeastern part of the San Juan Structural Basin. Ground-water discharge has been assumed to take place from the Rio Puerco and Puerco River, as discussed in Sections 4.D.5 and 4.E.2.c.

Calculated drawdowns and calculated changes in natural discharges for development Cases 3 and 4 are very similar to those for Cases 1 and 2, respectively. Therefore, contour maps of drawdowns are not presented for Cases 3 and 4. Slight differences in calculated drawdown in the Westwater Canyon Member aquifer near Crownpoint are apparent between Cases 1 and 3 for a relatively short time period, as shown graphically on Figure 4-9.

4.E.1.c New Mexico Generating Station Well Field (Cases 2 and 4)

The impacts of the proposed pumping for NMGS on the potentiometric surface of the Dakota Sandstone, the Entrada Sandstone, and the Westwater Canyon Member aquifers were calculated by subtracting the impacts calculated for cases 1 and 3 from those calculated for cases 2 and 4, respectively. Both subtractions produced very similar results (the results are not the same because the system is not linear, as pumping for NMGS reduces dewatering rates needed at the uranium mines). The maximum calculated drawdowns in the potentiometric surface of the Dakota Sandstone, Entrada Sandstone, and Westwater Canyon Member aquifers, which occur before year 2188 due to NMGS are shown in Maps 4-27, 4-28 and 4-29. Drawdowns in the aquifer layers in years 2010 and 2030 are shown in Appendix F.

Maximum drawdowns exceed 25 feet in almost the entire modeled area in each of the aquifer layers, and drawdowns exceed 400 feet in the Westwater Canyon Member and Dakota Sandstone aquifers near the NMGS well field. Drawdowns greater than 25 feet are considered to be significant (Section 2.D), and drawdowns greater than 400 feet were used by the New Mexico State Engineer in the Phillips hearing (see Section 4.B.2) as an indicator



	MAXIMUM IMPACT *	
	Case 1	Case 2
San Juan River	0.01	0.02
Puerco River	0.09	0.09
Rio San Jose	0.35	0.35
Rio Puerco	0.27	0.27
Rio Salado	0.02	0.02

* Maximum impact in each river does not occur during the same time period

Figure 4-15. CALCULATED CHANGE IN NATURAL DISCHARGES FROM THE WESTWATER CANYON MEMBER AQUIFER SYSTEM; CASES 1 AND 2 of impairment. In the Westwater Canyon Member aquifer maximum drawdowns exceed 400 feet in an area that encompasses about 2000 square miles, and drawdowns exceed 400 feet in the Dakota Sandstone aquifer in an area that encompasses about 900 square miles. Maximum drawdowns in the Westwater Canyon Member aquifer exceed 1,000 feet in an area of about 900 square miles and exceed 2,000 feet in an area of about 400 square miles. Maximum drawdowns occur near the well field soon after pumping for NMGS ceases, but do not occur at the edges of the basin for several decades after pumping for NMGS ceases (Maps 4-27, 4-28, and 4-29).

Water wells completed in the aquifers depicted, and in which more than 25 feet of drawdown (significant impact) have been calculated, are presented in Appendix G. The identification numbers and owners of the wells completed in the Entrada Sandstone, Westwater Canyon Member (or undifferentiated Morrison Formation) and Dakota Sandstone are listed in Tables G-1, G-2, and G-3 (Appendix G), respectively. Drawdowns due to NMGS of greater than 25 feet occur at 149 wells in the Westwater Canyon Member aquifer, 100 wells in the Dakota Sandstone aquifer, and at 13 wells in the Entrada Sandstone aquifer. A summary of the number of wells with significant impacts (drawdown greater than 25 feet) is shown on Table 4-14; the uses of these wells are listed on Table 4-15.

The pumping for NMGS is calculated to reduce natural discharges from the Westwater Canyon Member Aquifer System by a maximum of 0.09 cfs (Figure 4-16). The maximum reduction will occur about year 2100. Maximum reductions range from 0.04 cfs to the Rio Puerco, to 0.02 cfs to the Puerco River and the San Juan River, to 0.01 cfs to the Rio San Jose. These flow reductions are about 0.16 percent, 0.13 percent, 0.0005 percent, and 0.10 percent of the average daily flows in the Rio Puerco, Puerco River, San Juan River, and the Rio San Jose, respectively. These reductions in natural discharge are not significant (less than 15 percent of average daily flow--see Section 2.D).

Pumping for NMGS is calculated to cause a maximum increase of about 0.4 cfs in inflow to the Westwater Canyon Member aquifer from the Chuska

LEGEND

Indian Reservations

NMGS Well Field

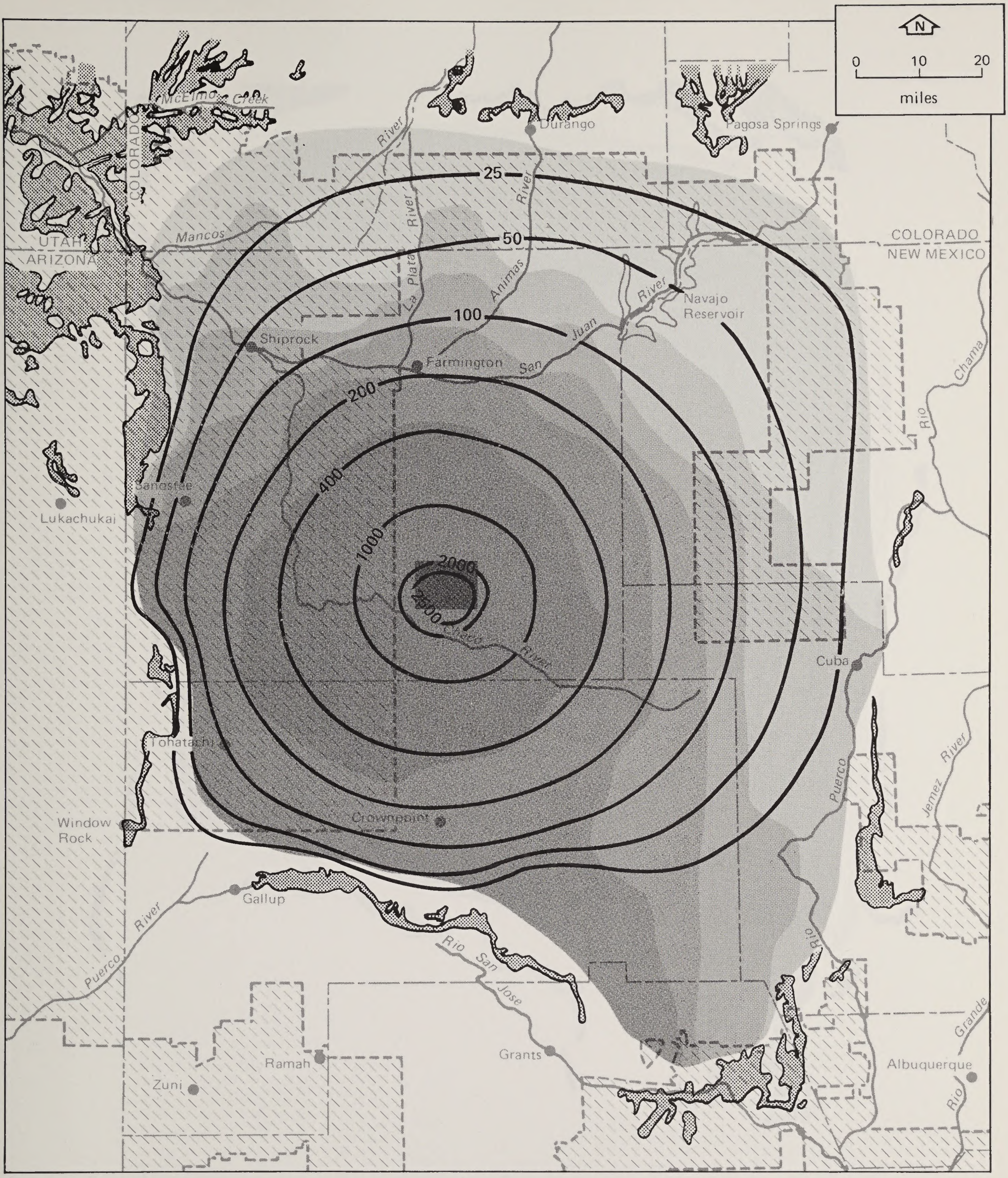
Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

Time of Maximum Drawdown

- before 2048
- 2049–2068
- 2069–2108
- after 2109

—100— Line of equal drawdown in feet

Map 4-27. MAXIMUM CALCULATED DRAWDOWNS DUE TO NMGS IN THE ENTRADA SANDSTONE AQUIFER



LEGEND

Indian Reservations

NMGS Well Field

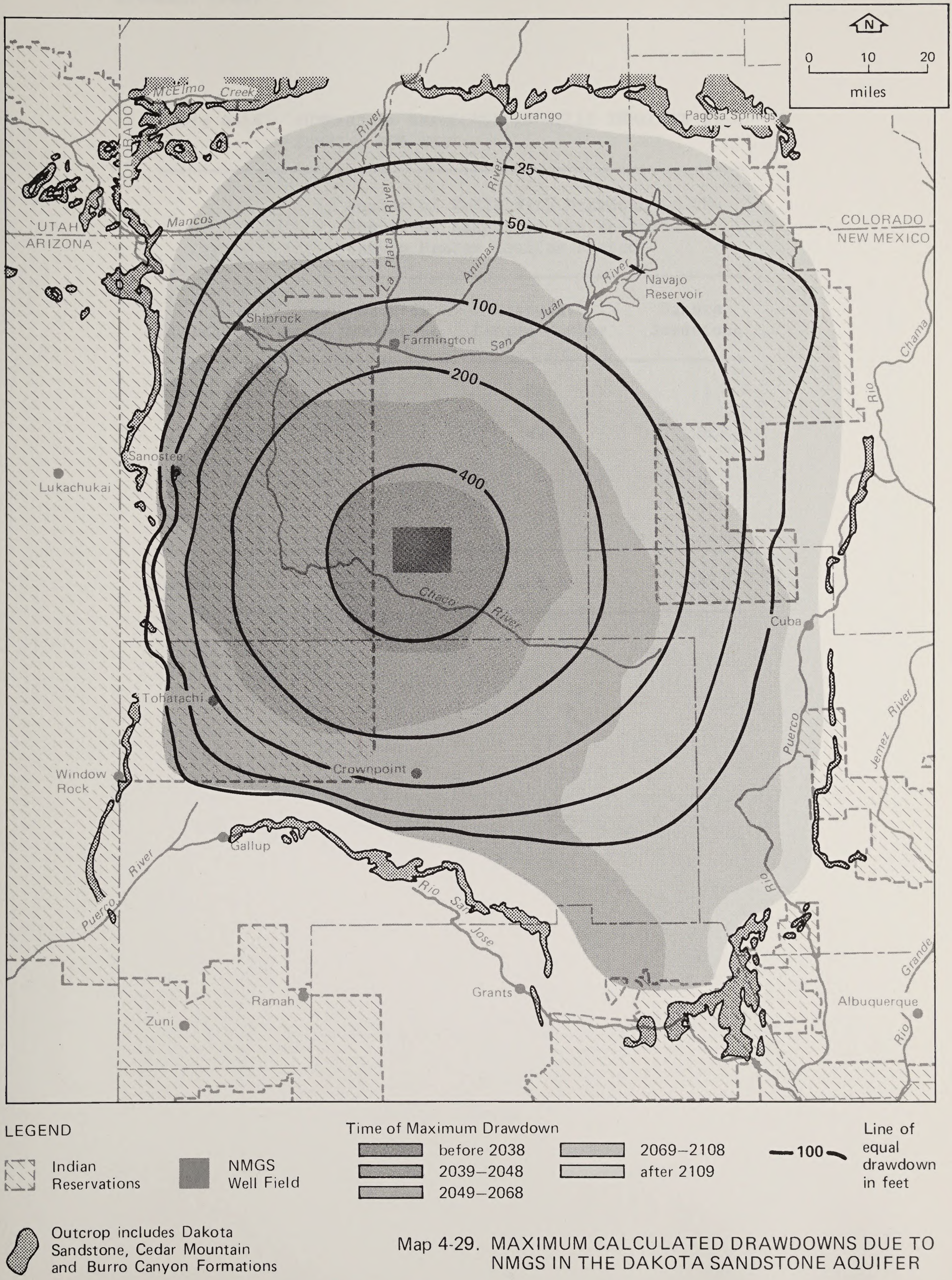
Outcrop includes Morrison, Wanakah, Summerville and Entrada Formations

Time of Maximum Drawdown

- before 2033
- 2034–2038
- 2039–2048
- 2049–2068
- 2069–2108
- after 2109

—100— Line of equal drawdown in feet

Map 4-28. MAXIMUM CALCULATED DRAWDOWNS DUE TO NMGS IN THE WESTWATER CANYON MEMBER AQUIFER



Map 4-29. MAXIMUM CALCULATED DRAWDOWNS DUE TO NMGS IN THE DAKOTA SANDSTONE AQUIFER

Table 4-14. SUMMARY OF DRAWDOWNS IN WELLS IMPACTED BY PUMPING FOR NMGS

	Number of Wells With Drawdown in the Specified Ranges in the Westwater Canyon Member Aquifer System		
Drawdown (feet)	Entrada Sandstone	Westwater Canyon Member	Dakota Sandstone
25 - 99	13	89	71
100 - 399		49	28
400 - 799		8	1
800 - 1200		3	
Totals	13	149	100

Table 4-15. SUMMARY OF WATER USE FROM WELLS WITH DRAWDOWN OF GREATER THAN 25 FEET IN WESTWATER CANYON MEMBER AQUIFER SYSTEM

	Aquifer		
Use	Entrada Sandstone	Westwater Canyon Member	Dakota Sandstone
Stock or Domestic		4	3
Municipal		7	3
Industrial	1	10	2
Mine Dewatering		2	
Observation Well or Test Well	3	11	8
Abandoned		5	
Unknown	9	110	84
Total	13	149	100

Sources: Guyton & Associates (1978), USGS (1981a), New Mexico State Engineer Office (1981).

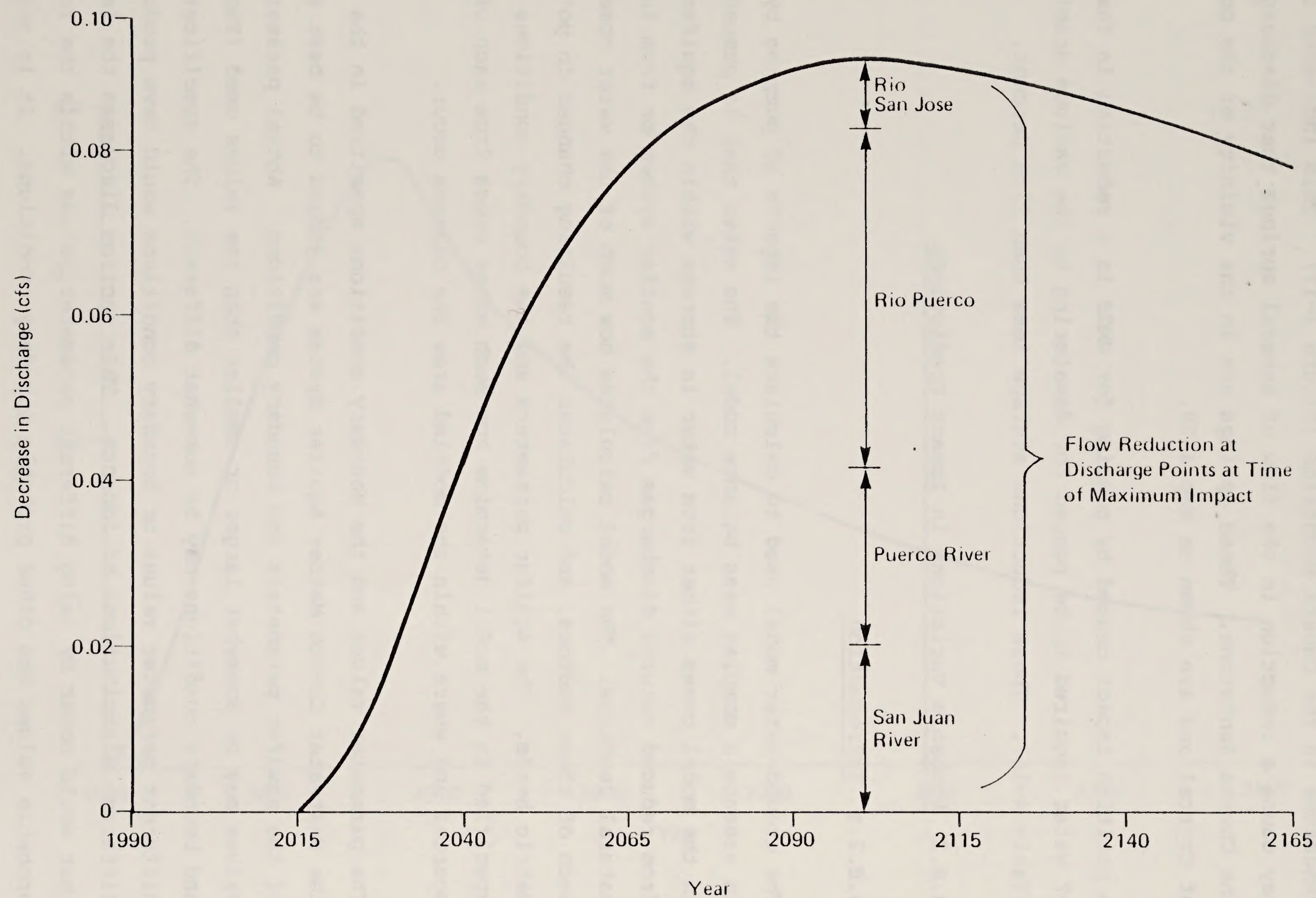


Figure 4-16. DECREASES IN NATURAL DISCHARGE FROM THE WESTWATER CANYON AQUIFER DUE TO PUMPING FOR NMGS

Sandstone in the Chuska Mountains (Figure 4-17). This increased inflow may cause a reduction in the flow of several springs that discharge from the Chuska Sandstone. These springs are in the vicinity of the community of Crystal and are shown on Map 4-20.

A positive impact caused by pumping for NMGS is a reduction in the amount of water required to be pumped for dewatering by the various uranium mines (Table 4-16). These reductions average less than five percent.

4.E.2 Probable Variations in Impact Predictions

4.E.2.a Introduction

The ground-water model used to calculate the impacts of pumping by NMGS is in essence a complex mass balance model. The water that is pumped by NMGS in the model comes either from water in storage within the aquifer system, from reduced natural discharges from the aquifer system or from increased natural recharge. The model calculates how much of the water comes from each of these sources, and calculates the resulting changes in potentiometric heads. The aquifer parameters and the boundary conditions that are specified in the model determine how much water comes from each of the sources and where within the modeled area the changes occur.

The parameter values and the boundary conditions specified in the model of the Westwater Canyon Member Aquifer System are judged to be best estimates of the aquifer parameters and boundary conditions. Actual parameter values may be somewhat larger or smaller than the values used (Table 4-6), and boundary conditions may be somewhat different. The specification of different parameter values or boundary conditions would have produced different distributions of impacts. This section discusses the impacts that would occur by using different parameter values within the range of probable values and other probable boundary conditions. It is necessary to stress, though, that regardless of what parameter values or boundary conditions have been specified, the total quanity of water that is derived from the aquifer system is the same, and this water either comes from

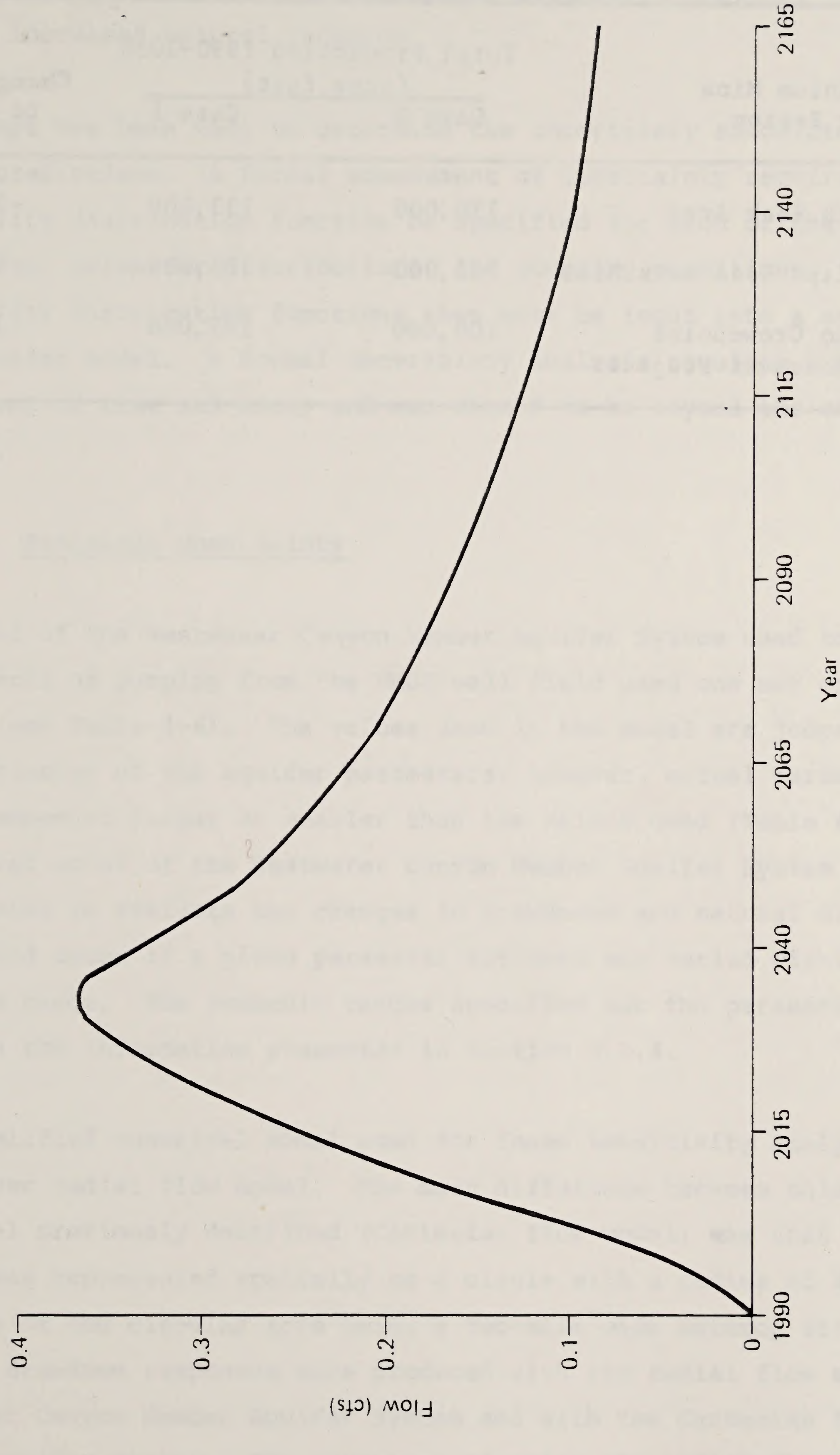


Figure 4-17. INCREASED FLOW FROM THE CHUSKA SANDSTONE TO THE WESTWATER CANYON MEMBER INDUCED BY PUMPING FOR NMGS

Table 4-16. TOTAL URANIUM MINE DEWATERING PRODUCTION - 1990 TO 2030, CASES 1 AND 2

Uranium Mine or Region	Total Production 1990-2030 (acre feet)		Change due to NMGS
	Case 2	Case 1	
Church Rock Area	130,000	133,000	-2%
Phillips Nose Rock Mine	365,000	383,000	-5%
Conoco Crownpoint and Monument Projects	100,000	102,000	-2%

storage within the aquifer system, from decreases in natural discharges, or from increased natural recharge.

No attempt has been made to determine the uncertainty associated with the impact predictions. A formal assessment of uncertainty requires that a probability distribution function be specified for each of the model parameters, parameter distributions, and boundary conditions. These probability distribution functions then must be input into a stochastic ground-water model. A formal uncertainty analysis requires a large investment of time and money and was deemed to be beyond the scope of this project.

4.E.2.b <u>Parameter Uncertainty</u>

The model of the Westwater Canyon Member Aquifer System used to calculate the impacts of pumping from the NMGS well field used one set of parameter values (see Table 4-6). The values used in the model are judged to be best estimates of the aquifer parameters; however, actual parameter values may be somewhat larger or smaller than the values used (Table 4-6). A simplified model of the Westwater Canyon Member Aquifer System was constructed to evaluate the changes in drawdowns and natural discharges that would occur if a given parameter estimate was varied within a probable range. The probable ranges specified for the parameters were based on the information presented in Section 4.D.4.

The simplified numerical model used for these sensitivity analyses was a five-layer radial flow model. The main difference between this model and the model previously described (Cartesian flow model) was that the aquifer system was represented spatially as a circle with a radius of 42 miles, the edge of the circular area being a two-mile wide outcrop strip. Very similar drawdown responses were produced with the radial flow model of the Westwater Canyon Member Aquifer System and with the Cartesian flow model of the aquifer system. The advantage of using the radial flow model was that computing costs were cut by a factor of 30, and therefore the parameter sensitivities could be investigated inexpensively.

In the sensitivity analyses each of the aquifer parameters in the model (transmissivity, storage coefficient, vertical hydraulic conductivity) was varied one at a time within reasonable bounds, and the drawdown and natural discharge responses were recorded. The parameter distributions used in the eight sensitivity runs are listed in Table 4-17. The results of the sensitivity runs are listed in Table 4-18. All results are listed as a percentage change from drawdowns and natural discharges calculated with the base parameter distributions (Table 4-17). The percentage change from the base case, which occurs in drawdowns and natural discharges as a result of varying parameter estimates, was calculated after 40 years of pumping for NMGS. For example, increasing the vertical hydraulic conductivity by a factor of 3.3 causes drawdowns in the Entrada Sandstone to increase by a factor of 150 to 214 percent (Table 4-18).

The sensitivity analyses showed that drawdowns in the Westwater Canyon Member aquifer are relatively insensitive to changes in specific storage within the ranges specified, but that drawdowns in the other aquifer units are very sensitive to changes in specific storage. The analyses also showed that drawdowns in the Dakota Sandstone and Entrada Sandstone aquifers are very sensitive to changes in vertical hydraulic conductivity in the confining beds, but that drawdowns in much of the Westwater Canyon Member aquifer are not very sensitive to these changes. Uncertainty in the transmissivity estimates for the Westwater Canyon Member aquifer used in the radial flow model are shown to introduce only a small degree of uncertainty in the calculated results. Because of the simplicity inherent in the radial flow model, Table 4-18 should be used only to qualitatively evaluate the changes that would occur in drawdowns or natural discharges as a result of specifying different parameter estimates.

4.E.2.c <u>Boundary Condition Uncertainty</u>

The boundary conditions used in the model are relatively simple:

- no flow boundaries around the periphery of each of the aquifer units in the study area;

Table 4-17. PARAMETER ESTIMATES USED IN THE RADIAL FLOW MODEL OF THE WESTWATER CANYON MEMBER AQUIFER SYSTEM FOR THE SENSITIVITY ANALYSES

		Transmissivity (ft^2/day)			
Run No.	Specific Storage in All Layers (ft^{-1})	Entrada Sandstone	Westwater Canyon Member	Dakota Sandstone	Vertical Hydraulic Conductivity in Confining Bed (ft/day)
1	4×10^{-7}	86	190	50	2.8×10^{-6}
2	2.4×10^{-7}	86	190	50	2.8×10^{-6}
3	8×10^{-7}	86	190	50	2.8×10^{-6}
4	4×10^{-7}	86	190	50	9.2×10^{-6}
5	4×10^{-7}	86	190	50	9.3×10^{-7}
6	4×10^{-7}	86	285	50	2.8×10^{-6}
7	4×10^{-7}	86	142	50	2.8×10^{-6}
8	4×10^{-7}	43	190	50	2.8×10^{-6}

Table 4-18. CHANGES IN DRAWDOWNS AND LATERAL DISCHARGES THAT OCCUR IF PARAMETER ESTIMATES ARE CHANGED FROM THE ESTIMATES USED IN THE WESTWATER CANYON MEMBER AQUIFER SYSTEM MODEL AFTER 40 YEARS OF PUMPING FOR NMGS[a]

Location in Miles from Center of Well Field	Sensitivity Run Number[b]							
	1	2	3	4	5	6	7	8
	Base Run[c]	S*0.6	S*2	K_v*3.3	K_v/3.0	T_3*1.5	T_3*0.75	T_1*.5
Layer 3 (Westwater)								
0	0	+4%	-6%	-11%	+10%	-28%	+25%	0
4	0	+7%	-11%	-17%	+16%	-25%	+21%	0
12	0	+14%	-4%	-9%	+49%	-5%	+34%	+18%
26	0	+22%	-16%	-15%	+68%	+6%	+26%	+21%
Layer 1 (Entrada)								
0	0	+66%	-59%	+214%	-79%	-21%	+16%	+41%
4	0	+68%	-62%	+203%	-78%	-21%	+14%	+36%
12	0	+61%	-65%	+180%	-77%	-18%	+13%	+30%
26	0	+61%	-71%	+150%	-76%	-15%	+ 7%	+15%
Layer 5 (Dakota)								
0	0	+26%	-38%	+63%	-57%	-23%	+18%	0
4	0	+28%	-41%	+53%	-56%	-22%	+17%	0
12	0	+37%	-41%	+51%	-47%	- 9%	+28%	+13%
26	0	+51%	-50%	+69%	-38%	+ 4%	+29%	+20%
Flow to Constant Head Nodes								
Layer 1	0	+93%	-73%	+132%	-25%	-14%	+5%	-46%
Layer 3	0	+30%	-37%	-33%	+45%	+37%	-25%	0
Layer 5	0	+55%			-46%	-12%	+3%	-1%

[a]All impacts are normalized to the base case. The table is read as follows: In layer 3 at 12 miles from the well field, increasing the transmissivity of the Westwater Canyon Member by a factor of 1.5 (run #6) decreased drawdowns 5 percent from the base case drawdowns.

[b]Symbols defined as follows:

s = specific storage

K_v = vertical hydraulic conductivity

T_N = transmissivity in layer N

[c]Parameter estimates used in sensitivity runs shown in Table 4-17.

- no flow boundaries above the Dakota Sandstone and below the Entrada Sandstone;

- constant head boundary where the Chuska Sandstone overlies the Westwater Canyon Member;

- constant head boundaries where the San Juan River, the Rio Puerco, the Puerco River, the Rio San Jose, and the Rio Salado cross the aquifer units.

The significance of each of these boundary conditions, other possible boundary conditions, and the effect that different boundary conditions would have on predicted impacts is discussed below.

<u>No flow boundaries around the periphery</u>

The no-flow boundaries specified at the periphery of the aquifer units within the modeled area probably represent actual conditions closely. The aquifer units outcrop around much of the perimeter of the study area, and physically, flow cannot occur beyond the outcrop area. Three areas where the aquifer units do not outcrop, and where flow may occur out of the study area, are: The Gallup Sag area, the Arculeta Arch area, and the Rio Puerco Gap area. Guyton & Associates (1978) studied these areas and concluded that:

- in the Gallup Sag area ground-water flow likely does occur beyond the Puerco River, as water level data indicate that the river is a regional discharge area;

- in the Archuleta Arch area ground water is unlikely to move into any adjoining areas because the aquifer units are apparently truncated against relatively impermeable units; and

- in the Rio Puerco Gap area flow may occur to the Rio Grande basin.

Lyford, et.al., (1980) also concluded that flow may occur to the Rio Grande basin, and they specified constant heads in their model to simulate this flow. In the present study, constant heads were considered to be an inappropriate technique to use to simulate flow to the Rio Grande Basin. Constant heads were considered to be inappropriate because the specification of a constant head along this boundary would imply that no changes in the quantity of water in storage in the aquifer units occurs along the boundary. This is simply not the case, as flow from the Westwater Canyon Member to the Rio Grande Basin, if any does occur, is limited by low transmissivity along the Rio Puerco Fault Zone and, therefore, there is no source of water to maintain constant storage. Presently, a potentiometric head change of 400 to 500 feet occurs across the Rio Puerco fault zone (Guyton and Associates, 1978). The change in flow across the fault zone that would occur from NMGS pumping can be roughly calculated by evaluating the change in total head drop that occurs across the fault zone. The percent change in total head drop by pumping for NMGS would be less than 1 percent.

No-flow boundaries above and below the Westwater Canyon Member Aquifer System

No-flow boundaries were placed above the Dakota Sandstone and below the Entrada Sandstone because drawdowns in aquifers above the Dakota Sandstone and below the Entrada Sandstone were calculated to be less than twenty-five feet (see Section 4.D.2). The units above the Dakota Sandstone and below the Entrada Sandstone are not impermeable; therefore, these boundaries are not really no-flow boundaries. The specification of no-flow boundaries causes an overprediction of impacts in the modeled area. The magnitude of overprediction was qualitatively calculated to be small, because the changes in storage that would occur in units above the Dakota Sandstone and below the Entrada Sandstone if these units were modeled, would be small.

Constant-head boundaries at the Chuska Sandstone

Constant heads were placed near the Chuska Mountains where flow from the Chuska Sandstone could be expected to increase with head declines in the Westwater Canyon Member aquifer. Constant heads were used in this location because 1) the transmissivity of the Chuska Sandstone, which overlies the Westwater Canyon Member, probably is greater than that in the Westwater Canyon Member and 2) the Chuska Sandstone is saturated, and water flows from many springs in the sandstone. Therefore, if the aquifers are not separated by a low permeability layer, any change in head in the Westwater Canyon Member aquifer would cause flow to occur from the Chuska Sandstone to the Westwater Canyon Member. This would cause a relatively constant head to be maintained in the Westwater Canyon Member, and spring flows from the Chuska Sandstone could be reduced by as much as an equal amount as a result.

The use of constant heads in this region implictly assumes that the Chuska Sandstone and Westwater Canyon Member are not separated by a layer of relatively low permeability. If a layer of relatively low permeability separates the two aquifers, a constant head would not be maintained in the Westwater Canyon Member when pumping stresses are applied to the system. Therefore, if a layer of relatively low permeability separates the aquifers, the model used in this study overpredicts the increased inflow (and probable decrease in spring flow) from the Chuska Sandstone. A field hydrogeologic investigation of this area in the Chuska Mountains would be required to determine if a layer of relatively low permeability is present and, consequently, to evaluate the hydrologic factors causing the springs.

Constant head boundaries at discharge points

Constant head boundaries were specified where outcrop areas of the aquifer layers are crossed by the San Juan River, the Rio Puerco, the Puerco River, the Rio San Jose, and the Rio Salado. These boundary specifications imply that no water is removed from storage in the aquifer system at these locations. Constant storage can be maintained at these locations by decrease in natural discharge, or by infiltration from the rivers. Along the San Juan River, Rio San Jose, and the Rio Salado, ground-water discharge does occur from the aquifer system and constant storage would be maintained by decreases in the natural discharge. Along the Puerco River, the Rio Puerco and the Rio Salado, natural discharges from the aquifer system may or may not occur. Limited data suggest that potentiometric heads in the aquifer units are higher than land surface at these locations (see Map 4-10). Therefore, the potential for discharge does exist. The streams, though, are ephemeral (or were ephemeral before mine dewatering discharges began) suggesting that the natural ground-water discharges are not great. In these cases constant heads may be maintained by infiltration from the streams.

If constant heads were not placed along these reaches of the streams, only slightly larger drawdowns would have been calculated in the aquifer system because the constant heads are located far from the NMGS well field. Therefore, the specification of constant heads at these locations likely results in an overprediction of reductions in natural discharges.

Recharge

Recharge was not represented in this model as a boundary condition because it was assumed that the lowering of water levels in the outcrop areas would not increase the amount of recharge that occurs to the aquifer system. Recharge is only represented as a boundary condition when there is rejected recharge at the outcrop area (e.g., Chuska Mountains). Not representing recharge, therefore, does not cause drawdowns to be overpredicted.

4.E.3 Subsidence Potential

In ground-water basins that have undergone large drawdowns in the potentiometric surface, subsidence of the land surface often has accompanied such ground-water development. Land subsidence generally takes place as a broad, gentle lowering of the elevation of the land surface. Ground cracks have occurred in some areas undergoing land subsidence (e.g., Las Vegas Valley, Nevada). Differential movement of the land surface, such as is caused by tectonic fault movement and settlement of building foundations, does not result from land subsidence due to ground-water withdrawal. The conceivable impacts of land subsidence are damage to wells and changes in the gradients of streams and structures for drainage, flood protection and water conveyance.

There are three possible methods to evaluate the potential for land subsidence due to ground-water withdrawal: (1) extrapolation of the existing subsidence/head-decline ratio (Lofgren, 1971), (2) the analytical approach, and (3) the comparative-empirical method (Allen, 1976). The first method requires that rates of both subsidence and head-decline have been documented in the study area. The second method, the analytical approach, uses compressibility test data and other information from the study area to quantitatively predict future subsidence rates. In the comparative-empirical method, geologic data from the study area are compared to analogous subsiding areas. The geologic similarity is used as a basis to qualitatively evaluate the potential for subsidence in the study area.

Subsidence/Head-Decline Method. The most direct method of evaluating the strain response of a ground-water reservoir to pumping stresses is to assess how much subsidence has occurred in the study area due to historical ground-water pumpage (Lofgren, 1971). The resultant subsidence/head-decline ratio can be used to estimate future subsidence due to a projected lowering of the potentiometric surface.

The consolidation history of the aquifer system must be defined before future subsidence can be accurately estimated. Numerous laboratory core tests or data from in-situ instrumentation of the aquifer system are required to calculate the consolidation history of the sediments. These types of information are not available in the San Juan Structural Basin.

There are no available published reports of existing subsidence rates due to fluid withdrawal in the San Juan Structural Basin. Therefore, available releveling data were examined to ascertain if any of the study area has historically experienced subsidence. First order and second order leveling data were obtained from the National Geodetic Survey (NGS). The NGS releveling lines in the San Juan Structural Basin are only one year apart (Newcombs Store to Shiprock New Mexico, 1927, second order; Farmington to Shiprock, New Mexico, 1928, first order) and, therefore, are not useful in assessing the rates of land subsidence. Also, the San Juan Structural Basin was not being stressed by groundwater pumpage at that time.

Analytical Method. The analytical method of evaluating subsidence potential utilizes unit compressibilities, thickness of a particular aquifer system, and the expected change in potentiometric surface (change in effective stress) to compute the ultimate amount of subsidence to be expected due to groundwater withdrawal from that aquifer system (Miller, 1961; Allen, 1976).

Compressibility values of an aquifer system can be derived from a large number of laboratory core tests or from in-situ instrumentation of the aquifer system for the San Juan Structural Basin. Published information of either type is not available. Therefore, the analytical method could not be used to compute future potential for land subsidence.

Comparative-Empirical Method. Subsidence potential was qualitatively evaluated by a theoretical consideration of geologic factors known to be involved in subsidence processes and by analogy to other hydrogeologically similar areas undergoing subsidence.

There are numerous geologic parameters that are involved in subsidence processes and can therefore be used as criteria to qualitatively estimate the potential for subsidence. The geologic parameters relevant to subsidence potential that are known in the San Juan Structural Basin are: aquifer type; current trend of the potentiometric surface; induced head decline in the well field due to pumping for NMGS; and degree of consolidation, age and depositional environment of the aquifer system. These geologic parameters have been used as criteria for evaluating the subsidence potential in the study area (Table 4-19). An additional valuable criterion is the analogy of the study area to another hydrogeologically similar area undergoing large-scale fluid withdrawal and associated subsidence. The local and regional variations of some parameters are not known in the study area in sufficient detail to warrant their inclusion in an evaluation of subsidence potential. The omitted parameters include: petrology, bedding (Bull, 1975), compressibility, particle size and shape, and geochemistry of pore water (Poland and Davis, 1969).

Unconfined, semiconfined, and confined aquifer systems have a different range of compressibility and therefore a different potential for land subsidence. Unconfined sediments generally have lower compressibilities and undergo less subsidence than confined sediments. The lower compressibility is largely due to the lesser amount of extensive fine-grained aquitards in unconfined aquifer systems. The greater compressibility of confined aquifer systems is demonstrated by the fact that the compaction of aquitards may release up to 50 times as much water as the elastic expansion of stored water and elastic compression of the aquifer (Poland, 1961). The thickness and areal extent of the compactable beds are directly related to the subsidence potential of a subsurface reservoir.

Knowledge of the depositional environment of the aquifer system can provide insight into the thickness and areal extent of the compactable beds to be expected. Subsurface reservoirs in the San Juan Structural Basin are comprised of sediments deposited in several depositional environments: alluvial; lacustrine; aeolian; and marine. Laterally extensive, compactable fine-grained units predominantly are characteristic of lacustrine depositional systems and not alluvial-fill systems (Reineck and Singh, 1975). Therefore, subsurface reservoirs containing fine-grained lacustrine units in the zone to be depressurized or dewatered will have a greater subsidence potential than subsurface reservoirs containing only alluvial deposits (Bull, 1975). Bull (1975) also differentiated the subsidence potential for various types of alluvial deposits according to mode and source of deposition. Source and mode of deposition of the alluvial

Table 4-19. VALUES OF SELECTED CRITERIA USED IN EVALUATION OF SUBSIDENCE POTENTIAL

	Subsidence Potential Class [a]			Subsidence Potential San Juan Basin
	Low	Moderate	High	
Aquifer Type	Unconfined (0)	Semi-confined (1)	Confined (2)	Confined - 2
Environment of Deposition	Marine and Eolian (0)	Alluvial (2)	Alluvial and Lacustrine (5)	Alluvial - 2
Degree of Sediment Consolidation (geologic, not soil mechanics usage)	Consolidated (0)		Unconsolidated (5)	Consolidated - 0
Age (as an approximate index of preconsolidation)	Mesozoic & Older (0)	Cenozoic (1)		Mesozoic - 0
Existing Potentiometric Surface Trend	Stationary (0)	Declining (1)		Stationary - 0
Postulated Maximum Well Field Head Decline	0'-200' (0)	200'-500' (3)	500' (5)	500' - 5
Analogy to Other Hydrogeologically Similar Areas Experiencing Large Scale Fluid Withdrawal	Analogous Areas Have Not Subsided (0)		Analogous Areas Have Subsided (10)	None Reported - 0
Composite Ranking	(0 - 3)	(3 - 15)	(15 - 27)	Moderate - 9

[a]Number in parentheses indicates numerical value entered in column on right for evaluation of subsidence potential in the San Juan Structural Basin.

units in the study areas are not known in sufficient detail to warrant inclusion in this analysis.

Subsidence potential is partially also a function of the degree of sediment consolidation in the aquifer system. The increase in effective stress associated with a decrease in pore pressure will produce less strain in an aquifer system that has had a high preconsolidation load. Comprehensive field or laboratory measurements of aquifer/aquitard compressibility in the study area are not presently available. Therefore, consolidation is incorporated into this subsidence evaluation in a strictly geologic sense and refers to a qualitative estimate of the degree of sediment induration (e.g., consolidated sandstone, unconsolidated alluvium).

The age of the producing aquifer and adjoining aquitards appears to affect the susceptibility for subsidence (Allen, 1976). One can conceptualize that the degree of cementation and preconsolidation will often increase in geologic time. The choice of a time boundary as a criterion is somewhat arbitrary. Allen (1976) chooses the Pliocene-Miocene boundary. Because the depositional hiatus representing the Pliocene-Miocene boundary is relatively brief (Van Couvering, 1978), the more diastrophic and more conservative Cenozoic-Mesozoic boundary is arbitrarily used in this evaluation of subsidence potential.

Changes in the potentiometric surface can induce subsidence by changing pore pressure and effective stress as indicated in the following relationship:

$$p' = p - u_w$$

where p is total geostatic stress, u_w is pore pressure, and p' is effective stress (intergranular load). As pore pressure (u_w) is decreased during pumping, effective stress increases and compaction results. Additionally, seepage stresses are induced during the period of disequilibrium as compaction water drains from an aquitard into a depressurized aquifer. If depressurization occurs only beneath a confining layer, seepage stress will be directed downwards and would increase the potential for subsidence.

Two components of rate of decline of the potentiometric surface are considered for the San Juan Structural Basin: (1) the existing rate of decline due to the present water balance, and (2) the decline due to the pumping of a well field for NMGS.

The most plausible empirical evaluation of subsidence potential is by analogy to other subsiding areas. If other areas hydrogeologically similar to the study area have experienced subsidence due to large scale ground-water withdrawal, it is a reasonable and accepted assumption to expect subsidence to be associated with ground-water production in the study area. No information was found about areas hydrogeologically similar to the San Juan Structural Basin that are experiencing fluid withdrawal and subsidence.

Impacts. Pumping of ground water from the well field for NMGS is judged to cause measurable land subsidence, in the San Juan Structural Basin. One would expect subsidence due to production from the Westwater Canyon Member of the Morrison Formation (Jurassic-aged consolidated aquifer), at depths of greater than 4000 feet, to be minimal because such a unit would have experienced large preconsolidation stresses. However, using the comparative-empirical method discussed above, the San Juan Structural Basin is estimated to have a moderate potential for land subsidence due to pumpage of ground water for NMGS (Table 4-19). Although there would be substantial projected head declines in the well field used for NMGS (see Section 4.E.1.c), the San Juan Structural Basin is assigned only a moderate potential for subsidence because of the lack of published reports of an analogous area undergoing subsidence. As a worst-case analysis, it is assumed that measurable land subsidence due to pumpage for NMGS would take place.

Land subsidence due to ground-water withdrawal probably would not be significant (greater than 1 foot). Measurable land subsidence due to ground-water production for NMGS is assumed to take place and probably would be greatest in the immediate vicinity of the well field. A more quantitative statement about the magnitude or geographical extent of possible subsidence cannot be made until additional data on rock properties of the aquifer system have been collected.

5.0

NEW MEXICO GENERATING STATION

PLANT SITE

5.A INTRODUCTION

5.A.1 Hydrologic Issues

The principal hydrologic issues that will be addressed are:

1) flooding potential;
2) changes in runoff conditions; and
3) impact on existing water users.

Analysis of flooding potential consists of the comparison of the locations of project facilities with the floodplains caused by 100- and 500-year recurrence interval storms (100- and 500-year floodplains) of De-na-zin Wash.

Under the Floodplain Management Guidelines issued by the U.S. Water Resources Council (1978), flooding potential is generally evaluated with respect to a "base" floodplain, the 100-year floodplain. However, the 500 year floodplain must be used in the evaluation of "critical actions", which are defined as "those project activities for which even a slight chance of flooding would be too great." One of the key criteria in the evaluation of whether or not a project activity is a "critical action" is,

> "If flooded, would the proposed action create an added dimension to the disaster as could be the case for liquified natural gas terminals and facilities producing and storing highly volatile, toxic, or water-reactive materials? (U.S. Water Resources Council, 1978) (emphasis added)."

The effluent holding ponds on the plant site are considered to be a critical action because the flooding of these ponds could release toxic and/or water-reactive constituents into De-na-zin Wash. The evaluation of the flooding potential at the plant site must therefore concentrate on the extent of the 500-year floodplain for De-na-zin Wash.

The second major hydrologic issue is the impact on the characteristics of flow in De-na-zin Wash resulting from the construction and/or operation of any project facilities. De-na-zin Wash is an ephemeral stream, and flow occurs primarily as short-duration flood events with high peak discharge. The primary effects on flow in De-na-zin Wash, therefore, may be changes in peak flood discharge and/or flood elevation.

The third major hydrologic issue is the possible impact on recharge to shallow aquifers in the vicinity of the plant site. Any decrease in recharge may affect the water supply available to ground-water users.

5.A.2 Methods of Investigation

The first step in the delineation of the 500-year floodplain was the estimation of the corresponding peak flood discharge. The U.S. Water Resources Council (1977) recommends that the log Pearson Type III method be used to calculate peak flood discharges for various recurrence intervals only when 10 or more years of streamflow data are available. There are less than ten years of streamflow data available for De-na-zin Wash. As a result a log Pearson Type III streamflow analysis could not be employed to estimate various peak flood discharges associated with various recurrence intervals. Regional regression techniques, therefore, were employed to estimate flood magnitude also as recommended by the Water Resources Council (1977).

In regional regression techniques a mathematical relationship is established between flood magnitude and basin characteristics (such as drainage area and main channel slope). There have been a number of studies made to derive regional regression equations for New Mexico, including those by Scott (1971 and 1974), Scott and Kunkler (1976), and Hejl (1980). The most recent and comprehensive assessment was completed by Thomas (1981), and was the method used in this analysis. The report by Thomas (1981) was the result of a ten-year study of flood events on small streams in New Mexico. The U.S. Army Corps of Engineers HEC-2 computer program (U.S. Army Corps of Engineers, 1981) was used to compute water surface profiles for that reach of De-na-zin Wash where project facilities (in particular the effluent ponds) might be located in the 500-year floodplain. From these water surface profiles the approximate extent of the 500-year floodplain was delineated.

For the investigation of possible changes in peak discharge and/or flood elevations, the location and extent of the various project facilities were examined. Any changes to the native ground cover on the plant site, and any surface-water storage reservoirs, were also included in this analysis. Hydrologic judgment was then employed to estimate the general size and nature of possible impacts on the environment. If this assessment revealed the possibility of significant impacts, then the need for additional, more detailed studies was investigated.

For the investigation of possible impacts on recharge to shallow aquifers, all available descriptive data on the aquifers were first collected. The nature and extent of the geologic formations in this area were compiled from a 1:500,000 scale geologic map of the state of New Mexico (Dane and Bachman, 1965) and from a report on a ground-water monitoring system at the NMGS site by Shomaker (1980). This information was then integrated with information on the changes in streamflow characteristics in De-na-zin Wash. If this assessment revealed the possibility of significant impacts, then the need for additional, more detailed studies was investigated.

5.A.3 Study Area

The study area for the hydrologic issues of flooding potential and changes in runoff conditions is confined primarily to the drainage area of De-na-zin Wash in the vicinity of the plant site. The potential for flooding of project facilities is confined to the plant site. Changes in runoff conditions would be caused primarily by construction and operation of plant facilities (including any paving over of natural ground cover). If major flooding of the plant site or changes in runoff conditions were to be predicted, then the effects could be manifested in the Chaco River Basin downstream from the mouth of De-na-zin Wash, and the study area would need to be expanded accordingly.

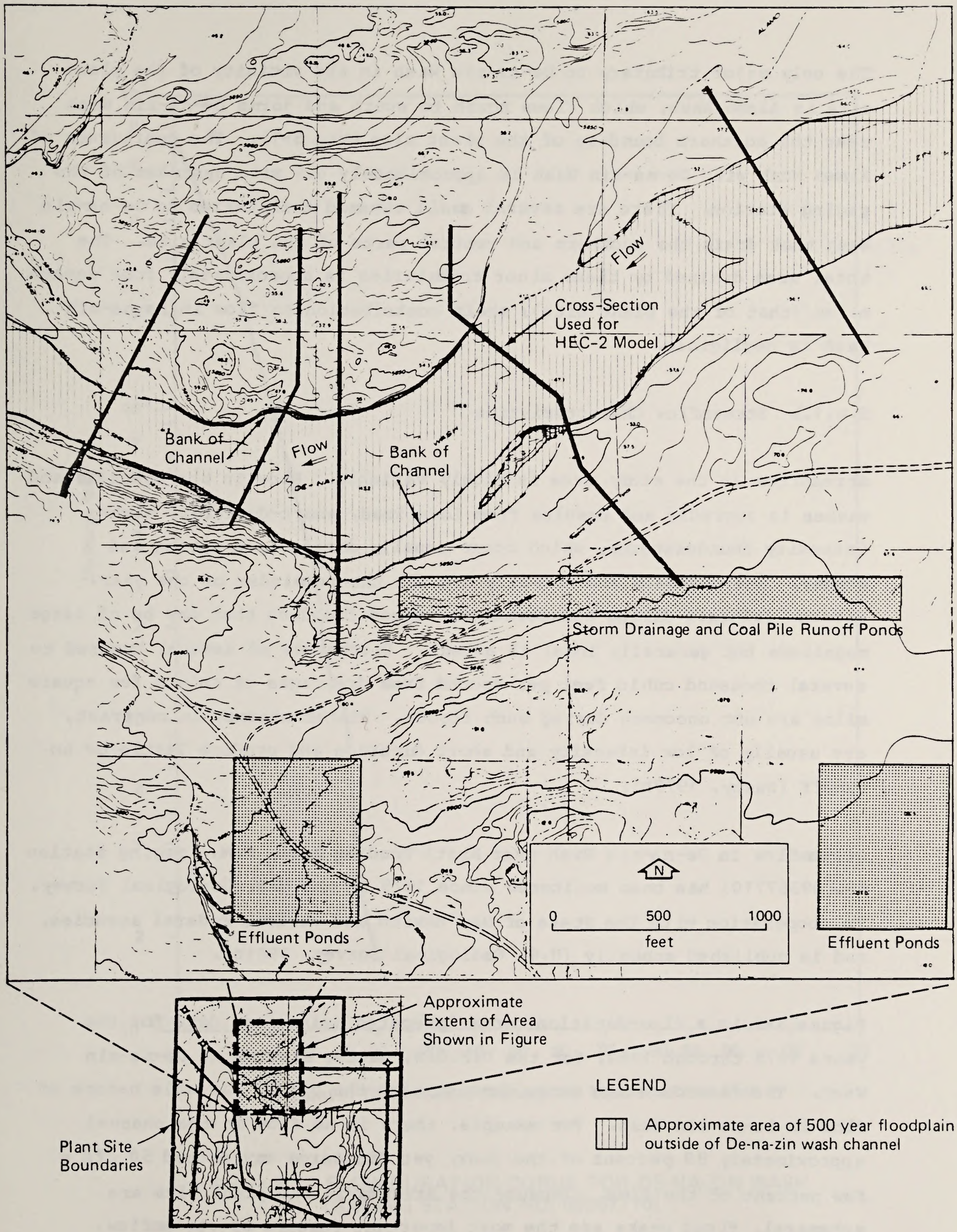
The study area for the alternative storage reservoir includes the Chaco River Basin upstream of De-na-zin Wash. The drainage area of the reservoir is part of the Tsaya Canyon watershed, which is a contributor to the Chaco River upstream of De-na-zin Wash.

5.B HYDROLOGY OF NMGS PLANT SITE AND VICINITY

5.B.1 Surface Water

5.B.1.a Surface-Water Features

The principal stream in the plant site area is De-na-zin Wash, which flows east to west across the northern portion of the plant site. The drainage area for De-na-zin Wash upstream from the U.S. Geological Survey gaging station at the northwest corner of the plant site is approximately 184 square miles (U.S. Geological Survey, 1981b). The width of the channel of De-na-zin Wash in the vicinity of the project structures is approximately 600 feet, at a point upstream of the confluence with Alamo Wash, and then abruptly narrows to approximately 400 feet downstream from the bend (see Map 5-1). The approximate channel slope changes from 0.006 ft/ft upstream of the confluence with Alamo Wash, to 0.002 ft/ft at the bend in the channel to 0.004 ft/ft further downstream. For the most part the banks of the channel are steep and sharply defined, especially on the southern bank. The channel floor is sand with some gravel, and the overbank areas are interbedded sandstone and shale with some scrub vegetation.



Map 5-1. EXTENT OF FLOODPLAIN FOR 500-YEAR RECURRENCE INTERVAL FLOOD

The only major tributary to De-na-zin Wash in the vicinity of the plant site is Alamo Wash, which flows north to south and joins De-na-zin Wash near the northern boundary of the plant site (Map 5-1). The confluence of Alamo Wash with De-na-zin Wash is approximately 0.8 mile upstream of the gaging station. There are several small unnamed tributaries to De-na-zin Wash that drain the southern and central parts of the plant site. The total area drained by these minor tributaries is approximately four square miles (that of the plant site); their contribution to flow in De-na-zin Wash is negligible.

5.B.1.b Streamflow Characteristics

Streamflow in the study area is highly variable. Flow in the channels and washes is sporadic and results from localized, short-duration, high-intensity thunderstorms, which occur usually during late spring and summer. The channels are normally dry for the remainder of the year. Intense rainfall during thunderstorms causes flooding that may be of large magnitude but generally local in extent. Discharges of several hundred to several thousand cubic feet per second from drainages of only a few square miles are not uncommon during such floods. Winter storms, in contrast, are usually of low intensity and short duration and produce little or no runoff (Busby, 1979b).

Streamflow in De-na-zin Wash near Bisti Trading Post, N.M. (gaging station no. 09367710) has been monitored since 1975 by the U.S. Geological Survey, in cooperation with the State of New Mexico and various Federal agencies, and is published annually (U.S. Geological Survey, 1981b).

Figure 5-1 is a flow-duration curve (prepared using flow data for the years 1975 through 1980) for the U.S.G.S. gaging station at De-na-zin Wash. The flow-duration curve demonstrates the highly variable nature of flow in De-na-zin Wash. For example, there is no flow in the channel approximately 80 percent of the year, yet discharge may exceed 50 cfs a few percent of the time. Because the streams in the plant site are ephemeral, flood peaks are the most important feature of streamflow.

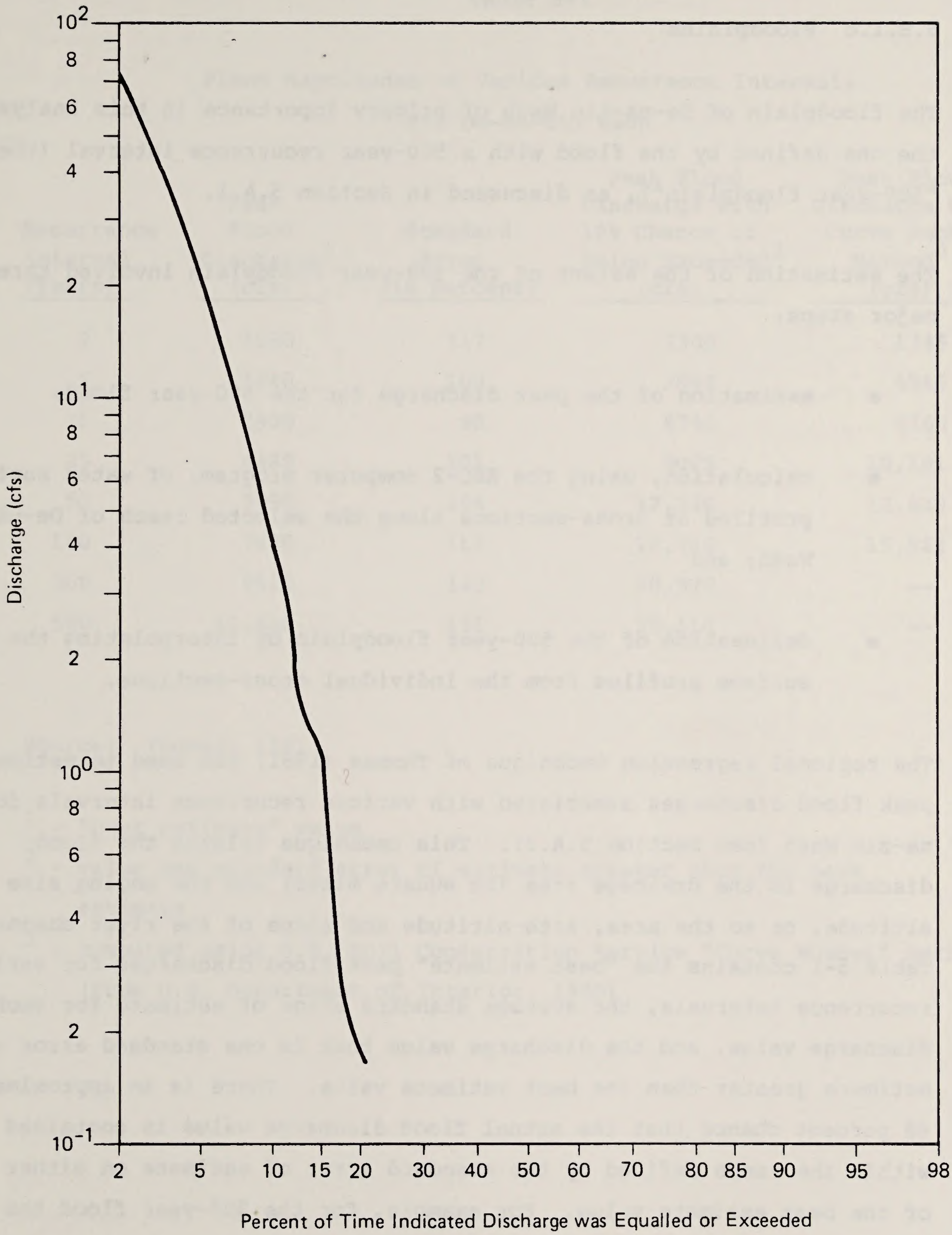


Figure 5-1. FLOW-DURATION CURVE FOR DE-NA-ZIN WASH (GAGING STATION NO. 09367710)

5.B.1.c Floodplains

The floodplain of De-na-zin Wash of primary importance in this analysis is the one defined by the flood with a 500-year recurrence interval (the "500-year floodplain"), as discussed in Section 5.A.1.

The estimation of the extent of the 500-year floodplain involved three major steps:

- estimation of the peak discharge for the 500-year flood;
- calculation, using the HEC-2 computer program, of water surface profiles at cross-sections along the selected reach of De-na-zin Wash; and
- delineation of the 500-year floodplain by interpolating the water surface profiles from the individual cross-sections.

The regional regression technique of Thomas (1981) was used to estimate peak flood discharges associated with various recurrence intervals for De-na-zin Wash (see Section 5.A.2). This technique relates the flood discharge to the drainage area (in square miles) and the gaging site altitude, or to the area, site altitude and slope of the river channel. Table 5-1 contains the "best estimate" peak flood discharges for various recurrence intervals, the average standard error of estimate for each discharge value, and the discharge value that is one standard error of estimate greater than the best estimate value. There is an approximately 68 percent chance that the actual flood discharge value is contained within the range defined by the standard error of estimate on either side of the best estimate value. For example, for the 500-year flood the value one standard error of estimate above the peak discharge of 12,600 cfs is 29,110 cfs =12,600 + (1.31) (12,600) . This larger value was taken as the upper limit of the estimate of the 500-year flood discharge.

Table 5-1

Flood Magnitudes at Various Recurrence Intervals

for De-na-zin Wash

Recurrence Interval (Years)	Peak Flood Discharge[1] (cfs)	Standard Error (in percent)	Peak Flood Discharge with 16% Chance of Being Exceeded[2] (cfs)	Peak Flood Discharge Using Curve Number Method[3] (cfs)
2	1060	117	2300	1745
5	1940	100	3880	4546
10	2900	98	5740	6765
25	4480	101	9005	10,191
50	5990	106	12,340	12,849
100	7670	113	16,340	15,924
200	9510	120	20,920	--
500	12,600	131	29,110	--

Source: Thomas, 1981

1 - "best estimate" value

2 - value one standard error of estimate greater than the best estimate

3 - computed using U.S. Soil Conservation Service "Curve Number" method (from U.S. Department of Interior, 1980)

The use of a peak flood estimate that is one standard error of estimate greater than the "best" estimate, in conjunction with the "best" estimate, is a reasonably conservative approach to establishing a range for the 500-year peak flood discharge. The large standard error of estimate (as a percentage of the "best" estimate) for all recurrence intervals in Table 5-1 implies a consistent degree of uncertainty in the Thomas (1981) estimation method. The range in peak flood discharge established by these two estimates properly represents this degree of uncertainty.

Other methods have been developed to estimate peak floods for ungaged or short-record watersheds, such as De-na-zin Wash. One of the most commonly used is the "Curve Number" (CN) method developed by the Soil Conservation Service (U.S. Department of Agriculture, 1973). The CN method has been applied to De-na-zin Wash very near the plant site (U.S. Department of Interior, 1980) and the results are shown in Table 5-1. The results for the CN method support the range of estimtes developed from the Thomas (1981) study.

The HEC-2 computer program was used to estimate the water surface profiles along the selected reach of De-na-zin Wash in the vicinity of the NMGS plant site. Five cross-sections were constructed covering both the channel and overbank areas of that particular part of De-na-zin Wash (Map 5-1). The HEC-2 computer program used the data on cross-section geometry and on other flow characteristics (including Manning's roughness coefficient) to compute water surface elevations at each cross-section for a given discharge. Both subcritical and supercritical flow regimes were considered.

Two values of the 500-year peak flood discharge were used in HEC-2 water surface computations. The first value was 12,600 cfs (best estimate). The second value of 29,110 cfs was one standard error of estimate above the best estimate. The extent of the floodplain caused by a 12,600 cfs discharge is shown on Map 5-1. The floodplain caused by the 29,110 cfs discharge was almost identical with that shown on Map 5-1. For both discharges the flow is contained almost entirely within the banks of the wide alluvial channel of De-na-zin Wash. At a discharge of 12,600 cfs the flow at the two most upstream cross-sections near the junction with Alamo Wash was at or near critical depth. Further downstream, the flow regime changes to subcritical flow.

Critical depth generally can be defined as the depth of flow that for a given discharge requires the minimum amount of energy. For depths of flow above critical depth (subcritical flow) or below critical depth (supercritical flow) more energy is required for a given discharge. The elevation of the water surface is greater for subcritical flow than at critical depth. For supercritical flow the velocity of the water is sufficiently greater than the velocity at critical depth, which requires more energy at a given discharge than that required for critical depth.

For a discharge of 29,110 cfs the flow is at supercritical depth at the upstream cross-sections, changes to subcritical depth for the next two cross-sections and then returns to supercritical depth at the final downstream cross-section. This change between flow regimes reflects a similar change in the channel geometry of De-na-zin Wash (Map 5-1). At the upstream portion of the reach under study the slope of the channel bed is greater than that at the downstream bend in the river, and the channel slope then increases at the cross-section farthest downstream. The channel is narrower upstream than at the downstream bend, and then narrows again at the cross-section farthest downstream.

The general implication is that as the peak discharge increases from 12,600 to 29,110 cfs the flow appears to increase in velocity more than in depth of flow. This increase in velocity is responsible for the relatively small increase in the floodplain extent as the discharge is increased.

The most important area of uncertainty in the interpretation of these results is lack of available streamflow data. There are less than ten years of available streamflow data for De-na-zin Wash. This lack of available data required the use of the Thomas (1981) regression technique with a correspondingly large standard error of estimate (131 percent for the 500-year flood discharge).

5.B.2 Ground Water

The only conceivable hydrological effect on ground-water users from construction and/or operation of plant facilities (with the exception of the impacts from pumping of the well field) would be from changes in characteristics of flow in De-na-zin Wash. This streamflow may provide recharge to the ground-water flow system in the vicinity of the plant site.

The primary shallow aquifers in the study area are the Pictured Cliffs Sandstone and the Cliff House Sandstone (both Cretaceous) and the local alluvium. The lower part of the Pictured Cliffs Sandstone consists of interbedded thin sandstone and shale, while the upper part consists of more massive sandstone interbedded with thin shale. The sandstone is generally fine- to medium-grained and well sorted. The Cliff House Sandstone consists of thick-bedded gray, buff and orange-brown medium- to fine-grained sandstone and minor amounts of gray shale (Dane and Bachman, 1965). Significant amounts of recharge to these sandstone aquifers probably do not take place through percolation of runoff in the channels of De-na-zin Wash and its tributaries in the vicinity of the plant site.

The local alluvium is derived from the Cretaceous rocks and is of widely varying composition and thickness. It blankets bedrock in areas of low topographic relief, forming clay flats and partly filling arroyo channels. The composition of the alluvium ranges from silty clay to poorly-sorted sand and gravel. In general the finer-grained alluvium is found flooring the clay flats in the minor drainages close to predominantly shale or claystone source areas, and the coarser sediments are found as channel fillings associated with the more important drainages. The thickness of alluvium ranges from zero, in minor channels cut in bedrock, to an unknown maximum, probably in the present channel or a buried channel of De-na-zin Wash. The greatest thickness penetrated in any of the monitoring wells drilled in De-na-zin Wash was 41 feet, and the smallest thickness was 12 feet. The average thickness was about 30 feet (Shomaker, 1980).

Wells completed in the Pictured Cliff Sandstone or the Cliff House Sandstone in the vicinity of the plant site have a depth-to-water (from ground surface) of 75 to 500 feet; wells completed in the alluvium have a depth-to-water of less than 10 feet (USGS, 1981a; Link and Kelly, 1980).

5.C. IMPACTS ASSOCIATED WITH THE PLANT SITE

5.C.1 Flooding Potential and Changes in Flood Elevation

There will be no significant impacts due to flooding of project facilities, and no significant impacts due to changes in flood elevation. A significant impact is defined as an increase in peak flood discharge of the 10-year or greater recurrence interval flood, or an increase in peak flood elevation greater than one foot (see Section 2.D). The ten-year recurrence interval peak flood discharge, as presented in Table 5-1, is 2900 cfs, and 15 percent of this amount is approximately 435 cfs.

No project facilities, including the effluent ponds, are located in the floodplains defined by either the 100-year or 500-year recurrence interval floods. The extent of the 500-year floodplain is shown in Map 5-1, and the procedures used to estimate the extent of the floodplain are described in Sections 5.A.2 and 5.B.1.c.

Changes in flood elevation in De-na-zin Wash could be caused by: (1) replacement of natural ground cover with plant structures and pavement material; (2) construction of surface storage reservoirs; (3) construction of the storm drainage and coal pile runoff ponds; and (4) modifications of the channel of De-na-zin Wash.

The replacement of natural ground cover by impermeable material (buildings and pavement) would tend to increase the amount of runoff produced, decrease its time of concentration, and possibly increase the flood elevation. In the proposed project, however, land will be left in (or restored to) its natural state, except that taken up by structures. Pavement materials will be used for some roads (WCC, 1982). A conservative estimate of the total land area taken up by the project structures (including the coal piles) is approximately 0.5 square mile. Since the land area taken up by project structures is less than one percent of the drainage area of De-na-zin Wash in the vicinity of the plant site, increases in peak discharge and, consequently, flood elevations are judged not to be significant.

Surface storage reservoirs and ponds at the plant site (see Map 4-1) would decrease peak flood discharges and, consequently, flood elevations.

During construction and operation of the plant site no diversions of flow or modifications of the channel banks (such as installation of rip-rap) in De-na-zin Wash are anticipated. Furthermore, there will be no encroachment on the floodplain of De-na-zin Wash by any project facilities (WCC, 1982).

5.C.2. Changes in Peak Discharge

There will be no significant impacts due to changes in peak discharge in De-na-zin Wash. The possible causes for changes in peak discharge and their evaluation are the same as those discussed in Section 5.C.1 concerning changes in flood elevation. The impact on the peak discharge of a 10-year or greater recurrence-interval flood caused by the construction or operation of project facilities is judged not to be significant (less than 15 percent of discharge).

5.C.3. Changes in Ground-Water Recharge and Effects on Ground-Water Users

There are no anticipated changes in recharge to the alluvial aquifers or effects on ground-water users in De-na-zin Wash in the vicinity of the plant site. These changes could conceivably result from impoundment of tributrary runoff to De-na-zin Wash or modifications of the stream channel. As discussed in Section 5.C.1, no diversion of flow or modifications of the channel banks are anticipated.

The drainage area of either the proposed and alternate reservoirs, or the storm drainage and coal pile runoff ponds, is approximately one square mile (Map 4-1) (WCC, 1982). The area of either these plant structures and storage reservoirs is less than one percent of the approximately 184 square-mile drainage area of De-na-zin Wash above the U.S. Geological Survey gaging station. The impact on recharge to the alluvium of De-na-zin Wash caused by the reduction in runoff-producing areas is judged not to be significant. Consequently, ground-water users whose wells tap the alluvium of De-na-zin Wash downstream of the plant site would not be affected.

construction or operation of project facilities is judged not to be significant. [illegible]

[illegible]

3.C.7. [illegible]

There are no [illegible] [illegible] of [illegible] [illegible] or [illegible] [illegible] the plant site. [illegible] [illegible]. [illegible]

The [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] and [illegible] [illegible] [illegible] [illegible] [illegible] to be [illegible]. Consequently, [illegible] [illegible] [illegible] the [illegible] [illegible].

[illegible] of flow [illegible] [illegible] [illegible]

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6.A. INTRODUCTION

6.A.1 Hydrologic Issues

The two hydrologic issues of concern with respect to conceivable impacts due to the construction and operation of water pipelines are:

1) changes in flow and/or flood characteristics of washes or streams at locations of pipeline crossings and intake structures on the San Juan River; and

2) impacts on ground-water or surface-water users due to construction or operation of the pipelines.

6.A.2 Methods of Investigation

The first step in the investigation was an assessment of the construction and operation procedures for the water pipelines, as taken from the project description (WCC, 1982). The nature and extent of the geologic formations crossed by the pipelines were compiled from a 1:500,000 scale geologic map of the state of New Mexico (Dane and Bachman, 1965). An inventory of wells along the pipeline routes was assembled through examination of available well inventories--one of strippable coal areas in New Mexico (Link and Kelly, 1980) and another of the San Juan Basin (USGS, 1981a). Hydrologic judgment was then used to evaluate the nature and extent of any impacts. If this assessment revealed the possibility of significant impacts, then the need for additional, more detailed studies was investigated.

6.A.3 Study Area

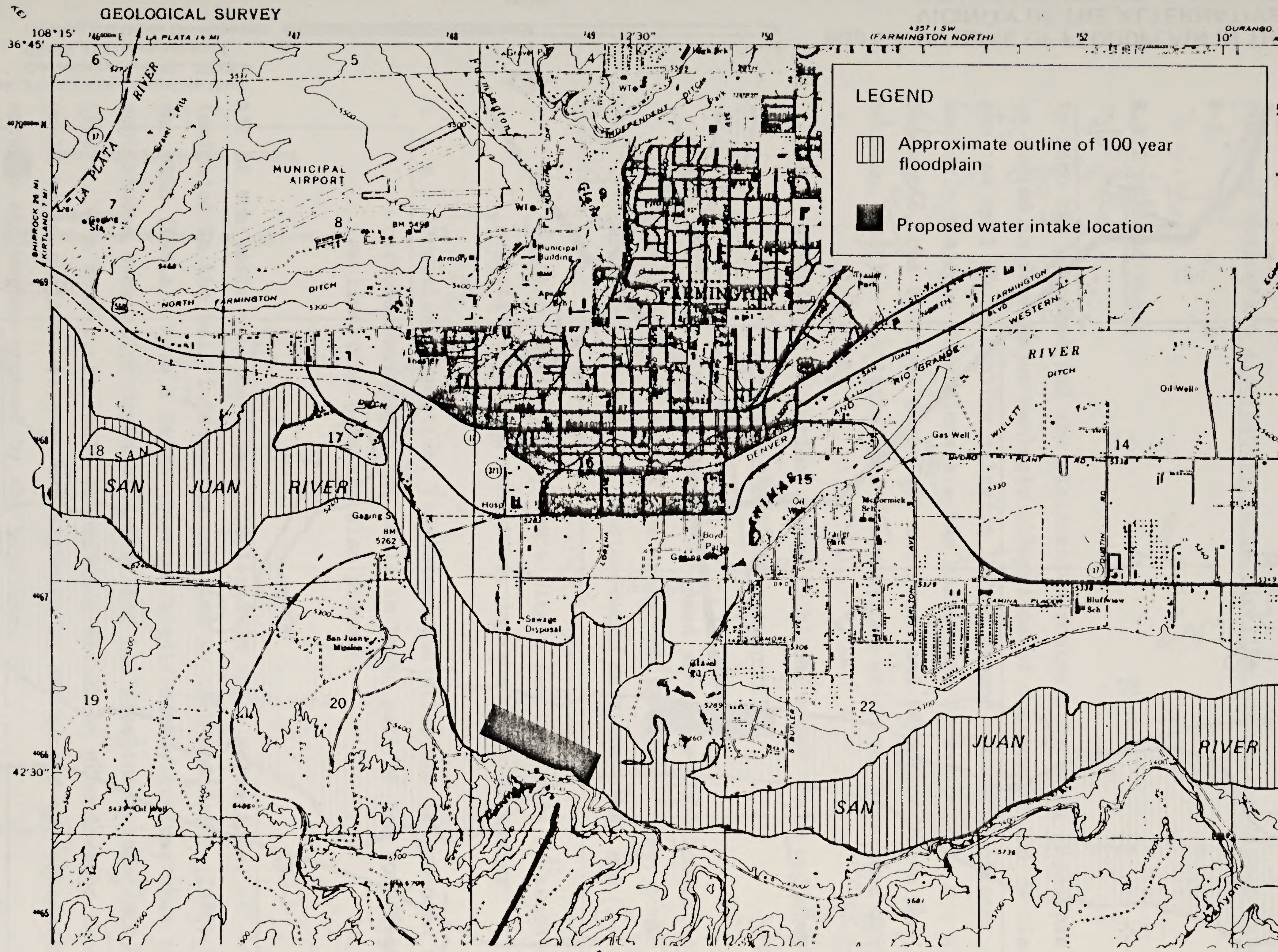
The study area for this investigation included the Chaco River, the Gallegos Canyon and Kutz Canyon sub-basins of the San Juan River Basin. The combined area of these sub-basins encompassed the proposed route and the two alternative routes for the water pipeline from the San Juan River and the intake structures on the San Juan River.

6.B AFFECTED ENVIRONMENT

6.B.1 Surface Water

Streamflow in the study area is highly variable. Flow in the channels and washes is sporadic and results from localized, short-duration, high-intensity thunderstorms, which occur usually during late spring and summer. The channels are normally dry for the remainder of the year. Intense rainfall during thunderstorms causes flooding that may be of large magnitude but generally local in areal extent. Discharges of several hundred to several thousand cubic feet per second from drainages of only a few square miles are not uncommon during such floods. Winter storms, in contrast, are usually of low intensity and short duration and produce little or no runoff (Busby, 1979b).

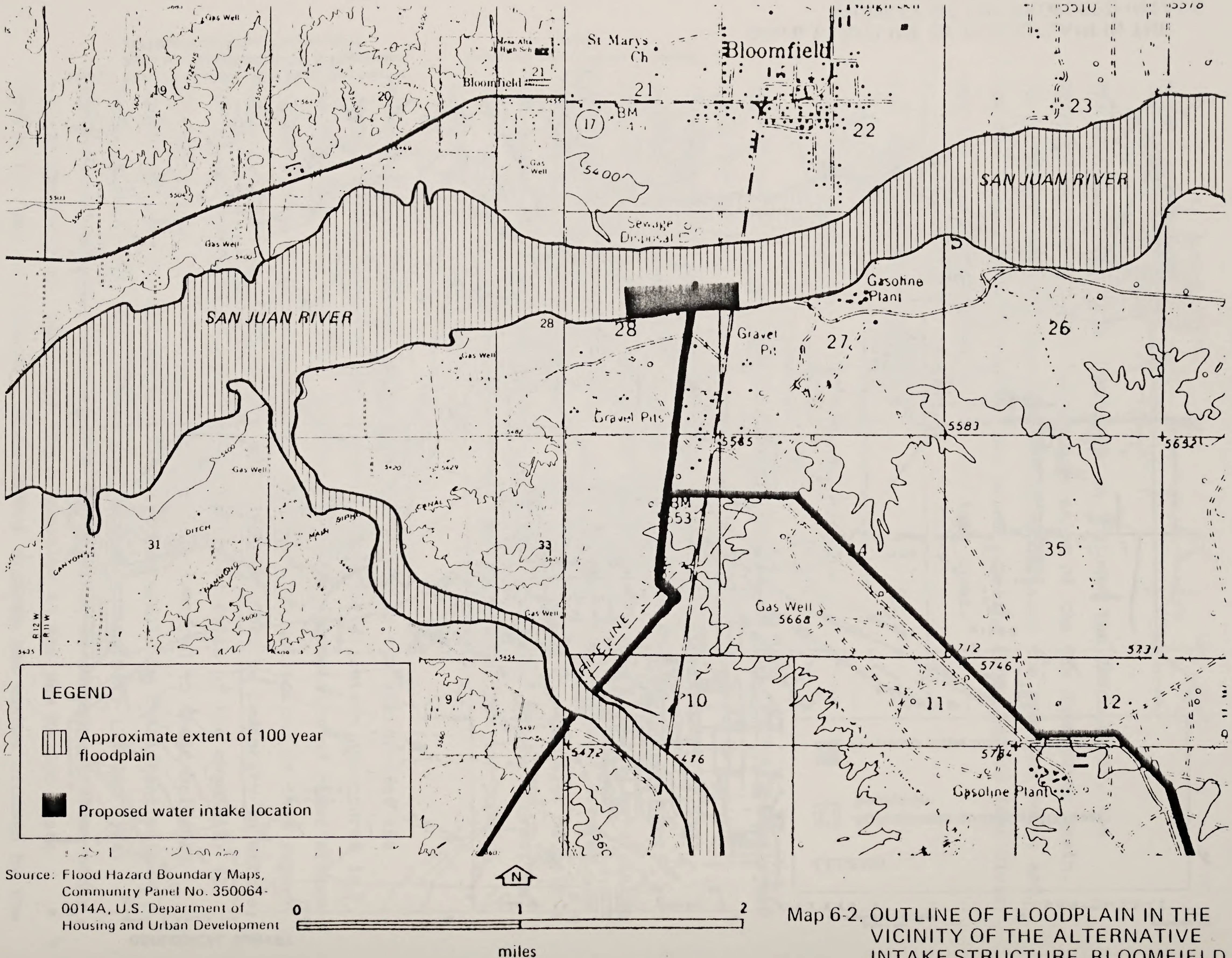
The 100-year floodplain of the San Juan River in the vicinity of the proposed (Farmington) and alternative (Bloomfield) intake structures is shown on Maps 6-1 and 6-2, respectively. The floodplains of other stream channels crossed by the pipelines have not been delineated in this report because: (1) construction of such crossings would be temporary in nature; (2) pipelines would be buried below the scour depth of the channels; (3) stream gradient and channel banks would be restored to their original condition; and (4) streambed reconstruction wouild be consistent with Corps of Engineers requirements for Section 404 permits (33 USC 1344). Flood Hazard Boundary Maps showing the 100-year floodplain of these other stream channels are available for inspection at the New Mexico State Office of BLM, in Santa Fe. These other streams and washes crossed by the



Source: Flood Hazard Boundary Maps, Community Panel No. 350064-0013A, U.S. Department of Housing and Urban Development.

0 1 miles

Map 6-1. OUTLINE OF FLOODPLAIN IN THE VICINITY OF THE PROPOSED INTAKE STRUCTURE, FARMINGTON, NEW MEXICO



Source: Flood Hazard Boundary Maps, Community Panel No. 350064-0014A, U.S. Department of Housing and Urban Development

Map 6-2. OUTLINE OF FLOODPLAIN IN THE VICINITY OF THE ALTERNATIVE INTAKE STRUCTURE, BLOOMFIELD, NEW MEXICO

Proposed Action and alternative water pipeline routes are listed in Table 6-1.

6.B.2 Ground Water

In both the proposed and the alternative routes, the water pipelines will be buried in four major geologic formations of Cretaceous and Tertiary age, as well as in shallow alluvium in and around ephemeral streams and washes. The four formations are the Nacimiento Formation, the Ojo Alamo Sandstone, the Kirtland Shale and the Fruitland Formation (Dane and Bachman, 1965). The lithologic descriptions of these formations are:

- Nacimiento Formation: gray to black banded shale and clay and lenticular channel sandstone.
- Ojo Alamo Sandstone: interbedded sandstone, conglomeratic sandstone, and shale; the sandstone is buff to rusty brown, arkosic, and locally conglomeratic near the base; and
- Kirtland Shale: gray shale with a few thin beds of sandstone and siltstone; and sandstone, interbedded with shale;
- Fruitland Formation: sandstone and siltstone interbedded with carbonaceous shale and coal; in lower part of the formation a few limestone beds are also present;

All of the wells that have been completed in these formations, as indicated in the well inventories compiled by Link and Kelly (1980) and the USGS (1981a), have a depth-to-water significantly greater than the approximate excavation depth of 6 feet for the pipeline trench (WCC, 1982). As a result, the only conceivable effect on ground-water users would be on shallow wells in the alluvium in and around the ephemeral streams and washes crossed by the pipeline.

Table 6-1. STREAMS AND WASHES CROSSED BY WATER PIPELINES

A. Proposed Route (P1)

Stream or Wash	Location	Crossing Width	Comments
Hunters Wash	NE 1/4 sect. 31 T24N, R13W	500-1000 ft	Approx. 1/8 mi downstream of Bisti Trading Post
De-na-zin Wash	SW 1/4 NW 1/4 sect. 14 T23N, R13W	1000 ft	At northwest corner of plant site

B. Alternative Route No. 1 (P2)

Stream or Wash	Location	Crossing Width	Comments
Kutz Canyon	Western half section 10 T28N, R11W	2000 ft	Approx. 2 mi. upstream of junction with San Juan River
Horn Canyon	SE 1/4 sect. 20 T28N, R11W	200 ft	Approx. 3 mi upstream of junction with San Juan River
Gallegos Canyon	NW 1/4 sect. 2 T26N, R12W	800 ft	
West Fork Gallegos Canyon	SW 1/4 SE 1/4 sect. 17 NW 1/4 NE 1/4 sect. 20 T26N, R12W	400 ft	
Hunter Wash	NE 1/4 sect. 31 T24N, R13W	500-1000 ft	Same crossing as for proposed route, alternative joins proposed route prior to crossing

C. Alternative Route No. 2 (P3)

Stream or Wash	Location	Crossing Width	Comments
Gallegos Canyon	SE 1/4 NE 1/4 sect. 17 T25N, R10W	200 ft	
East Fork, Gallegos Canyon	SE 1/4 SE 1/4 sect. 17 T27N, R10W	1000 ft	Crossing is approx. 1/2 mi. upstream of junction with main branch

Note: Flood Hazard Boundary Maps for these streams and washes are available for inspection at the BLM New Mexico State Office in Santa Fe.

This alluvium is derived from the Cretaceous and Tertiary rocks and is of widely varying composition and thickness. It blankets bedrock in areas of low topographic relief, forming clay flats and partly filling arroyo channels. The composition of the alluvium ranges from silty clay to poorly-sorted sand and gravel. In general the finer-grained alluvium is found flooring the clay flats in the minor drainages close to predominantly shale or claystone source areas, and the coarser sediments are found as channel fillings associated with the more important drainages.

The thickness of alluvium ranges from zero, in minor channels cut in bedrock, to an unknown maximum, probably in the present channel or in a buried channel of De-na-zin Wash. The greatest thickness penetrated in any of the monitoring wells drilled in De-na-zin Wash was 41 feet, and the smallest thickness was 12 feet. The average thickness was about 30 feet (Shomaker, 1980).

6.C. IMPACTS ASSOCIATED WITH WATER PIPELINES

6.C.1 Flooding Potential and Peak Discharge

Pipelines

There will be no significant impacts with respect to flooding potential and changes in peak discharge due to construction and operation of the proposed or alternative water pipelines from the San Juan River. An impact is significant if changes in flood elevation are greater than one foot or changes in peak discharge are greater than 15 percent of streamflow that results from a rainfall event with a 10-year recurrence interval (Section 2.D). Cofferdams will be built to close off parts of the channel of any stream or wash crossed by the pipelines if water were encountered (WCC, 1982). If a flood were to occur in an ephemeral stream during pipeline construction, the flood elevation and peak discharge of the stream might be temporarily affected. If a cofferdam is used the peak discharge might be reduced and the local flood elevation might be increased due to backwater effects. A sufficiently large flood might disrupt construction operations.

Because of eight general design and construction procedures to be employed during the project for pipeline crossings of streams and washes, no long-term significant impacts to the surface- or ground-water environment are expected. These eight procedures are (WCC, 1982):

1) streams and washes would generally not be crossed during periods of periodic high flow (e.g., late summer), and time of construction would not exceed 14 days;

2) streambed reconstruction would be consistent with Corps of Engineers (COE) requirements for Section 404 permits (33USC 1344);

3) drainage or storm runoff from construction staging areas would be controlled;

4) pipes would be buried beneath scour depth of streams and washes;

5) pipeline trench would be graded on each approach to the stream, wash, or arroyo to fit the profiles of the pipelines and to avoid potential exposure of the pipe at the banks due to erosion;

6) stream gradient would be restored upon completion of construction;

7) stream banks would be restored to resemble their original grade; and

8) where necessary, erosion control measures would be employed along the banks.

Intake Structures

The proposed and alternative intake structures for the water pipelines would be surrounded by a dike, or the entire site area would be filled and raised above the 100-year flood elevation, prior to construction of the intake pumping plant. The protective dike would be constructed on a suitable foundation near the riverbank, using excess materials from required excavations and from borrow materials. The dike would have 3:1 slopes both on the river side and on the landward side. The riverside slopes would be protected with riprap or a reinforced-concrete surfacing if suitable rock for riprap were not economically available. Riprap or the concrete slab would extend well below the riverbed to prevent undermining. The dike would have a 10-foot top width for a road for inspecting and maintaining the dike and for equipment access to the headgate area. Alternatively, if the site were filled to provide a level surface above the 100-year flood elevation, slope protection along the river would be constructed as described above. Approximately 35 acres on the floodplain of the San Juan River would be required for the entire intake pumping plant and river diversion site (WCC, 1982).

The proposed and alternative intake structures are located within the 100-year floodplain of the San Juan River (see Maps 6-1 and 6-2). An analysis of the approximate impacts of the proposed (at Farmington) and the alternative (at Bloomfield) intake structures on the San Juan River floodplain has been performed on a qualitative basis. This evaluation is based specifically on an examination of: (1) the location of each intake structure and its general design (WCC, 1982); and (2) the general hydraulic characteristics of the river at the intake location and the extent of the floodplain. The intake structure at Farmington (see Map 6-1) is located in a portion of the San Juan River floodplain that relatively is wider, less constricted, and may have a smaller channel slope than the floodplain of San Juan River at the Bloomfield intake structure (see Map 6-2). On this basis, the Proposed Action intake structure at Farmington would appear to have less of an impact on flow and/or flood characteristics of the San Juan River than the alternative

intake structure at Bloomfield. Based upon information available at present, it is not possible to estimate whether these impacts would be significant (changes in flood elevation greater than one foot or changes in peak flood discharge greater than 15 percent). "To determine that adverse effects on river flow would not result from constructing these protective works (dike or raising of elevation of site), hydraulic conditions would be carefully analyzed during final designs and, if required, PNM would take corrective action to protect property abutting the river" (WCC, 1982). This specific analysis will be deferred until the Section 404 permitting process (U.S. Army Corps of Engineers).
If a flood were to occur during construction of the intake structure, changes in flood elevation and peak discharge of the San Juan River might occur. A sufficiently large flood might disrupt construction operations. The construction procedures outlined above should prevent damage to the intake structure during a flood event.

6.C.2 Ground-Water Users

During pipeline construction at wash or arroyo crossings, cofferdams would be built to control flow, and ground water would be pumped from the alluvium in and around each wash to ensure dry construction conditions (WCC, 1982). The former procedure could temporarily interfere with recharge through the streambed to alluvial aquifers, and the latter procedure could temporarily reduce water levels in the alluvial aquifers.

Impacts on ground-water users due to pumping of ground water would appear as reduced water levels in wells completed in the alluvial aquifers. These impacts probably would be limited to an area extending approximately 200 yards from construction operations and would be of limited duration, extending perhaps several weeks beyond the 14 days of pipeline construction at each crossing. Well inventories, which included both areas of strippable coal (Link and Kelly, 1980) and of the San Juan Basin (USGS, 1981a), show that one well completed in alluvium is located within approximately 200 yards of a pipeline crossing. This well is located near the crossing of the proposed water pipeline with De-na-zin Wash.

Following the well-numbering system for the state of New Mexico, the well has been assigned the number 23.13.14.141 and is located in Section 14 of T.23N., R.13W. The depth-to-water in this well was 4.2 feet in 1976 (USGS, 1981a).

No significant impacts on recharge to the alluvial aquifers are expected because of the limited extent and short duration of changes to the intermittent flows in the washes that provide the recharge.

No significant long-term impacts on ground-water users from construction or from long-term operation of the intake structure for the water pipeline are expected. Ground water encountered during subsurface construction activities would be pumped out of the excavation and discharged into the San Juan River (WCC, 1982). This pumping could conceivably lower water levels in shallow wells in the surrounding alluvium on a temporary basis. However, no wells are located in the alluvial aquifer within 200 yards of the proposed and alternative intake structures (USGS, 1981; Link and Kelly, 1980).

The alluvial aquifer in and adjacent to the channel of the San Juan River may be recharged by flow in the river, especially during high-flow stages. Changes in the flow characteristics of the San Juan River could affect this recharge mechanism. A temporary reduction in recharge to the alluvial aquifer may occur during construction of the intake structure and river diversion site. No long-term impacts on recharge are expected because changes in streamflow characteristics of the San Juan River would be limited to the duration of construction.

7.A. INTRODUCTION

7.A.1 Hydrologic Issues

The two hydrologic issues of concern with respect to conceivable impacts of the construction and operation of transmission lines are:

1) changes in streamflow characteristics and/or flood elevations of washes or streams at location of transmission line crossings; and

2) impacts on ground-water or surface-water users due to construction or operation of the transmission lines.

7.A.2 Methods of Investigation

The first step in the investigation was an assessment of the construction and operation procedures for the transmission lines, as taken from the project description (WCC, 1982). Hydrologic judgment was used to evaluate the nature and extent of significant impacts, if any. If this assessment revealed the possibility of significant impacts, then the need for additional, more detailed studies was investigated.

7.A.3. Study Area

The proposed and alternative transmission line routes are shown in the project description (WCC, 1982). The area covered by these routes includes the southern portion of San Juan County, the western and northwestern portion of Sandoval County, the eastern half of McKinley County, and the far northeastern corner of Cibola County, all in New Mexico.

7.B AFFECTED ENVIRONMENT

7.B.1 Surface Water

Streamflow in the study area is highly variable. Flow in the channels and washes is sporadic and results from localized short-duration, high-intensity thunderstorms, which occur usually during late spring and summer. The channels are normally dry for the remainder of the year. Intense rainfall during thunderstorms causes flooding that may be of large magnitude but generally local in extent. Discharges of several hundred to several thousand cubic feet per second from drainages of only a few square miles are not uncommon during such floods. Winter storms, in contrast, are usually of low intensity and short duration and produce little or no runoff (Busby, 1979b).

7.C. IMPACTS ASSOCIATED WITH TRANSMISSION LINES

The conceivable environmental impacts of construction and operation of transmission lines on the hydrologic environment are:

1) changes in flood elevation and/or peak discharge at locations where the transmission lines cross intermittent streams and washes; and

2) damage to transmission line towers at these crossings; and

3) scouring of the streambed in the immediate vicinity of the foundations of the transmission line towers.

These impacts can occur only if the towers are located in the floodplain of a stream or wash.

Because of five general design and construction procedures to be employed during the project, no significant impacts to the surface- or ground-water environment are expected. These five procedures are (WCC, 1982):

1) Placement of structures within floodplains would be minimized to the fullest extent possible, and in most areas the floodplain would be spanned;

2) When placed in the floodplain, the tower foundations will be raised above ground surface;

3) Where required because of flooding potential the foundation depth will be increased and/or additional unsupported foundation lengths added;

4) Construction activities at stream crossings will be accomplished, as described in Section 6.C.1 for water pipeline stream crossings, to reduce damage to the stream channel; and

5) Construction sites will be restored to original ground-surface contours.

The scouring around any transmission-line tower foundations located in a floodplain is judged to be local in extent and not to have a significant impact to the surface- or ground-water environment.

8.0
SUMMARY OF SIGNIFICANT IMPACTS AND SUGGESTED MITIGATION

8.A SIGNIFICANT IMPACTS

8.A.1 Water Supply - Proposed Action

The Proposed Action water supply from Navajo Reservoir used in conjunction with the Proposed Action intake structure at Farmington would not result in significant impacts to surface-water users from the San Juan River or the Colorado River. In addition, reductions in streamflow at the Proposed Action intake structure and the alternative intake structure at Bloomfield due to an average diversion of 48 cubic feet per second (cfs) (average annual discharge of 35,000 acre-feet) for NMGS would not be significant (less than 15 percent of average streamflow during critical dry period).

Use of the alternative point of diversion at Bloomfield may result in shortages to users of water from Navajo Reservoir during a severe drought period. There is a qualitatively small chance that such shortages would occur; however, the magnitude of these shortages cannot be estimated with the operations model of the San Juan River system used in this impact analysis. The basis for predicting these possible shortages is that water from irrigation return flows of other diversions from the San Juan River would not be available at Bloomfield, whereas some of these return flows would enter the river upstream of Farmington. The duration of these possible shortages probably would be several isolated or consecutive months during a severe drought period.

8.A.2 Water Supply - Alternative

The alternative water supply from the well field (16 wells that are completed in the Westwater Canyon Member of the Morrison Formation) would result in significant impacts (drawdowns greater than 25 feet) to ground-water users whose wells tap the Westwater Canyon Member, the Dakota

Sandstone and the Entrada Sandstone aquifers in the San Juan Structural Basin. Indicators of significance are discussed in Section 2.D. Significant impacts would occur over almost the entire basin in all three aquifers. The maximum drawdowns in the Westwater Canyon Member would occur in the vicinity of the well field in year 2033, when pumping for NMGS would be reduced from 15,000 acre-feet per year (AFY) to 6,250 AFY. These maximum drawdowns would be approximately 2,500 feet in the vicinity of the well field.

The maximum drawdowns in the Dakota Sandstone and Entrada Sandstone aquifers would also occur in the vicinity of the well field used for NMGS. The maximum drawdowns in the Dakota Sandstone would be approximately 400 to 600 feet and would occur in year 2038, at about the time when all pumping from the well field would cease. The maximum drawdowns in the Entrada Sandstone would be approximately 150 to 200 feet and would occur 10 to 20 years after the well field for NMGS would stop pumping.

The duration of significant impacts to ground-water users whose wells are completed in the Westwater Canyon Member, the Dakota Sandstone and the Entrada Sandstone could be 150 years or more after the well field for NMGS stops pumping. The duration of drawdowns greater than 25 feet due to pumping for NMGS cannot be accurately quantified with the model used for this impact assessment.

A beneficial impact of pumping the well field for NMGS would be to lessen the dewatering requirements of existing and proposed future uranium mines (BLM's Baselines 1 and 2) by as much as 5 percent. This beneficial impact is judged to be significant.

Decreases in natural discharge to the San Juan River, Puerco River, Rio San Jose, Rio Salado, and Rio Puerco due to pumping of the well field for NMGS would not be significant (less than 15 percent of average daily flow of stream). The combined maximum decrease in natural discharge to these 5 water bodies due to the well field for NMGS is estimated to be approximately 0.09 cfs. This decrease in natural discharge may be overestimated because ground-water discharge is assumed to be taking place from the Rio Puerco and Puerco River, even though these streams are ephemeral where they cross outcrops of the aquifer system.

Pumping the well field for NMGS might cause a significant impact on the flow of selected springs in the Chuska Mountains. Several springs in the vicinity of the community of Crystal discharge from the Chuska Sandstone where, geologically, the Chuska Sandstone overlies the Westwater Canyon Member of the Morrison Formation. Pumping the well field for NMGS is estimated to cause a maximum increase of approximately 0.4 cfs in inflow from the Chuska Sandstone to the Westwater Canyon Member. This increased inflow may cause a reduction in the flow of several springs; however, available information on the hydrogeology and average discharge of these springs is not sufficient to quantify whether the reduction in flow would be significant (greater than 15 percent of average daily flow).

Measurable land subsidence is assumed to result from withdrawal of ground water from the well field for NMGS. Based on the substantial projected declines in the potentiometric surface of the Westwater Canyon Member aquifer due to pumpage for NMGS, the San Juan Structural Basin has been assigned a moderate potential for land subsidence. Such subsidence probably would be greatest in the immediate vicinity of the well field but probably would not be significant (greater than one foot). A more quantitative estimate of the magnitude or geographical extent of possible land subsidence cannot be made without additional information on rock properties of the aquifer system. Any land subsidence that results from pumping ground water for NMGS most likely would be irreversible.

8.A.3 NMGS Plant Site

No significant impacts on surface-water and ground-water users, flooding potential, and changes in runoff conditions would be likely to result from construction or operation of the plant site.

8.A.4 Water Pipelines

Where the proposed water pipeline route crosses De-na-zin Wash, pumping of water from the alluvium of the wash during construction of the pipeline crossing may lower the water level in one well (23.13.14.141) that is completed in the alluvium. This well has most likely been hand dug, and its depth is not known, but probably is relatively shallow. Therefore, the lowering of the water level in this well is judged to be a significant impact. The duration of this impact would be limited, extending several weeks beyond the 14 days (maximum) of pipeline construction at this crossing.

During construction of the proposed or alternative intake structure and river diversion site, impacts due to increases in flood elevation and peak discharge of the San Juan River and decreases in recharge to the alluvial aquifer along the San Juan River may occur. Recharge to the alluvial aquifer in and adjacent to the channel of the San Juan River during high-flow stages may be decreased by construction activities. Although these potential impacts may be significant, they are of limited duration, occuring only during construction of the intake structure and river diversion site.

The intake structure and river diversion site would occupy approximately 35 acres within the 100-year floodplain of the San Juan River. These structures would encroach upon the floodplain and may result in increases in flood elevation. It is not possible with available information to estimate if these impacts would be significant (greater than 1 foot). PNM is planning to carefully analyze hydraulic conditions in the vicinity of the river diversion sites during final design of these facilities (WCC, 1982). A specific analysis of impacts would be deferred until the Section 404 permitting process.

8.B MITIGATING MEASURES

8.B.1 Water Supply - Proposed Action

Adverse impacts in the form of possible shortages to users of water from Navajo Reservoir may occur during a severe drought period with use of the alternative point of diversion at Bloomfield. Institutionally, uncertainties in how water would be allocated to users from Navajo Reservoir during periods of short supply are already mitigated by the legislation (Public Law 87-483, Navajo Indian Irrigation Project Act) that authorized Navajo Reservoir. This legislation requires that all users of water from Navajo Reservoir share proportionately in water shortages on the basis of their respective authorized diversion. Shortages in physical supply could be mitigated by use of the Proposed Action point of diversion at Farmington. Careful management of the San Juan River system, including releases from storage projects, would be necessary during a severe drought period to prevent signficant impacts due to projected future uses of water, including uses for NMGS.

8.B.2 Water Supply - Alternative

Significant impacts in the form of drawdown in water levels in wells of other ground-water users in the San Juan Structural Basin, which are completed in the Westwater Canyon Member, Dakota Sandstone and Entrada Sandstone aquifers, could be mitigated by replacement of the water supply. Such replacement of water could consist of the furnishing of a substitute water supply, the modification of existing water supply facilities such as installation of larger pumps, the drilling of replacement wells, the assumption of additional operating costs, and/or artificial recharge.

Under New Mexico water law, a water-rights applicant may submit a Plan of Replacement to the State Engineer, which would specify measures for replacement of the water supply of existing water rights that otherwise would be impaired by the new appropriation, if approved. In New Mexico, the State Engineer has the authority to administer rights to ground water and to determine (in declared underground water basins) which effects due to a new appropriation would constitute impairment of existing water rights. The State Engineer would review a Plan of Replacement submitted by an applicant in accordance with existing laws and procedures governing the appropriation of ground water (see Section 4.B.1).

Impacts due to reductions in the flow of several springs in the Chuska Mountains might occur as a result of the well field for NMGS. However, available information on the hydrogeology and average discharge of these springs is not sufficient to quantify whether the impacts would be significant. A hydrogeologic reconnaissance of these springs to study their occurence and relation to the Westwater Canyon Member is recommended as the first part of a monitoring program, which would help to quantify the potential impacts. The second part of the recommended monitoring program is to establish stations for gaging the flow of certain springs and to collect spring flow data periodically to develop a baseline of average annual discharge of these springs. If the monitoring program indicates that significant impacts on existing water users due to reduction in the flow of one or several springs are occurring, these impacts could be mitigated by replacement of the water supply. Methods of replacement of water could be similar to that for wells, and could consist of the furnishing of a subsitute water supply.

Measurable land subsidence probably would occur as a consequence of ground-water withdrawals from the well field. Additional information on the rock properties of the affected aquifer system would be required to attempt to quantify this potential subsidence. It is recommended that a relatively small leveling network in the immediate vicinity of the well field be established to monitor for land subsidence. In addition, when the wells in the NMGS well field are being drilled, it is recommended that several representative rock samples be collected and analyzed for properties such as shear strength and compressibility. These data subsequently could be used to evaluate whether or not land subsidence due to ground-water withdrawal would be a significant impact.

Significant impacts due to the well field could be mitigated by reducing the water production from the well field. Such smaller production might be possible by placing greater reliance on the Proposed Action water supply (San Juan River) and/or by use of some dry cooling.

8.B.3 Water Pipelines

The significant impact on one well completed in the alluvium of De-na-zin Wash (well 23.13.14.141), in which a lowering of the water level may occur during construction of the water pipeline crossing, could be mitigated by furnishing a substitute water supply. This form of replacement of the water supply probably is the most practical alternative in this case because the duration of the significant impact would be only several weeks.

Significant impacts due to increases in flood elevation and peak discharge of the San Juan River and decreases in recharge to the alluvial aquifer along the river may occur during construction of the proposed or alternative intake structure and river diversion site. These potential impacts would be of limited duration, occuring during the construction phase of these project facilities.

Based on information available at present, it is not possible to estimate whether significant impacts due to increased flood elevations would result during operation of the intake structure and river diversion site. "To determine that adverse effects on river flow would not result from constructing these protective works dikes or raising ground elevation of river diversion site , hydraulic conditions would be carefully analyzed during final designs and, if required, PNM would take corrective action to protect property abutting the river." (WCC, 1982).

Significant impacts could be mitigated by incorporating certain provisions into the final design of this facility. These provisions would probably be selected after a trial-and-error iterative process that would evaluate how various design features and construction procedures help to minimize adverse changes in flood elevation, peak discharge and aquifer recharge.

UNAVOIDABLE ADVERSE IMPACTS, IRRETRIEVABLE COMMITMENT OF RESOURCES, AND THE RELATIONSHIP BETWEEN SHORT-TERM USES OF THE ENVIRONMENT AND MAINTENANCE OF LONG-TERM PRODUCTIVITY

Impact	Unavoidable Adverse Impacts	Commitment of Resources: Irreversible	Commitment of Resources: Irretrievable	Short-Term Use of Environment (40-year project life)	Maintenance and Enhancement of Long-Term Productivity
Consumptive use of 20,000 or 35,000 ac-ft/yr of San Juan River water at NMGS.	Yes	No	Project life	Yes	Water lost to evaporation in the power generating process would eventually be returned via the hydrologic cycle.
Reduction in San Juan River average streamflow of 28 or 48 cfs below the proposed or alternative intake sites.	Yes	No	No	Project life	Water diversions would end with the abandonment of plant facilities.
Ground-Water Supply Alternative Consumptive use of 15,000 ac-ft/yr of ground water; significant draw-downs in three aquifers; unknown reduction in flow from springs in the Chuska Mountains; decrease in natural ground-water discharge to local springs; measurable land subsidence near the well field.	Yes	No[a]	Project life and beyond	Project life and beyond	Recharge of the aquifers would require an unknown period of time after the project life.

[a] Any land subsidence would be irreversible.

POSSIBLE NEW TOWN

AFFECTED ENVIRONMENT

The possible new town site is located in the drainage basin of De-na-zin Wash. An unnamed wash trends east-northeast to west-southwest across the site and is tributary to De-na-zin Wash approximately 6 miles southwest of the new town site. Several smaller intermittent stream channels are present in the southern part of the site and trend generally to the southwest.

The possible new town site is underlain by the lower shale member of the Kirtland Shale (O'Sullivan and Beikman 1963). These deposits consist of a greenish gray shale that is considered to have relatively low permeability. The Kirtland Shale is in turn overlain by soil deposits that are well drained (see Technical Report on Soils and Prime and Unique Farmlands).

There are no known surface-water impoundments, wells, or springs at or in the immediate vicinity of the possible new town site (USGS 1981a; Link and Kelly 1980). Alluvium in the unnamed wash most likely contains minor amounts of shallow ground water. The depth to other water-bearing units at the site (e.g., sandstone beds in the Fruitland Formation or Pictured Cliffs Sandstone) is on the order of 100 feet or more. The expected yields of wells that tap these units probably would be sufficient for stock or domestic uses. The depth to the Westwater Canyon Member of the Morrison Formation, the most extensive regional aquifer in the San Juan Basin, is approximately 5500 feet beneath the site.

[illegible]

[illegible]

The [illegible] site is located in the [illegible] basin of [illegible] Wash. [illegible] surface [illegible] to [illegible] [illegible] site [illegible] (Figure [illegible]) [illegible] site. [illegible] site and [illegible] the [illegible].

The [illegible] of the [illegible] consist of [illegible] deposits. These deposits consist of a [illegible] that is [illegible] low permeability. [illegible] deposits [illegible] and [illegible].

There are no known [illegible] groundwater, wells, or springs at or in the immediate vicinity of the [illegible] (Cooley [illegible] 1969; [illegible] and [illegible]). [illegible] the proposed [illegible] contains minor amounts of [illegible] ground water. The depth to [illegible] water-bearing units at the site [illegible] in the [illegible] Formation or [illegible] is on the order of 100 feet or more. The expected yields [illegible] would probably would be [illegible] gallons per minute. The depth to the [illegible] Member of the [illegible] Formation, the most [illegible] regional aquifer in the [illegible] Basin, is [illegible] 2000 feet beneath the site.

2.0

ENVIRONMENTAL CONSEQUENCES

Impacts on the hydrologic environment due to the construction and operation of the possible new town are conceivable with respect to flooding potential and source of construction and/or municipal water supply. If any facilities for the possible new town were built in the floodplain of the unnamed wash that crosses the site, impacts due to increased flooding may result. It is assumed that a well tapping a deep aquifer, such as the Westwater Canyon Member of the Morrison Formation, would be drilled at the possible new town site to provide a source of construction and/or municipal water supply. Such use of ground water may cause drawdown of the water levels in wells that also tap that aquifer.

[illegible]

Impacts on the hydrological environment [illegible] and operation of the [illegible] with respect to flooding potential [illegible] quantity of [illegible] water supply. If the [illegible] in the floodplain of [illegible] factor, [illegible] Formation, would be [illegible] source of [illegible] water supply. [illegible] ground water [illegible] of the [illegible] for that aquifer.

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APPENDIX B - GLOSSARY

INTRODUCTION

This appendix presents definitions of selected technical terms used in this report and accompanying appendices. Terms selected were those judged by the authors to be uncommon or specific to a particular context.

TECHNICAL TERMS

acre-foot - the volume of water that would cover one acre to a depth of one foot, equivalent to 43,560 cubic feet. 1.98 acre-feet is equivalent to one cubic foot per second (CFS) flowing for 24 hours.

alluvial - pertaining to or composed of clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by running surface water.

aquifer - one or more formations that contain sufficient permeable material to yield significant quantities of water to wells and springs.

artesian - see confined aquifer.

basalt - a dark- to medium-dark colored, extrusive, mafic igneous rock composed chiefly of calcic plagioclase and clinopyroxene in a glassy or fine-grained groundmass.

basement, basement complex - a series of rocks with generally complex structure beneath the dominantly sedimentary rocks; in many places igneous and metamorphic rocks.

basin (structural) - a general term for a depressed or concave, downward sediment-filled area, which may be either consolidated or unconsolidated.

basin (watershed) - the area drained by a river or river system.

confined aquifer - an aquifer containing confined ground water.

coffer dam - a watertight enclosure placed or constructed in waterlogged soil or under water and pumped dry to allow construction or repairs.

confined ground water - water in an aquifer under pressure significantly greater than atmospheric. Its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

contact - in geology, a plane or irregular surface between two different types or ages of rocks.

<u>declared underground water basin</u> - as used in New Mexico, the State Engineer by declaration may establish reasonably ascertainable boundaries around a ground-water basin when he feels that management controls are necessary. Such a basin is called a declared underground water basin.

<u>dome</u> - a roughly symmetrical and closed upfold, the beds dipping in all directions, more or less equally, from a point.

<u>drawdown</u> - the difference between the elevations of the water level in a well under non-pumping (static) conditions and under pumping conditions.

<u>ephemeral stream</u> - a stream or reach of stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

<u>facies</u> - the sum of all primary lithologic and paleontologic characteristics exhibited by a sedimentary rock and from which its origin and environment of formation may be inferred.

<u>hydraulic conductivity</u> - the volume of water that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

<u>impairment</u> - a finding by the State Engineer that a proposed appropriation would permanently diminish the value of an existing water right.

<u>intermittent stream</u> - a stream or reach of stream that flows only at certain times of the year, as when it receives water from springs, ground-water discharge, or some surface source.

<u>mean sea level (MSL)</u> - the average height of the surface of the sea for all stages of the tide over a 19-year period; adopted as a datum for the measurement of heights. Elevations MSL are assumed to be positive unless otherwise noted.

<u>monocline</u> - a unit of strata that dips or flexes from the horizontal in one direction only, and is not part of an anticline or a syncline. It is generally a large feature of gentle dip.

<u>perennial stream</u> - a stream or reach of a stream that flows continuously throughout the year and whose upper surface generally stands lower than the water table in the region adjoining the stream.

<u>potentiometric surface</u> - a surface that represents the static water level or head in an aquifer. In an artesian aquifer, water will rise in tightly cased wells. The water table is a particular potentiometric surface.

<u>senior appropriator</u> - an owner of a water right whose right has a relatively early priority date compared to another water rights owner.

specific yield - the ratio of (1) the volume of water that a given mass of soil or rock, after being saturated, will yield by gravity to (2) the volume of that mass of soil or rock. In the natural environment, specific yield is generally observed as the change that occurs in the amount of water in storage per unit area of unconfined aquifer as the result of a unit change in head.

storage coefficient - the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield.

transmissivity - the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

unconfined aquifer - an aquifer containing unconfined ground water.

unconfined ground water - water in an aquifer that has a water table.

undeclared area - as used in New Mexico, an area not declared as an underground water basin by the State Engineer.

water table - that surface in a ground-water body at which the water pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water.

Appendix C

COLORADO RIVER AGREEMENTS

- Colorado River Compact
- Upper Colorado River Basin Compact
- Memo from Solicitor, U.S. Department of the Interior, December 6, 1974

COLORADO RIVER COMPACT
SIGNED AT SANTA FE, NEW MEXICO,
November 24, 1922

The States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, having resolved to enter into a compact under the act of the Congress of the United States of America approved August 19, 1921, (42 Stat. L., p. 171), and the acts of the legislatures of the said States, have through their governors appointed as their commissioners: W. S. Norviel for the State of Arizona, W. F. McClure for the State of California, Delph E. Carpenter for the State of Colorado, J. G. Scrugham for the State of Nevada, Stephen B. Davis, Jr. for the State of New Mexico R. E. Caldwell for the State of Utah, Frank C. Emerson for the State of Wyoming, who, after negotiations participated in by Herbert Hoover, appointed by the President as the representative of the United States of America, have agreed upon the following articles.

Article I

The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River system; to establish the relative importance of different beneficial uses of water; to promote interstate comity; to remove causes of present and future controversies and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two basins, and an apportionment of the use of part of the water of the Colorado River system is made to each of them with the provision that further equitable apportionment may be made.

Article II

As used in this compact:

(a) The term "Colorado River system" means that portion of the Colorado River and its tributaries within the United States of America.

(b) The term "Colorado River Basin" means all of the drainage area of the Colorado River system and all other territory within the United States of America to which the waters of the Colorado River system shall be beneficially applied.

(c) The term "States of the upper division" means the States of Colorado, New Mexico, Utah, and Wyoming.

(d) The term "States of the lower division" means the States of Arizona, California, and Nevada.

(e) The term "Lee Ferry" means a point in the main stream of the Colorado River 1 mile below the mouth of the Paria River.

(f) The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry.

(g) The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system below Lee Ferry.

(h) The term "domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power.

Article III

(a) There is hereby apportioned from the Colorado River system in perpetuity to the upper basin and to the lower basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.

(b) In addition to the apportionment in paragraph (a), the lower basin is hereby given the right to increase its beneficial consumptive use of such waters by 1,000,000 acre-feet per annum.

(c) If, as a matter of international comity, the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River system, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus shall prove insufficient for this purpose, then the burden of such deficiency shall be equally borne by the upper basin and the lower basin, and whenever necessary the States of the upper division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph (d).

(d) The States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years reckoned in continuing progressive series beginning with the 1st day of October next succeeding the ratification of this compact.

(e) The States of the upper division shall not withhold water, and the States of the lower division shall not require the delivery of water, which can not reasonably be applied to domestic and agricultural uses.

(f) Further equitable apportionment of the beneficial uses of the waters of the Colorado River system unapportioned by paragraphs (a), (b), and (c) may be made in the manner provided in paragraph (g) at any time after October 1, 1963, if and when either basin shall have reached its total beneficial consumptive use as set out in paragraphs (a) and (b).

(g) In the event of a desire for further apportionment as provided in paragraph (f) any two signatory States, acting through their governors, may give joint notice of such desire to the governors of the other signatory States and to the President of the United States of America, and it shall be the duty of the governors of the signatory States and of the President of the United States of America forthwith to appoint representatives, whose duty it shall be to divide and apportion equitably between the upper basin and lower basin the beneficial use of the unapportioned water of the Colorado River system as mentioned in paragraph (f), subject to the legislative ratification of the signatory States and the Congress of the United States of America.

Article IV

(a) Inasmuch as the Colorado River has ceased to be navigable for commerce and the reservation of its waters for navigation would seriously limit the development of its basin, the use of its waters for purposes of navigation shall be subservient to the uses of such waters for domestic, agricultural, and power purposes. If the Congress shall not consent to this paragraph, the other provisions of this compact shall nevertheless remain binding.

(b) Subject to the provisions of this compact, water of the Colorado River system may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(c) The provisions of this article shall not apply to or interfere with the regulation and control by any State within its boundaries of the appropriation, use, and distribution of water.

Article V

The chief official of each signatory State charged with the administration of water rights, together with the Director of the United States Reclamation Service and the Director of the United States Geological Survey, shall cooperate, ex officio—

(a) To promote the systematic determination and coordination of the facts as to flow, appropriation, consumption, and use of water in the Colorado River Basin, and the interchange of available information in such matters.

(b) To secure the ascertainment and publication of the annual flow of the Colorado River at Lee Ferry.

(c) To perform such other duties as may be assigned by mutual consent of the signatories from time to time.

Article VI

Should any claim or controversy arise between any two or more of the signatory States: (a) With respect to the waters of the Colorado River system not covered by the terms of this compact; (b) over the meaning or performance of any of the terms of this compact; (c) as to the allocation of the burdens incident to the performance of any article of this compact or the delivery of waters as herein provided; (d) as to the construction or operation of works within the Colorado River Basin to be situated in two or more States, or to be constructed in one State for the benefit of another State; or (e) as to the diversion of water in one State for the benefit of another State, the governors of the States affected upon the request of one of them, shall forthwith appoint commissioners with power to consider and adjust such claim or controversy, subject to ratification by the legislatures of the States so affected.

Nothing herein contained shall prevent the adjustment of any such claim or controversy by any present method or by direct future legislative action of the interested States.

Article VII

Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes.

Article VIII

Present perfected rights to the beneficial use of waters of the Colorado River system are unimpaired by this compact. Whenever storage capacity of 5,000,000 acre-feet shall have been provided on the Main Colorado River within or for the benefit of the lower basin, then claims of such rights, if any, by appropriators or users of water in the lower basin against appropriators or users of water in the upper basin shall attach to and be satisfied from water that may be stored not in conflict with Article III.

All other rights to beneficial use of waters of the Colorado River system shall be satisfied solely from the water apportioned to that basin in which they are situated.

Article IX

Nothing in this compact shall be construed to limit or prevent any State from instituting or maintaining any action or proceeding, legal or equitable, for the protection of any right under this compact or the enforcement of any of its provisions.

Article X

This compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination, all rights established under it shall continue unimpaired.

Article XI

This compact shall become binding and obligatory when it shall have been approved by the legislatures of each of the signatory States and by the Congress of the United States. Notice of approval by the legislatures shall be given by the governor of each signatory State to the governors of the other signatory States and to the President of the United States, and the President of the United States is requested to give notice to the governors of the signatory States of approval by the Congress of the United States.

In witness whereof the commissioners have signed this compact in a single original, which shall be deposited in the archives of the Department of State of the United States of America and of which a duly certified copy shall be forwarded to the governor of each of the signatory States.

Done at the city of Santa Fe, New Mexico, this twenty-fourth day of November, A. D. one thousand nine hundred and twenty-two.

W. S. Norviel
W. F. McClure
Delph E. Carpenter
J. G. Scrugham
Stephen B. Davis, Jr.
R. E. Caldwell
Frank C. Emerson

Approved:
Herbert Hoover

UPPER COLORADO RIVER BASIN COMPACT

Entered Into By The States of

ARIZONA

COLORADO

NEW MEXICO

UTAH

WYOMING

Santa Fe, New Mexico October 11, 1948

UPPER COLORADO RIVER BASIN COMPACT

The State of Arizona, the State of Colorado, the State of New Mexico, the State of Utah and the State of Wyoming, acting through their commissioners,

Charles A. Carson for the State of Arizona,
Clifford H. Stone for the State of Colorado,
Fred E. Wilson for the State of New Mexico,
Edward H. Watson for the State of Utah and
L. C. Bishop for the State of Wyoming,

after negotiations participated in by Harry W. Bashore, appointed by the President as the representative of the United States of America, have agreed, subject to the provisions of the Colorado River Compact, to determine the rights and obligations of each signatory State respecting the uses and deliveries of the water of the Upper Basin of the Colorado River, as follows:

Article 1

(a) The major purposes of this Compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System, the use of which was apportioned in perpetuity to the Upper Basin by the Colorado River Compact; to establish the obligations of each State of the Upper Division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact; to promote interstate comity; to remove causes of present and future controversies; to secure the expeditious agricultural and industrial development of the Upper Basin, the storage of water and to protect life and property from floods.

(b) It is recognized that the Colorado River Compact is in full force and effect and all of the provisions hereof are subject thereto.

Article II

As used in this Compact:

(a) The term "Colorado River System" means that portion of the Colorado River and its tributaries within the United States of America.

(b) The term "Colorado River Basin" means all of the drainage area of the Colorado River System and all other territory within the United States of America to which the waters of the Colorado River System shall be beneficially applied.

(c) The term "States of the Upper Division" means the States of Colorado, New Mexico, Utah and Wyoming.

(d) The term "States of the Lower Division" means the States of Arizona, California and Nevada.

(e) The term "Lee Ferry" means a point in the main stream of the Colorado River one mile below the mouth of the Paria River.

(f) The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain into the Colorado River System above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the Colorado River System above Lee Ferry.

(g) The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico and Utah within and from which waters naturally drain into the Colorado River System below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the Colorado River System below Lee Ferry.

(h) The term "Colorado River Compact" means the agreement concerning the apportionment of the use of the waters of the Colorado River System dated November 24, 1922, executed by Commissioners for the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, approved by Herbert Hoover, representative of the United States of America, and proclaimed effective by the President of the United States of America, June 25, 1929.

(i) The term "Upper Colorado River System" means that portion of the Colorado River System above Lee Ferry.

(j) The term "Commission" means the administrative agency created by Article VIII of this Compact.

(k) The term "water year" means that period of twelve months ending September 30 of each year.

(l) The term "acre-foot" means the quantity of water required to cover an acre to the depth of one foot and is the equivalent to 43,560 cubic feet.

(m) The term "domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial and other like purposes, but shall exclude the generation of electrical power.

(n) The term "virgin flow" means the flow of any stream undepleted by the activities of man.

Article III

(a) Subject to the provisions and limitations contained in the Colorado River Compact and in this Compact, there is hereby apportioned from the Upper Colorado River System in perpetuity to the States of Arizona, Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use of water as follows:

(1) To the State of Arizona the consumptive use of 50,000 acre-feet of water per annum.

(2) To the States of Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use per annum of the quantities resulting from the application of the following percentages to the total quantity of consumptive use per annum apportioned in perpetuity to and available for use each year by Upper Basin under the Colorado River Compact and remaining after the deduction of the use, not to exceed 50,000 acre-feet per annum, made in the State of Arizona.

State of Colorado	51.75 per cent,
State of New Mexico	11.25 per cent,
State of Utah	23.00 per cent,
State of Wyoming	14.00 per cent.

(b) The apportionment made to the respective States by paragraph (a) of this Article is based upon, and shall be applied in conformity with, the following principles and each of them:

(1) The apportionment is of any and all man-made depletions;

(2) Beneficial use is the basis, the measure and the limit of the right to use;

(3) No State shall exceed its apportioned use in any water year when the effect of such excess use, as determined by the Commission, is to deprive another signatory State of its apportioned use during that water year; provided, that this subparagraph (b) (3) shall not be construed as:

(i) Altering the apportionment of use, or obligations to make deliveries as provided in Article XI, XII, XIII or XIV of this Compact;

(ii) Purporting to apportion among the signatory States such uses of water as the Upper Basin may be entitled to under paragraphs (f) and (g) of Article III of the Colorado River Compact; or

(iii) Countenancing average uses by any signatory State in excess of its apportionment.

(4) The apportionment to each State includes all water necessary for the supply of any rights which now exist.

(c) No apportionment is hereby made, or intended to be made, of such uses of water as the Upper Basin may be entitled to under paragraphs (f) and (g) of Article III of the Colorado River Compact.

(d) The apportionment made by this Article shall not be taken as any basis for the allocation among the signatory States of any benefits resulting from the generation of power.

Article IV

In the event curtailment of use of water by the States of the Upper Division at any time shall become necessary in order that the flow at Lee Ferry shall not be depleted below that required by Article III of the Colorado River Compact, the extent of curtailment by each State of the consumptive use of water apportioned to it by Article III of this Compact shall be in such quantities and at such times as shall be determined by the Commission upon the application of the following principles:

(a) The extent and times of curtailment shall be such as to assure full compliance with Article III of the Colorado River Compact;

(b) If any State or States of the Upper Division, in the ten years immediately preceding the water year in which curtailment is necessary, shall have consumptively used more water than it was or they were, as the case may be, entitled to use under the apportionment made by Article III of this Compact, such State or States shall be required to supply at Lee Ferry a quantity of water equal to its, or the aggregate of their, overdraft or the proportionate part of such overdraft, as may be necessary to assure compliance with Article III of the Colorado River Compact, before demand is made on any other State of the Upper Division;

(c) Except as provided in subparagraph (b) of this Article, the extent of curtailment by each State of the Upper Division of the consumptive use of water apportioned to it by Article III of this Compact shall be such as to result in the delivery at Lee Ferry of a quantity of water which bears the same relation to the total required curtailment of use by the States of the Upper Division as the consumptive use of Upper Colorado River System water which was made by each such State during the water year immediately preceding the year in which the curtailment becomes necessary bears to the total consumptive use of such water in the States of the Upper Division during the same water year; provided, that in determining such relation the uses of water under rights perfected prior to November 24, 1922, shall be excluded.

Article V

(a) All losses of water occurring from or as the result of the storage of water in reservoirs constructed prior to the signing of this Compact shall be charged to the State in which such reservoir or reservoirs are located. Water stored in reservoirs covered by this paragraph (a) shall be for the exclusive use of and shall be charged to the State in which the reservoir or reservoirs are located.

(b) All losses of water occurring from or as the result of the storage of water in reservoirs constructed after the signing of this Compact shall be charged as follows:

(1) If the Commission finds that the reservoir is used, in whole or in part, to assist the States of the Upper Division in meeting their obligations to deliver water at Lee Ferry imposed by Article III of the Colorado River Compact, the Commission shall make findings, which in no event shall be contrary to the laws of the United States of America under which any reservoir is constructed, as to the reservoir capacity allocated for that purpose. The whole or that proportion, as the case may be, of reservoir losses as found by the Commission to be reasonably and properly chargeable to the reservoir or reservoir capacity utilized to assure deliveries at Lee Ferry shall be charged to the States of the Upper Division in the proportion which the consumptive use of water in each State of the Upper Division during the water year in which the charge is made bears to the total consumptive use of water in all States of the Upper Division during the same water year. Water stored in reservoirs or in reservoir capacity covered by this subparagraph (b) (1) shall be for the common benefit of all of the States of the Upper Division.

(2) If the Commission finds that the reservoir is used, in whole or in part, to supply water for use in a State of the Upper Division, the Commission shall make findings, which in no event shall be contrary to the laws of the United States of America under which any reservoir is constructed, as to the reservoir or reservoir capacity utilized to supply water for use and the State in which such water will be used. The whole or that proportion, as the case may be, of reservoir losses as found by the Commission to be reasonably and properly chargeable to the State in which such water will be used shall be borne by that State. As determined by the Commission, water stored in reservoirs covered by this subparagraph (b) (2) shall be earmarked for and charged to the State in which the water will be used.

(c) In the event the Commission finds that a reservoir site is available both to assure deliveries at Lee Ferry and to store water for consumptive use in a State of the Upper Division, the storage of water for consumptive use shall be given preference. Any reservoir or reservoir capacity hereafter used to assure deliveries at Lee Ferry shall by order of the Commission be used to store water for consumptive use in a State, provided the Commission finds that such storage is reasonably necessary to permit such State to make the use of the water apportioned to it by this Compact.

Article VI

The Commission shall determine the quantity of the consumptive use of water, which use is apportioned by Article III hereof, for the Upper Basin and for each State of the Upper Basin by the inflow-outflow method in terms of man-made depletions of the virgin flow at Lee Ferry, unless the Commission, by unanimous action, shall adopt a different method of determination.

Article VII

The consumptive use of water by the United States of America or any of its agencies, instrumentalities or wards shall be charged as a use by the State in which the use is made; provided, that such consumptive use incident to the diversion, impounding, or conveyance of water in one State for use in another shall be charged to such latter State.

Article VIII

(a) There is hereby created an interstate administrative agency to be known as the "Upper Colorado River Commission." The Commission shall be composed of one Commissioner representing each of the States of the Upper Division, namely, the States of Colorado, New Mexico, Utah and Wyoming, designated or appointed in accordance with the laws of each such State and, if designated by the President, one Commissioner representing the United States of America. The President is hereby requested to designate a Commissioner. If so designated the Commissioner representing the United States of America shall be the presiding officer of the Commission and shall be entitled to the same powers and rights as the Commissioner of any State. Any four members of the Commission shall constitute a quorum.

(b) The salaries and personal expenses of each Commissioner shall be paid by the Government which he represents. All other expenses which are incurred by the Commission incident to the administration of this Compact, and which are not paid by the United States of America, shall be borne by the four States according to the percentage of consumptive use apportioned to each. On or before December 1 of each year, the Commission shall adopt and transmit to the Governors of the four States and to the President a budget covering an estimate of its expenses for the following year, and of the amount payable by each State. Each State shall pay the amount due by it to the Commission on or before April 1 of the year following. The payment of the expenses of the Commission and of its employees shall not be subject to the audit and accounting procedures of any of the four States; however, all receipts and disbursement of funds handled by the Commission shall be audited yearly by a qualified independent public accountant and the report of the audit shall be included in and become a part of the annual report of the Commission.

(c) The Commission shall appoint a Secretary, who shall not be a member of the Commission, or an employee of any signatory State or of the United States of America while so acting. He shall serve for such term and receive such salary and perform such duties as the Commission may direct. The Commission may employ such engineering, legal, clerical and other personnel as, in its judgment, may be necessary for the performance of its functions under this Compact. In the hiring of employees, the Commission shall not be bound by the civil service laws of any State.

(d) The Commission, so far as consistent with this Compact, shall have power to:

(1) Adopt rules and regulations;

(2) Locate, establish, construct, abandon, operate and maintain water gaging stations;

(3) Make estimates to forecast water run-off on the Colorado River and any of its tributaries;

(4) Engage in cooperative studies of water supplies of the Colorado River and its tributaries;

(5) Collect, analyze, correlate, preserve and report on data as to the stream flows, storage, diversions and use of the waters of the Colorado River, and any of its tributaries;

(6) Make findings as to the quantity of water of the Upper Colorado River System used each year in the Upper Colorado River Basin and in each State thereof;

(7) Make findings as to the quantity of water deliveries at Lee Ferry during each water year;

(8) Make findings as to the necessity for and the extent of the curtailment of use, required, if any, pursuant to Article IV hereof;

(9) Make findings as to the quantity of reservoir losses and as to the share thereof chargeable under Article V hereof to each of the States;

(10) Make findings of fact in the event of the occurrence of extraordinary drought or serious accident to the irrigation system in the Upper Basin, whereby deliveries by the Upper Basin of water which it may be required to deliver in order to aid in fulfilling obligations of the United States of America to the United Mexican States arising under the Treaty between the United States of America and the United Mexican States, dated February 3, 1944 (Treaty Series 994) becomes difficult, and report such findings to the Governors of the Upper Basin States, the President of the United States of America, the United States Section of the International Boundary and Water Commission, and such other Federal officials and agencies as it may deem appropriate to the end that the water allotted to Mexico under Division III of such treaty may be reduced in accordance with the terms of such Treaty;

(11) Acquire and hold such personal and real property as may be necessary for the performance of its duties hereunder and to dispose of the same when no longer required;

(12) Perform all functions required of it by this Compact and do all things necessary, proper or convenient in the performance of its duties hereunder, either independently or in cooperation with any state or federal agency;

(13) Make and transmit annually to the Governors of the signatory States and the President of the United States of America, with the estimated budget, a report covering the activities of the Commission for the preceding water year.

(e) Except as otherwise provided in this Compact the concurrence of four members of the Commission shall be required in any action taken by it.

(f) The Commission and its Secretary shall make available to the Governor of each of the signatory States any information within its possession at any time, and shall always provide free access to its records by the Governors of each of the States, or their representatives, or authorized representatives of the United States of America.

(g) Findings of fact made by the Commission shall not be conclusive in any court, or before any agency or tribunal, but shall constitute prima facie evidence of the facts found.

(h) The organization meeting of the Commission shall be held within four months from the effective date of this Compact.

Article IX

(a) No State shall deny the right of the United States of America and, subject to the conditions hereinafter contained, no State shall deny the right of another signatory State, any person, or entity of any signatory State to acquire rights to the use of water, or to construct or participate in the construction and use of diversion works and storage reservoirs with appurtenant works, canals and conduits in one State for the purpose of diverting, conveying, storing, regulating and releasing water to satisfy the provisions of the Colorado River Compact relating to the obligation of the States of the Upper Division to make deliveries of water at Lee Ferry, or for the purpose of diverting, conveying, storing or regulating water in an upper signatory State for consumptive use in a lower signatory State, when such use is within the apportionment to such lower State made by this Compact. Such rights shall be subject to the rights of water users, in a State in which such reservoir or works are located, to receive and use water, the use of which is within the apportionment to such State by this Compact.

(b) Any signatory State, any person, or any entity of any signatory State shall have the right to acquire such property rights as are necessary to use of water in conformity with this Compact in any other signatory State by donation, purchase or through the exercise of the power of eminent domain. Any signatory State, upon the written request of the Governor of any other signatory State, for the benefit of whose water users property is to be acquired in the State to which such written request is made, shall proceed expeditiously to acquire the desired property either by purchase at a price satisfactory to the requesting State, or, if such purchase cannot be made, then through the exercise of its power of eminent domain and shall convey such property to the requesting State or such entity as may be designated by the requesting State; provided, that all costs of acquisition and expenses of every kind and nature whatsoever incurred in obtaining the requested property shall be paid by the requesting State at the time and in the manner prescribed by the State requested to acquire the property.

(c) Should any facility be constructed in a signatory State by and for the benefit of another signatory State or States or the water users thereof, as above provided, the construction, repair, replacement, maintenance and operation of such facility shall be subject to the laws of the State in which the facility is located, except that, in the case of a reservoir constructed in one State for the benefit of another State or States, the water administration officials of the State in which the facility is located shall permit the storage and release of any water which, as determined by findings of the Commission, falls within the apportionment of the State or States for whose benefit the facility is constructed. In the case of a regulating reservoir for the joint benefit of all States in making Lee Ferry deliveries, the water administration officials of the State in which the facility is located, in permitting the storage and release of water, shall comply with the findings and orders of the Commission.

(d) In the event property is acquired by a signatory State in another signatory State for the use and benefit of the former, the users of water made available by such facilities, as a condition precedent to the use thereof, shall pay to the political subdivisions of the State in which such works are located, each and every year during which such rights are enjoyed for such purposes, a sum of money equivalent to the average annual amount of taxes levied and assessed against the land and improvements thereon during the ten years preceding the acquisition of such land. Said payments shall be in full reimbursement for the loss of taxes in such political subdivisions of the State, and in lieu of any and all taxes on said property, improvements and rights. The signatory States recommend to the President and the Congress that, in the event the United States of America shall acquire property in one of the signatory States for the benefit of another signatory State, or its water users, provision be made for like payment in reimbursement of loss of taxes.

Article X

(a) The signatory States recognize La Plata River Compact entered into between the States of Colorado and New Mexico, dated November 27, 1922, approved by the Congress on January 29, 1925 (43 Stat. 796), and this Compact shall not affect the apportionment therein made.

(b) All consumptive use of water of La Plata River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

Article XI

Subject to the provisions of this Compact, the consumptive use of the water of the Little Snake River and its tributaries is hereby apportioned between the States of Colorado and Wyoming in such quantities as shall result from the application of the following principles and procedures:

(a) Water used under rights existing prior to the signing of this Compact.

(1) Water diverted from any tributary of the Little Snake River or from the main stem of the Little Snake River above a point one hundred feet below the confluence of Savery Creek and the Little Snake River shall be administered without regard to rights covering the diversion of water from any down-stream points.

(2) Water diverted from the main stem of the Little Snake River below a point one hundred feet below the confluence of Savery Creek and the Little Snake River shall be administered on the basis of an interstate priority schedule prepared by the Commission in conformity with priority dates established by the laws of the respective States.

(b) Water used under rights initiated subsequent to the signing of this Compact.

(1) Direct flow diversion shall be so administered that, in time of shortage, the curtailment of use on each acre of land irrigated thereunder shall be as nearly equal as may be possible in both of the States.

(2) The storage of water by projects located in either State, whether of supplemental supply or of water used to irrigate land not irrigated at the date of the signing of this Compact, shall be so administered that in times of water shortage the curtailment of storage of water available for each acre of land irrigated thereunder shall be as nearly equal as may be possible in both States.

(c) Water uses under the apportionment made by this Article shall be in accordance with the principle that beneficial use shall be the basis, measure and limit of the right to use.

(d) The States of Colorado and Wyoming each assent to diversions and storage of water in one State for use in the other State, subject to compliance with Article IX of this Compact.

(e) In the event of the importation of water to the Little Snake River Basin from any other river basin, the State making the importation shall have the exclusive use of such imported water unless by written agreement, made by the representatives of the States of Colorado and Wyoming on the Commission, it is otherwise provided.

(f) Water use projects initiated after the signing of this Compact, to the greatest extent possible, shall permit the full use within the Basin

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in the most feasible manner of the waters of the Little Snake River and its tributaries, without regard to the state line; and, so far as is practicable, shall result in an equal division between the States of the use of water not used under rights existing prior to the signing of this Compact.

(g) All consumptive use of the waters of the Little Snake River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

Article XII

Subject to the provisions of this Compact, the consumptive use of the waters of Henry's Fork, a tributary of Green River originating in the State of Utah and flowing into the State of Wyoming and thence into the Green River in the State of Utah; Beaver Creek, originating in the State of Utah and flowing into Henry's Fork in the State of Wyoming; Burnt Fork, a tributary of Henry's Fork, originating in the State of Utah and flowing into Henry's Fork in the State of Wyoming; Birch Creek, a tributary of Henry's Fork originating in the State of Utah and flowing into Henry's Fork in the State of Wyoming; and Sheep Creek, a tributary of Green River in the State of Utah, and their tributaries, are hereby apportioned between the States of Utah and Wyoming in such quantities as will result from the application of the following principles and procedures:

(a) Waters used under rights existing prior to the signing of this Compact.

Waters diverted from Henry's Fork, Beaver Creek, Burnt Fork, Birch Creek and their tributaries, shall be administered without regard to the state line on the basis of an interstate priority schedule to be prepared by the States affected and approved by the Commission in conformity with the actual priority of right of use, the water requirements of the land irrigated and the acreage irrigated in connection therewith.

(b) Waters used under rights from Henry's Fork, Beaver Creek, Burnt Fork, Birch Creek and their tributaries, initiated after the signing of this Compact shall be divided fifty percent to the State of Wyoming and fifty percent of the State of Utah and each State may use said waters as and where it deems advisable.

(c) The State of Wyoming assents to the exclusive use by the State of Utah of the water of Sheep Creek, except that the lands, if any, presently irrigated in the State of Wyoming from the water of Sheep Creek shall be supplied with water from Sheep Creek in order of priority and in such quantities as are in conformity with the laws of the State of Utah.

(d) In the event of the importation of water to Henry's Fork, or any of its tributaries, from any other river basin, the State making the importation shall have the exclusive use of such imported water unless by written agreement made by the representatives of the States of Utah and Wyoming on the Commission, it is otherwise provided.

(e) All consumptive use of waters of Henry's Fork, Beaver Creek, Burnt Fork, Birch Creek, Sheep Creek, and their tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

(f) The States of Utah and Wyoming each assent to the diversion and storage of water in one State for use in the other State, subject to compliance with Article IX of this Compact. It shall be the duty of the water administrative officials of the State where the water is stored to release said stored water to the other State upon demand. If either the State of Utah or the State of Wyoming shall construct a reservoir in the other State for use in its own State, the water users of the State in which said facilities are constructed may purchase at cost a portion of the capacity of said reservoir sufficient for the irrigation of their lands thereunder.

(g) In order to measure the flow of water diverted, each State shall cause suitable measuring devices to be constructed, maintained and operated at or near the point of diversion into each ditch.

(h) The State Engineers of the two States jointly shall appoint a Special Water Commissioner who shall have authority to administer the water in both States in accordance with the terms of this Article. The salary and expenses of such Special Water Commissioner shall be paid, thirty percent by the State of Utah and seventy percent by the State of Wyoming.

Article XIII

Subject to the provisions of this Compact, the rights to the consumptive use of the water of the Yampa River, a tributary entering the Green River in the State of Colorado, are hereby apportioned between the States of Colorado and Utah in accordance with the following principles:

(a) The State of Colorado will not cause the flow of the Yampa River at the Maybell Gaging Station to be depleted below an aggregate of 5,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification and approval of this Compact. In the event any diversion is made from the Yampa River or from tributaries entering the Yampa River above the Maybell Gaging Station for the benefit of any water use project in the State of Utah, then the gross amount of all such diversions for use in the State of Utah, less any returns from such diversions to the River above Maybell, shall be added to the actual flow at the Maybell Gaging Station to determine the total flow at the Maybell Gaging Station.

(b) All consumptive use of the waters of the Yampa River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

Article XIV

Subject to the provisions of this Compact, the consumptive use of the waters of the San Juan River and its tributaries is hereby apportioned between the States of Colorado and New Mexico as follows:

The State of Colorado agrees to deliver to the State of New Mexico from the San Juan River and its tributaries which rise in the State of Colorado a quantity of water which shall be sufficient, together with water originating in the San Juan Basin in the State of New Mexico, to enable the State of New Mexico, to make full use of the water apportioned to the State of New Mexico by Article III of this Compact, subject, however, to the following:

(a) A first and prior right shall be recognized as to:

(1) All uses of water made in either State at the time of the signing of this Compact; and

(2) All uses of water contemplated by projects authorized, at the time of the signing of this Compact, under the laws of the United States of America whether or not such projects are eventually constructed by the United States of America or by some other entity.

(b) The State of Colorado assents to diversions and storage of water in the State of Colorado for use in the State of New Mexico, subject to compliance with Article IX of this Compact.

(c) The uses of the waters of the San Juan River and any of its tributaries within either State which are dependent upon a common source of water and which are not covered by (a) hereof, shall in times of water shortages be reduced in such quantity that the resulting consumptive use in each State will bear the same proportionate relation to the consumptive use made in each State during times of average water supply as determined by the Commission; provided, that any preferential uses of water to which Indians are entitled under Article XIX shall be excluded in determining the amount of curtailment to be made under this paragraph.

(d) The curtailment of water use by either State in order to make deliveries at Lee Ferry as required by Article IV of this Compact shall be independent of any and all conditions imposed by this Article and shall be made by each State, as and when required, without regard to any provision of this Article.

(e) All consumptive use of the waters of the San Juan River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State.

Article XV

(a) Subject to the provisions of the Colorado River Compact and of this Compact, water of the Upper Colorado River system may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(b) The provisions of this Compact shall not apply to or interfere with the right or power of any signatory State to regulate within its boundaries the appropriation, use and control of water, the consumptive use of which is apportioned and available to such State by this Compact.

Article XVI

The failure of any State to use the water, or any part thereof, the use of which is apportioned to it under the terms of this Compact, shall not constitute a relinquishment of the right to such use to the Lower Basin or to any other State, nor shall it constitute a forfeiture or abandonment of the right to such use.

Article XVII

The use of any water now or hereafter imported into the natural drainage basin of the Upper Colorado River System shall not be charged to any State under the apportionment of consumptive use made by this Compact.

Article XVIII

(a) The State of Arizona reserves its rights and interests under the Colorado River Compact as a State of the Lower Division and as a State of the Lower Basin.

(b) The State of New Mexico and the State of Utah reserve their respective rights and interests under the Colorado River Compact as States of the Lower Basin.

Article XIX

Nothing in this Compact shall be construed as:

(a) Affecting the obligations of the United States of America to Indian tribes;

(b) Affecting the obligations of the United States of America under the Treaty with the United Mexican States (Treaty Series 994);

(c) Affecting any rights or powers of the United States of America, its agencies or instrumentalities, in or to the waters of the Upper Colorado River System, or its capacity to acquire rights in and to the use of said waters;

(d) Subjecting any property of the United States of America, its agencies or instrumentalities, to taxation by any State or subdivision thereof, or creating any obligation on the part of the United States of America, its agencies or instrumentalities, by reason of the acquisition, construction or operation of any property or works of whatever kind, to make any payments to any State or political subdivision thereof, State agency, municipality or entity whatsoever, in reimbursement for the loss of taxes;

(e) Subjecting any property of the United States of America, its agencies or instrumentalities, to the laws of any State to an extent other than the extent to which such laws would apply without regard to this Compact.

Article XX

This Compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination, all rights established under it shall continue unimpaired.

Article XXI

This Compact shall become binding and obligatory when it shall have been ratified by the legislatures of each of the signatory States and approved by the Congress of the United States of America. Notice of ratification by the legislatures of the signatory States shall be given by the Governor of each signatory State to the Governor of each of the other signatory States and to the President of the United States of America, and the President is hereby requested to give notice to the Governor of each of the signatory States of approval by the Congress of the United States of America.

IN WITNESS WHEREOF, the Commissioners have executed six counterparts hereof, each of which shall be and constitute an original, one of which shall be deposited in the archives of the Department of State of the United States of America, and one of which shall be forwarded to the Governor of each of the signatory States.

Done at the City of Santa Fe, State of New Mexico, this 11th day of October, 1948.

CHARLES A. CARSON
Commissioner for the State of Arizona

CLIFFORD H. STONE
Commissioner for the State of Colorado

FRED E. WILSON
Commissioner for the State of New Mexico

EDWARD H. WATSON
Commissioner for the State of Utah

L. C. BISHOP
Commissioner for the State of Wyoming

GROVER A. GILES, Secretary

Approved:

HARRY W. BASHORE
Representative of the United States of America

UNITED STATES DEPARTMENT OF THE INTERIOR

Office of the Solicitor
Washington, D.C. 20240

December 6, 1974

Memorandum

To : Under Secretary

From : Solicitor

Subject: Navajo Indian Irrigation Project -- Water entitlement of Navajo Tribe

The Navajo Indian Irrigation Project, authorized by the Act of June 13, 1962, 43 U.S.C. 615ii, et seq., will deliver water from the Navajo Reservoir on the San Juan River (a tributary of the Colorado River) to various irrigable uplands on the Navajo Reservation.

Section 2 of the Act (43 U.S.C. 615jj) provides, in pertinent part, as follows:

> Pursuant to the provisions of the Act of April 11, 1956 [Colorado River Storage Project Act], as amended, the Secretary of the Interior is authorized to construct, operate, and maintain the Navajo Indian irrigation project for the principal purpose of furnishing irrigation water to approximately one hundred and ten thousand six hundred and thirty [110,630] acres of land, said project to have an average annual diversion of five hundred and eight thousand [508,000] acre-feet of water . . . .

You have inquired whether the Navajo Tribe is entitled under Section 2 to divert from the river all of the average annual diversion of 508,000 acre-feet, without regard to the purpose for which such diversion is made, or whether the Tribe is limited by the Act to use only so much of the 508,000 acre-feet as is reasonably necessary to irrigate 110,630 acres of land.

The issue has become critical now because of the pending proposal to convert from a gravity distribution system -- as originally planned for in the Navajo Indian Irrigation Project -- to a sprinkler system. Under the gravity system, it was estimated that to irrigate the 110,630 acres there would be an average annual diversion of 508,000 acre-feet from the river, and that about 256,000 acre-feet would find

(Retyped for printing of the FES)

its way back to the river in the form of return flows; thus, the average annual depletion from the river for gravity system would be about 252,000 acre-feet. By the conversion to a sprinkler system, it is estimated that only 370,000 acre-feet of water would be required to be diverted to irrigate the same amount of acres and that there would be a return flow of 140,000 acre-feet, with a net depletion of only about 230,000 acre-feet. The question has been raised whether, in connection with a sprinkler system, the Tribe is entitled to divert and to consumptively use for any purpose an additional 138,000 acre-feet -- i.e., the difference between the 508,000 acre-feet diversion authorized in Section 2 of the Act and the 370,000 acre-feet diversion required for irrigation of the lands by a sprinkler system.

My conclusion is that the Tribe is limited to the use of so much project water as would be reasonably necessary to irrigate the 110,630 acres, except to the extent it contracts to purchase other waters for municipal and industrial purposes under the separate procedures established in Section 4 of the Act, 43 U.S.C. 615-11. Thus, if the amount required to irrigate the 110,630 acres with a sprinkler system is 370,000 acre-feet, the Tribe is limited to that amount. An argument for a contrary conclusion has been advanced, based on the language of Section 2 which states that the Navajo Indian irrigation project shall be operated "for the principal purpose of furnishing irrigation water to approximately" 110,630 acres. It is argued that this, standing alone, may create the inference that other uses of diverted water are permissible, so long as irrigation is the "chief" purpose.

Any such inference, however, is completely negated by the language of both Section 4 and Section 8 of the Act, as well as its legislative history. Section 4 states:

> In developing the Navajo Indian irrigation project, the Secretary is authorized to provide capacity for municipal and industrial water supplies or miscellaneous purposes <u>over and above the diversion requirements for irrigation stated in section 2 of this Act</u> [emphasis added], but such additional capacity shall not be constructed and no appropriation of funds for such construction shall be made until contracts have been been executed which, in the judgment of the Secretary, provide satisfactory assurance of repayment of all costs properly allocated to the purposes aforesaid with interest as provided by law.

This section limits the 508,000 acre-foot diversion authorization in Section 2 to irrigation. Any other uses of water are "over and above" the irrigation diversion and, in addition, are to be pursuant to a contract that contains repayment provisions.

The repayment scheme, while present in Section 4, is not applicable to Section 2 because of the provision therein that repayment is subject to Section 4(d) of the act of April 11, 1956, 43 U.S.C. 620c. The latter Act, in turn, incorporates the so-called Leavitt Act (Act of July 1, 1932, 47 Stat 564) which defers repayment of construction costs for irrigating Indian lands. That Section 2 was thus made subject to the provision for deferment of Indian irrigation costs confirms my conclusion as to its limited purpose.

Reading Section 2 and Section 4 together, it is my opinion that Congress intended the 508,000 acre-feet to be diverted under Section 2 to be used exclusively for the irrigation of the 110,630 acres and not for municipal and industrial purposes. This conclusion is buttressed by Section 8 (43 U.S.C. 615pp) which refers to the San Juan-Chama project (also authorized by the Act). Section 8 provides in pertinent part as follows:

> Pursuant to the provisions of the Act of April 11, 1956, as amended, the Secretary is authorized to construct, operate, and maintain the initial stage of the San Juan-Chama project, Colorado-New Mexico, for the principal purposes of furnishing water supplies to approximately thirty-nine thousand three hundred acres of land in the Cerro, Taos, Llano, and Pojoque tributary irrigation units in the Rio Grande Basin and approximately eighty-one thousand six hundred acres of land in the existing Middle Rio Grande Conservancy District and for municipal, domestic and industrial uses, and providing recreation and fish and wildlife benefits [Emphasis added].

Section 8 also expressly states that the principal purpose of the San Juan-Chama project is for irrigation and then proceeds to list the other project purposes, which include in addition to "municipal, domestic and industrial uses," "recreation and fish and wildlife benefits." On the other hand, Section 2 mentions no purpose for the diversion other than the principal purpose of the project, irrigation.

Thus, from a reading of the three relevant sections of the Act together, it is clear that, in Section 2 (as well as Section 8) Congress used "principal purpose" in the sense of "principal purpose of the project," not in the sense of "principal purpose of the diversion." It is equally clear, both from a comparison with Section 8 and from the express language of Section 4, that the diversions authorized by Section 2 are to be only for the principal purpose of the Navajo Indian Irrigation Project, i.e., irrigation. Any diversion for any other purpose, as mentioned above, must be made pursuant to Section 4.

The conclusion reached in this opinion is further underscored by the focus in the planning of the project and in the legislative history of the Act on the amount of the 508,000 acre-foot diversion that would find its way back to the river as return flows.

The last sentence of Section 1 of the Act states:

> The Navajo Indian irrigation project and the initial stage of the San Juan-Chama project herein approved are substantially those described in the proposed coordinated report of the Acting Commissioner of Reclamation and the Commissioner of Indian Affairs, approved and adopted by the Secretary of the Interior on October 16, 1957, as conditioned, modified, and limited herein.

At page 275, the 1957 Report referred to in Section 1 of the Act described the Navajo Indian Irrigation Project as diverting 508,130 acre-feet and having an average annual stream depletion of 253,000 acre-feet (after adjusting for reservoir losses). In the Secretary of the Interior's April 5, 1961 letter to the Chairman of the House Committee on Interior and Insular Affairs recommending authorization of the project, which is part of the Committee Report (H. Rept. 685, 87th Cong., 1st Sess., p. 16), the Navajo Indian Irrigation Project is similarly described as having an average annual diversion of about 508,000 acre-feet and an average annual stream depletion of about 252,000 acre-feet.

There were some differences in the course of the hearings on whether New Mexico might not exceed its entitlement under the Colorado River Compact and the Upper Colorado River Basin Compact if the Act was passed, and the House Committee requested its own engineering consultant, Sidney L. McFarland, to analyze that data. His findings appear at page 332, 348-49, of the hearings before the Subcommittee on Irrigation and Reclamation of the House Interior Committee, 87th Cong., 1st Sess., April 24-25-26 and June 1, 1961. Mr. McFarland concluded that the Navajo Indian Irrigation Project would effect a diversion of 508,000, with 255,700 being returned to the river, for a net depletion of 252,300 acre-feet. He assured the Committee that based upon such a depletion, the Navajo Indian Irrigation Project could be authorized without causing New Mexico to exceed the amount of water available to it under the compacts.

The importance of the assurance provided by Mr. McFarland to the Congressional deliberations is highlighted by the following excerpt from page 7 of H. Rept. 685:

> Based upon the study of committee members and staff and upon the testimony given, the committee concludes that water is physicially available and within New Mexico's entitlement under the compacts for the successful operation of the Navajo Indian irrigation Project. At the same time, the committee points out that its studies indicate that. with these two

> projects in operation, water uses in New Mexico may be approaching New Mexico's expected compact entitlement. The committee has added language in the legislation to require that additional water uses from Navajo Reservoir be fully justified on the basis of additional hydrologic studies and to require that contracts covering such additional uses be approved by the Congress before such contracts are executed.

A similar preoccupation with the relationship between the depletions caused by the projects and New Mexico's entitlement under the compacts is reflected in the following finding at page 2 of Report No. 83 of the Senate Committee on Interior and Insular Affairs, 87th Congress, 1st Session:

> That the combined average annual stream depletion of the two projects as proposed for authorization totaling 362,300 acre-feet, together with existing and other authorized uses, will keep New Mexico's authorized draft on the Colorado River System well within the State's average annual entitlement estimated at 838,000 acre-feet.

The congressional concern that the authorization of the project not cause New Mexico to exceed its entitlement is reiterated in Section 11 of the Act, 43 U.S.C. 615ss, (where the Secretary is precluded from entering into long-term contracts for the sale of additional water from the San Juan River and its tributaries without additional congressional approval); Section 12, 43 U.S.C.tt, (where the Secretary is directed to operate the project so as not to divert more water than will exceed the water available to New Mexico and Arizona under the Upper Colorado River Basin Compact); Section 13, 43 U.S.C. 615uu, (which requires that the water used and diverted through the works authorized under the Act be subject to and controlled by the Colorado River Compact, the Upper Colorado River Basin Compact, and other pertinent statutes and treaties); and Section 14, 43 U.S.C. 615vv, (where the Secretary is further directed to operate and maintain the project in accordance with said authorities).

It is further important to keep in mind that the Act reflected the striking of a balance between Indian and non-Indian interests for the use of the waters of the San Juan River and that the Navajo Tribe understood and consented to the limitations imposed upon its right under the Act to receive delivery of the waters from the San Juan River through project works. By resolution of the Navajo Tribal Council of December 12, 1957, the Tribe endorsed the 1957 Report, wherein the estimated diversion and depletion entitlements for the Navajo Indian Irrigation Project are explicitly set forth.

The Resolution also states on page 1 that the Tribe fully appreciated the compromise nature of the Act:

> In return for the generous support of the State of New Mexico for the proposed Navajo Indian Irrigation Project, and in recognition of the fact that the maximum economic development of all parts of New Mexico is a benefit to all citizens of New Mexico, including Navajo citizens of New Mexico, the Navajo Tribal Administration has supported authorization of the proposed San Juan-Chama Transmountain Diversion at the same time the Navajo Indian Irrigation Project is authorized . . . .

June 13, 1962
[S. 107]

Navajo Indian irrigation project; San Juan-Chama project.

Moreover, the Tribe agreed in the Resolution to the principle of sharing shortages with other project users, and Section 11 of the Act makes the right of the Tribe to the delivery of project water conditional upon its willingness to share such shortages.

It should be noted that the question of the Tribe's Winters rights in the San Juan River is neither being addressed nor decided in this memorandum. Our concern is limited solely to the question of what the Tribe's rights are to the delivery of project water under the Act. The remaining question involves the availability to the Tribe of the approximately 24,000 acre-feet of water that, in terms of net depletion to the river, would be saved by the proposed conversion from a gravity to a sprinkler system. The Solicitor, in his memorandum of May 17, 1974, to the Under Secretary, has already noted that the Bureau of Reclamation (as well as the New Mexico Stream Commission) has agreed this water would be made available to the Tribe. It is clear that one way the Bureau may accomplish this and make such water available is under the authority of Section 4 by means of a contract executed pursuant to Section 11. In addition, the legislative history discussed above clearly demonstrates that it was the Congressional expectation that this 24,000 acre-feet of water would be consumptively used by the Tribe -- and not others. Therefore, to make it available to the Tribe under Section 4, or otherwise, would be consistent with the Congressional intent.

43 USC 620-620o.

43 USC 620c.

Publication in F.R.

41 Stat. 437.

In summary, the conclusion of this opinion is that (1) the Tribe is entitled under the Act to the use of so much project water as could be reasonably necessary to irrigate the 110,630 acres -- whether that amount actually turns out in the operation of the project sprinkler system to be 370,000 acre-feet, or some other figure (either greater or less than 370,000 acre-feet); (2) the Tribe may use water authorized to be diverted by Section 2 only in relation to the principal purpose of the project, i.e., irrigation; and (3) the Department has the authority (but not under Section 2) to make available to the Tribe the approximately 24,000 acre-feet net depletion saving resulting from the conversion to a sprinkler system.

Land acquisition.

/s/ David E. Lindgren
David E. Lindgren

Appendix D

RESULTS OF SAN JUAN RIVER
SYSTEM OPERATION STUDY

Sources: U.S. Fish and Wildlife Service (1981) and J. Morrison (1982).

(*) Note: these data transmitted to J.A. Gilman during Telecon w/ Jimmy Morrison 1/22/82

EFFECTS OF GALLUP-NAVAJO PROJECT ON THE SAN JUAN RIVER FLOW (FT3/S) NEAR ARCHULETA, NM DURING THE CRITICAL PERIOD AUGUST 1952-OCTOBER 1956. FLOWS ARE AVERAGE MONTHLY FLOWS. PROJECT FLOWS OF 267 AND 269 ARE ALSO MINIMUM FLOWS.

	NATURAL FLOW	(*) Flow at Animas R. @Farmington (1000 acre-ft)	2030 CONDITIONS FLOW WITHOUT PROJECT	SAN JUAN RIVER DIVERSION MAXIMUM	SAN JUAN RIVER DIVERSION MINIMUM	COTTONWOOD RESERVOIR MAXIMUM	COTTONWOOD RESERVOIR MINIMUM
1952							
AUG	988	5.6	341	341	341	267	299
SEP	331	6.6	341	341	341	269	299
OCT	146	4.0	343	343	343	269	301
NOV	173	9.2	341	341	341	269	299
DEC	299	10.1	341	341	341	269	299
1953							
JAN	306	10.3	341	341	341	269	299
FEB	272	9.2	343	343	343	269	301
MAR	659	10.9	341	341	341	269	299
APR	1405	21.2	341	341	341	269	299
MAY	2218	35.1	341	341	341	269	299
JUN	3032	96.3	343	343	343	269	301
JUL	655	1.4	435	452	435	435	435
AUG	365	1.2	341	341	341	267	299
SEP	0	1.0	341	341	341	269	299
OCT	133	6.5	343	343	343	269	301
NOV	348	11.8	341	341	341	269	299
DEC	240	12.1	341 (circled: minimum)	341	341	269	299
1954							
JAN	205	11.8	341	341	341	269	299
FEB	351	10.6	343	343	343	269	301
MAR	529	11.3	341	341	341	269	299
APR	1776	18.9	341	341	341	269	299
MAY	3023	55.8	341	341	341	269	299
JUN	1390	36.6	343	343	343	269	301
JUL	1023	22.8	457	457	457	457	455
AUG	750	3.9	341	341	341	267	299
SEP	534	7.1	341	341	341	269	299
OCT	215	22.6	343	343	343	269	301
NOV	131	7.2	341	341	341	269	299
DEC	234	7.7	341	341	341	269	299
1955							
JAN	224	9.0	341	341	341	269	299
FEB	224	8.3	343	343	343	269	301
MAR	486	9.7	341	341	341	269	299
APR	871	12.2	341	341	341	269	299
MAY	2659	50.4	341	341	341	269	299
JUN	2711	83.0	343	343	343	269	301
JUL	711	2.7	479	479	479	479	479
AUG	1355	9.8	341	341	341	267	299
SEP	318	1.2	341	341	341	269	299
OCT	84	3.9	343	343	343	269	301
NOV	202	6.3	341	341	341	269	299
DEC	277	9.3	341	341	341	269	299
1956							
JAN	296	8.8	341	341	341	269	299
FEB	267	8.7	343	343	343	269	301
MAR	882	14.2	341	341	341	269	299
APR	1531	15.6	341	341	341	269	299
MAY	3566	78.2	341	341	341	269	299
JUN	2573	62.5	343	343	343	269	301
JUL	531	0.5	489	489	489	491	489
AUG	308	0.5	341	341	341	267	299
SEP	10	0.2	341	341	341	269	299
OCT	18	3.9	343	343	343	269	301
Nov.		6.6					
Dec.		8.2					
1957		8.6	28.6				

cfs × 59 = acre-feet per month

acre-feet per month × .0168 = cfs

(*) original data on previous page

EFFECTS OF GALLUP-NAVAJO PROJECT ON THE SAN JUAN RIVER FLOW (FT3/S) AT FARMINGTON, NM DURING THE CRITICAL PERIOD AUGUST 1952-OCTOBER 1956.

	NATURAL FLOW	2030 CONDITIONS: FLOW WITHOUT PROJECT	Animas R. at Farmington (*) (cfs)	SAN JUAN RIVER DIVERSION MAXIMUM	SAN JUAN RIVER DIVERSION MINIMUM	COTTONWOOD RESERVOIR MAXIMUM	COTTONWOOD RESERVOIR MINIMUM
1952							
AUG	1390	484	94.1	392	434	410	442
SEP	714	541	110	464	497	469	499
OCT	366	553	67.2	497	524	479	511
NOV	427	635	154	598	613	563	593
DEC	573	644	170	612	627	571	602
1953							
JAN	576	613	173	581	597	541	571
FEB	481	534	154	506	516	460	492
MAR	918	555	183	506	531	482	513
APR	1963	674	356	605	635	602	632
MAY	3257	435	590	743	785	763	793
JUN	5349	1847	1618	1739	1786	1773	1805
JUL	1200	minimum 410	23.5	328	355	410	410
AUG	644	440	20.2	348	390	366	398
SEP	187	541	16.8	464	497	469	499
OCT	455	667	108	612	639	593	625
NOV	706	697	198	660	676	625	655
DEC	469	632	208	600	615	560	590
1954							
JAN	467	659	198	627	642	587	617
FEB	585	598	178	570	580	524	556
MAR	723	561	190	513	538	489	519
APR	2533	639	318	566	597	563	593
MAY	4877	1239	937	1146	1188	1166	1197
JUN	2622	676	447	568	615	602	634
JUL	2134	995	383	896	939	995	993
AUG	1126	487	65.5	395	437	413	445
SEP	939	627	119	550	583	555	585
OCT	1348	1331	380	1276	1302	1257	1289
NOV	529	724	131	687	702	652	682
DEC	466	560	129	528	543	487	518
1955							
JAN	514	618	151	587	602	546	576
FEB	481	580	139	551	561	506	538
MAR	825	600	163	551	576	528	558
APR	1252	531	205	462	492	459	489
MAY	3894	1092	847	1000	1042	1020	1050
JUN	4820	1623	1394	1516	1563	1549	1581
JUL	1156	476	45.4	376	420	476	476
AUG	1887	682	165	590	632	608	640
SEP	371	440	20.2	363	397	368	398
OCT	136	508	65.5	452	479	434	466
NOV	334	551	106	514	529	479	509
DEC	536	617	156	585	600	545	575
1956							
JAN	635	671	148	639	654	598	629
FEB	524	568	146	539	550	494	526
MAR	1360	682	238	634	659	610	640
APR	2112	587	262	518	548	514	545
MAY	5472	1560	1314	1467	1509	1487	1518
JUN	4405	1380	1151	1272	1319	1306	1338
JUL	881	472	8.4	373	417	474	472
AUG	543	514	8.4	422	464	440	472
SEP	156	437	8.4	360	393	365	395
OCT	104	543	65.5	487	514	469	501

minimum

APPENDIX E

HISTORIC, PRESENT, AND PROJECTED USES OF GROUND WATER FROM THE WESTWATER CANYON MEMBER AQUIFER SYSTEM

Table E-1. HISTORIC USERS OF WESTWATER CANYON MEMBER AQUIFER SYSTEM

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE AND RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
Municipal					Bush, 1979	
Crownpoint	T.17N., R.12W.			20,000 gpd (year?)		4 active wells
Well NTUA #1	sec. 19	Kd, Jmw	—	200 AFY (1977) increasing to 640 AFY in 30.5 years	Phillips Uranium Co., 1979, exhibit no. 29	
Well NTUA #2	sec. 20	Jmw				
Well #6 (BIA)	sec. 20	Kd(?), Jmw				
Well #3 (BIA)	sec. 30	Kd, Jmw		290 AFY (1978) – pumping began in 1940	Lyford, et al., 1980	
Well #5 (BIA)	sec. 30	Kd, Jmw, Jcs (?)				
Gallup	T.15 N., R.18W.			• see attached information on water use data and projections		11 operative wells in system in 1977; 5 wells not designated on this table tap only Kg
Santa Fe #1,3,7	sec. 16 (3 wells)	Kg, Kd, Jmw	(none for historic use)	• assume Jmw provided ½ of Gallup's supply from late 1950's to early 1970's; assume Jmw provided ⅓ of Gallup's supply since early 1970's	Mercer and Cooper, 1970; U.S. Geological Survey, 1981a; McLean, 1979; Umshler, 1979; Dinwiddie, et al., 1966	present well fields assumed to be able to supply 5.0 mgd (5600 AFY)
Santa Fe #9	sec. 17 (1 well)	Kg, Kd, Jmw				
Santa Fe #10 + 11	sec. 20 (2 wells)	Kg, Kd, Jmw				

from: Dinwiddie, G.A., Mourant, W.A., and Basler, J.A., 1966, Municipal water supplies + uses, n.w. N.M.: State Engineer Office Technical Report 29C

McKINLEY COUNTY 55

One 2.5-million-gallon, covered, steel, surface tank for treated water.

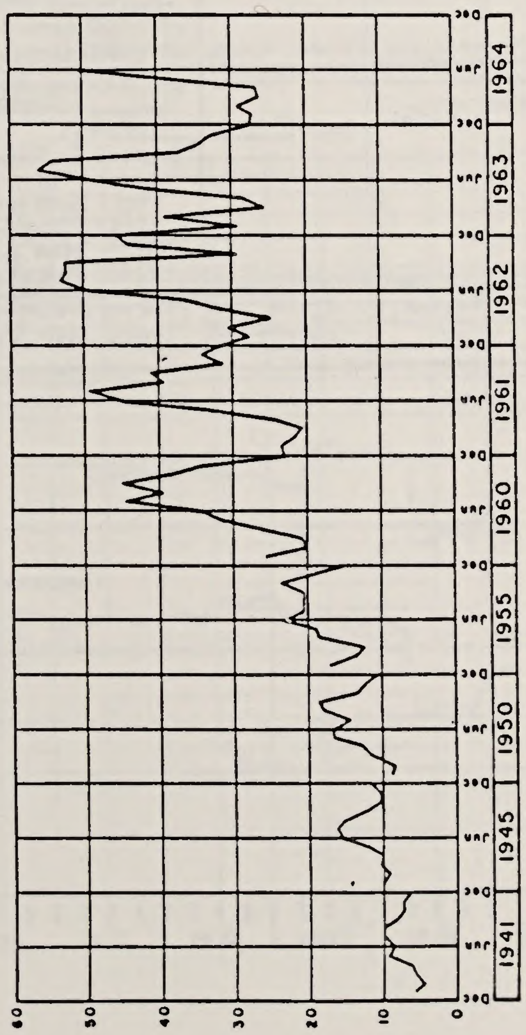


FIGURE 11. -- Quantity of water sold, in millions of gallons per month, in Gallup, McKinley County, N. Mex.

TABLE II

Gallup Population Projections and Associated Water Demands (16)

	1970 Census	1980	2000	2020
BBR 1968				
Population	14,596	31,300	54,800	100,000
Water Demand	2.19 mgd	4.70 mgd	8.77 mgd	19.0 mgd
Ober 1968	14,596	21,800	31,700	52,300
		3.27 mgd	5.07 mgd	9.94 mgd
BEA-BBR 1972	14,596	21,500	28,000	35,800
		3.225 mgd	4.48 mgd	6.80 mgd

BBR = Bureau of Business Research
OBER = Office of Business Economic Research
BEA-BBR = Census Estimates

Category 1 - Historic Users

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE & RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
• industrial Navajo tract well 14T-515	87-9.48x10.20	Kg, Kd, Jmw	—	existing (since 1954) 1440 AFY (assume ½ from Jmw)	Mercer and Cooper, 1970	flowing well (Pure Oil Co.) 900 gpm
	Church Rock area					
United Nuclear N.E. Church Rock	T.17N. R.16W. Sec. 35	Jmw	G-11, G-12 (declaration for 1865 gpm)	Oct. 1968 → Feb. 1975 (see Hearne, Table [illegible]) 1977 - 1300 gpm 1978 - 1250 gpm 1979 - 1200 gpm	Hearne, 1977 — — (3)	mine dewatering depth of mine ± 1700'
Old Church Rock	T.16N. R.16W. Sec. 17	Jmw	—	water withdrawn from 1960 through 1962 1960 + 1961 - 400 gpm reentered 1979 → present (1979) 160 gpm intermittent (1980) 225 gpm	(3) and Hearne, 1977	mine dewatering depth of mine ± 850'
Kerr-McGee Church Rock #1 and #1E	T.17N. R.16W. Sec. 35 T.17N. R.16W. Sec. 36	Jmw	—	production of water began in 1973 (shaft sinking) production from Jmw since 1977 1977 - 3200 gpm 1978 - 3750 gpm 1979 - 3800 gpm 1980 - 3800 gpm	(3) and Hearne, 1977	mine dewatering depth of mine ± 1851' (#1) ± 1529' (#1E) includes ~100 gpm from mine #1E (connected underground)
Gallup-Gamerco Coal Co.	T.16N. R.18W. Sec. 32	Kg, Kd, & Jmw	G-9 (declaration)	1956 → present peak use - 287 AFY	Mercer & Cooper '1970 (4)	

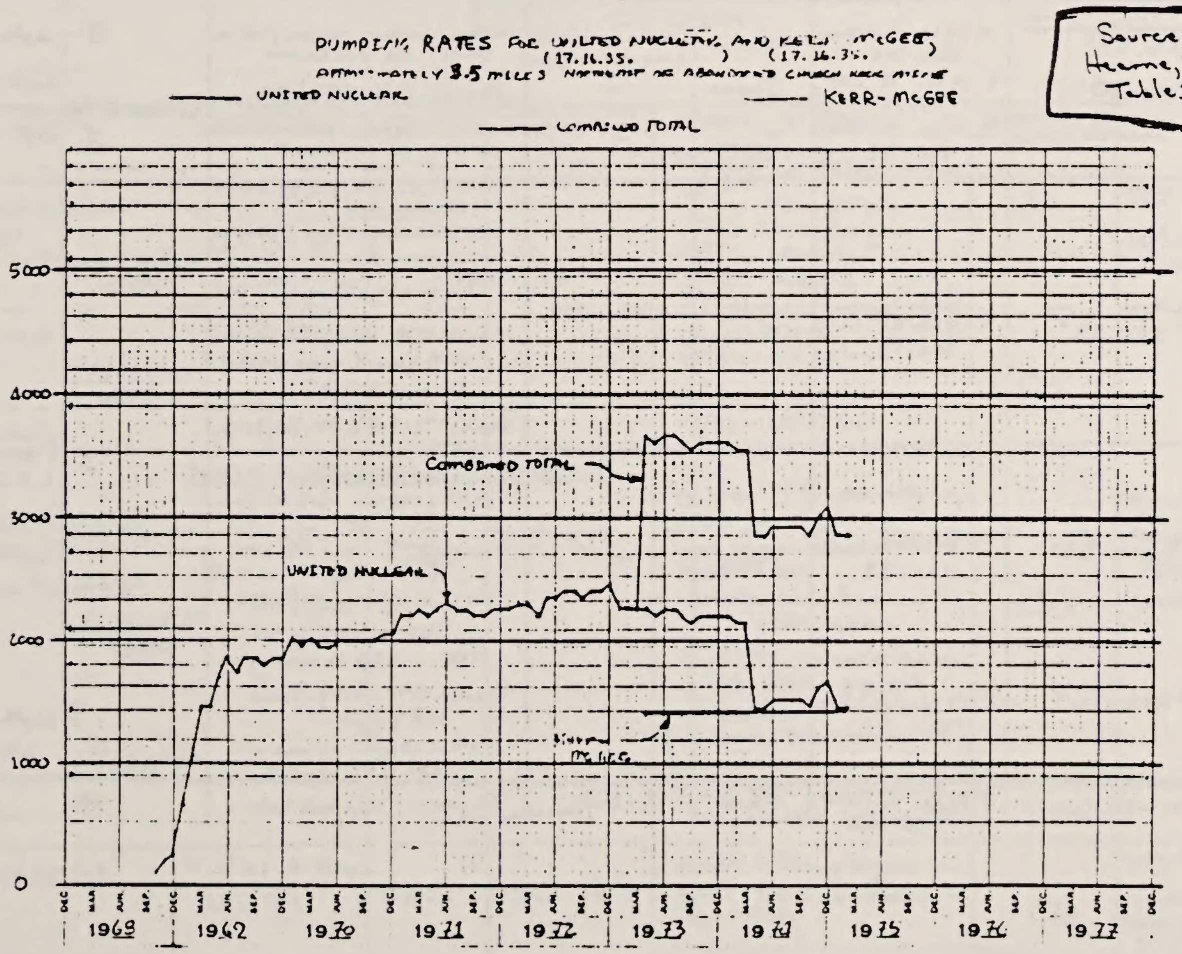
[From: Hearne, 1977]

Table 1.—Rate of withdrawal of water from mines near Church Rock.

Year	Mine	Average pumping rate in gallons per minute[1/] Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual withdrawal (acre-ft
1968	United Nuclear	-	-	-	-	-	-	-	-	-	100	200	250	-
1969	do.	650	1,050	1,450	1,450	1,700	1,850	1,750	1,850	1,850	1,800	1,850	1,850	2,550
1970	do.	2,000	1,950	2,000	1,950	1,950	2,000	2,000	2,000	2,000	2,000	2,050	2,050	3,200
1971	do.	2,200	2,200	2,250	2,200	2,250	2,300	2,250	2,250	2,200	2,200	2,250	2,250	3,600
1972	do.	2,250	2,300	2,300	2,200	2,350	2,350	2,400	2,400	2,350	2,400	2,400	2,450	3,800
(*) 1973	Kerr McGee	-	-	-	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	-
	United Nuclear	2,250	2,250	2,250	2,250	2,200	2,250	2,250	2,200	2,150	2,200	2,200	2,200	3,600
1974	Kerr McGee	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	2,250
	United Nuclear	2,200	2,150	2,150	1,450	1,450	1,450	1,500	1,500	1,500	1,450	1,600	1,650	2,700
1975	Kerr McGee	1,400	1,400	-	-	-	-	-	-	-	-	-	-	-
	United Nuclear	1,450	1,450	-	-	-	-	-	-	-	-	-	-	-

1/ Based on data supplied by Kerr-McGee Corp. and United Nuclear Corp.

(*) Note: N.M. EID, 1980, p.35 states that production from Jmw in Kerr-McGee mine began in 1977.



Source: Hearne, 1977, Table 1

Category 1-Historic Users

TABLE E-1 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Smith Lake area					
Gulf Mineral Resources Corp. (Mariano Lake Mine)	T.15N. R.14W. sec. 12	Jmb (Poison Canyon)	—	production of water (from Jmb) began in 1977 1977 - 50 gpm 1978 - 250 gpm 1979 - 190 gpm 1980 - 200 to 230 gpm	(3)	mine dewatering depth of mine ± 470' reserves to be depleted by 1982
	Ambrosia Lake area					
United Nuclear-Homestake Partners "sec. 23"	T.14N. R.10W. sec. 23	Jmw	—	Oct. 1954 → March 1962 avg. flow 444 gpm	(3) Kelly, et al., 1980	mine dewatering depth of mine ± 726'
"sec. 25"	T.14N. R.10W. sec. 25	Jmw	—	Oct. 1958 → Sept 1962 avg. flow 1150 gpm	(3) Kelly, et al., 1980	depth of mine ± 745'
"sec. 13"	T.14N. R.10W. sec. 13	Jmw	—	dry at present	(3)	depth of mine ± 530'
"sec. 15"	T.14N. R.10W. sec. 15	Jmw	—	dry at present	(3)	depth of mine ± 525'
"sec. 32"	T.14N. R.9W. sec. 32	Jmw	—	secs. 15,23,25,32 mines (combined) March 1975 - avg. flow 417 gpm 1980 - 400 to 600 gpm	(3) + Kelly, et al., 1980	depth of mine ± 530'
Kerr-McGee Corp. "sec. 17"	T.14N. R.9W. sec. 17	Jmw	—	mine water recirculation (only) at present	(3)	mine dewatering depth ± 1030'
"sec. 22"	T.14N. R.10W. sec. 22	Jmw	—	mine water recirculation (only) at present	(3)	depth ± 827'

Category 1-Historic Users

TABLE E-1 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
Kerr-McGee (cont.) "sec. 24"	T.14N. R.10W. sec. 24	Jmw	—	mine water recirculation (only) at present	(3)	depth ± 783'
"sec. 30W"	T.14N. R.9W. sec. 30	Jmw	—	March 1975 - avg. flow 944 gpm	Kelly, et al., 1980	depth ± 740'
"sec. 33"	T.14N. R.9W. sec. 33	Jmw	—	mine water recirculation (only) at present	3	depth ± 783'
				secs. 17, 22, 24, 30, 33 mines (combined) 1962 - avg. flow 1110 gpm (during shaft sinking) 1975 - avg. flow 694 gpm	Kelly, et al., 1980	—
"sec. 19"	T.14N. R.9W. sec. 19	Jmw	—	March 1975 - avg. flow 104 gpm (mine under development)	Kelly, et al., 1980	depth ± 779'
				secs. 17, 19, 22, 24, 30, 30W, + 33 mines (combined) 1979 + 1980 - 2500 gpm	(3)	(depth of sec. 30 mine ± 656')
"sec. 35"	T.14N. R.9W. sec. 35	Jmw	—	March 1975 - avg. flow 2618 gpm 1977 → 1979 - avg. flow 1300 to 1600 gpm 1980 - 1450 to 1600 gpm	(3) Kelly, et al., 1980	depth ± 1336'
"sec. 36"	T.14N. R.9W. sec. 36	Jmw	—	March 1975 - avg. flow 1535 gpm 1977 → 1980 - same as "sec. 35" mine	(3) Kelly, et al., 1980	depth ± 1,473'
Kerr-McGee	T14N. R.10W. sec 22	Jmw	B-363 (declared)	20 gpm ? for test hole	(4)	—

Category 1 - Historic Users

USER	LOCATION	AQUIFER	WATER RIGHTS PERMIT No.	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
Kerr-McGee (cont.)	-			Secs. 35 + 36 mines (combined) 6/7/78 + 8/3/78 - 2290 gpm	Kelly, et al., 1980	—
Ranchers Exploration + Development Corporation "Johnny M Mine"	T.13N. R.8W. secs. 7 + 18	Jmb (Poison Canyon)	—	1975 (under development) - 319 gpm 1977 - 800 gpm 1978 - 1,000 gpm 4/11/78 - 1320 gpm 1979 - 1,500 gpm 1980 - 900 to 1,100 gpm	Kelly, et al., 1980	mine dewate[ring] depth of min[e] ≈ 1340'
United Nuclear Corporation	T.14N. R.9W.			small intermittent discharge - most water recirculated (1979)		mine dewater[ing]
"Ann Lee" mine	sec. 28	Jmw	—			depth ≈ 68[illegible]
"Sec. 27" mine	sec. 27					depth ≈ 78[illegible]
"Sandstone" mine	sec. 34					depth ≈ 92[illegible]
Kerr-McGee Corp. + Philadelphia Electric Co. "Lee Mine"	T.13N. R.8W. Sec. 17	Jmb, Jmw	B-851 thru B-851-BW-3	shaft being sunk at present - 738 ft. in depth in July 1981 probably only dewatering from Tres Hermanos Ss. at present		mine dewatering target depth ≈ 1,470 ft
	Laguna - Cebolleta area					
Anaconda Co. "P-10 mine"	T.10N. R.5W. sec. 4	Jmb (Jackpile ss.)	—	1977 - 150 gpm 1979 - 104 gpm 1980 - 95 gpm		mine dewater[ing] depth ≈ 450' to close by March 31, 198[illegible]
Sohio Western Mining Co. - Reserve Oil + Minerals Corp. "JJ #1 mine"	T.11N. R.5W. sec. 13	Jmb (Jackpile ss.)		1977 - 30 to 40 gpm 1978 + 1979 - 25 gpm 1980 - 100 gpm (?)		mine dewater[ing] depth ≈ 67[illegible]
"L Bar Mill"	Cebolleta Grant.	Kd + Jmw	RG-27627 through RG-27627 S-11 (declaration) RG-27627 S-12 → S-T9 (application)	operated for a few years 1450 AFY (closed as of 6/81)		

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
United Nuclear Corp. "St. Anthony mine"	T.11N. R.4W. Sec. 19 + 30 (pit)	Jmb (Jackpile ss.)	—	1977 - 30 to 50 gpm 1978 - 20 to 30 gpm 1979 - 20 gpm 1980 - closed	(3)	mine dewatering depth ≈ 150-200'
	T.11N. R.5W. Sec. 24 (shaft)			1977 (under development) - 3 gpm 1978 - 25 gpm 1979 - 20 gpm 1980 - closed	(3)	depth ≈ 320'
	Nose Rock Area (Crownpoint)					
Phillips Uranium Co. "Nose Rock #1" "Nose Rock #2"	T.19N. R.11W. Sec. 31 T.19N. R.12W. sec. 36	Jmw	SJ-109	by Nov. 1979, dewatering wells for shafts 1 + 2 had been deepened to Dakota ss. production from wells ~ 1,800 gpm shaft #1 completed in July 1981 + project placed on standby [∴ some dewatering of Jmw] shaft #2 - construction suspended in May 1980	(3)	mine dewateri[ng] target depth 3295' (shaft #1)
Conoco Co.	T.17N. R.13W. Sec. 24	Jmw	SJ-125	shaft drilling begun in April 1980 + completed in Sept. 1980 production from Jmw unknown project shut down in May 1981	(3)	mine dewatering depth of development shaft ≈ 2,200'

Category 1 - Historic Users

TABLE E-1 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE & RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Mount Taylor (west) area					
Gulf Mineral Resources Corp. Mt. Taylor mine"	T.13N. R.8W. sec. 24	Jmw		1977 - deep dewatering wells (probably tapping Jmw) were pumping 1200 gpm 1978 - production from dewatering wells 1,000 gpm 1979 - 2 shafts penetrated Jmw - net inflow 4000 gpm 1980 - 4,000 gpm	(3)	mine dewatering target depth ≈ 3300'
	Mount Taylor (east) area					
Bokum Resources Corp. Marquez mine"	T.13N. R.5W. Sec. 36 (Land grant)	Jmw		main shaft still above top of Jmw in early 1981 Nov. 1979 - estimated dewatering contribution from Jmw ~ 800 gpm (total inflow of 4,034 gpm)	(3)	mine dewatering target depth ≈ 2,100' (ventilation shaft)
Marquez mine + mill	T.12N. R.7W. sec. 29	Jmw	RG-29300 (declaration)	Bokum applied for declaration of 3 wells to use water for milling ~1900 AFY project postponed in 1981	(4)	mining + milling
Kerr-McGee Corp. Rio Puerco mine"	T.12N. R.3W. Sec. 18	Jmw	RG-28727 Kerr-McGee + TVA (application for 850 AFY)	1977 - shaft did not penetrate Jmw, no dewatering wells 1978 - 500 gpm 1979 - 1422 gpm early 1980 - pumping discontinued, mine placed on standby		mine dewatering target depth ≈ 850'
	T.12N. R.4W. sec. 24	Jmb, Jmw	RG-28782 (applied to change location of use of well based on Declaration)	200 AFY		

Notes:

1 - stratigraphic symbols are as follows: Kg - Gallup Ss.; Kd - Dakota Ss; Jmb - Brushy Basin Member of Morrison Fm.; Jmw - Westwater Canyon Member of Morrison Fm.; Jcs. - Cow Springs Sandstone (Morrison Formation); Je - Entrada Ss.

2 - if applicable

3 - compiled from the following reports:
- N.M. Energy and Minerals Department, 1981a, Table 6
- N.M. Environmental Improvement Division, 1980, Tables I, II and III
- N.M. Energy and Minerals Department, 1981b, Table IV-2

4 - compiled from water rights files of New Mexico State Engineer
- Santa Fe Office, November 1981
- Albuquerque District I Office, December 1981

Table E-2. PRIOR USERS OF WESTWATER CANYON MEMBER AQUIFER SYSTEM

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO	COMMENTS
	Crownpoint - NoseRock area					
Phillips Uranium Co. "Nose Rock mine"	T. 19 N. R. 11 W. secs 10, 17, 30; T. 19 N. R. 12 W. sec. 36; T. 18 N. R. 12 W Sec. 1	Jmw	SJ-109	(see Table E-1 for historic pumpage) • assume dewatering wells produced from Jmw for 1 year (mid 1980 → mid 1981) until shaft #1 was completed. • assume project will start up in 1990 according to the schedule in the attached table (from Guyton report)	(4) Guyton + Associates, 1978	mine dewatering; avg. depth to top of Jmw at mines is 3,220 ft.
Conoco, Inc. Crownpoint project	T. 17 N. R. 13 W. Sec. 24 SE¼ SE¼ + NE¼ SE¼	Jmw	SJ-125	• diversion of water from Jmw from underground mines + dewatering wells • anticipated depth: 2,200' • water rights application as amended by letter of 1/23/81 applies for 7,500 AFY each from Crownpoint + Borrego Pass • mine life from 18 to 22 years -) assume start date: [illegible] 1990	4 Science Applications, Inc., 1981	mine dewatering. Conoco's plans are vague.
Borrego Pass project	T. 16 N. R. 10 W. Sec. 7 SE¼ SW¼ + SW¼ SW¼					

from: Guyton, 1978 [July 1978 - 12 mine system]

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Dewatering

The following paragraphs discuss mine locations and configurations, sequential events in mining that relate to dewatering of the Westwater Canyon in which the uranium ore is found, and estimated pumping rates required for dewatering. Information on mine locations, configurations, and sequential events was provided by Phillips Uranium Corporation personnel.

Mine Locations. Locations of the 12 mine sites given in Phillips' application to the State Engineer are listed below and shown on the map of Figure 2. The present study applies to dewatering at these sites.

Mine Number	Location
1	NW 1/4, NW 1/4, Sec. 30, T19N-R11W
2	SW 1/4, NW 1/4, Sec. 30, T19N-R11W
3	SW 1/4, SW 1/4, Sec. 36, T19N-R12W
4	NW 1/4, SW 1/4, Sec. 36, T19N-R12W
5	NW 1/4, NE 1/4, Sec. 30, T19N-R11W
6	SE 1/4, NE 1/4, Sec. 30, T19N-R11W
7	SW 1/4, SW 1/4, Sec. 17, T19N-R11W
8	NW 1/4, SW 1/4, Sec. 17, T19N-R11W
9	SE 1/4, NE 1/4, Sec. 10, T19N-R11W
10	NW 1/4, NE 1/4, Sec. 10, T19N-R11W
11	SE 1/4, NW 1/4, Sec. 1, T18N-R12W
12	SW 1/4, NE 1/4, Sec. 1, T18N-R12W

Conditions for Mining. Conditions related to the physical layout of the mines such as the depth, position, and configuration of ore bodies within the Westwater Canyon vary appreciably from one mine site to another. Therefore, as an aid in making calculations for estimating pumping for the 12-mine system, Phillips developed a mining program for a typical mine. The following discussion generally applies to conditions for this average or typical mine.

A vertical production shaft having an outside diameter of about 22 feet will be sunk through the Westwater Canyon and into the underlying Recapture shale. The average depth to the top of the Westwater Canyon at the mines is about 3,220 feet and the average depth to the top of the Recapture is about 3,430 feet. A ventilation shaft also will be sunk concurrently a few hundred feet from the production shaft. Both shafts will be lined with concrete as they are sunk.

Table E-2. PRIOR USERS OF WESTWATER CANYON MEMBER AQUIFER SYSTEM

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Crownpoint - NoseRock area					
Phillips Uranium Co. "Nose Rock mine"	T. 19 N. R. 11 W. secs 10, 17, 30 T. 19 N. R. 12 W. sec. 36 T. 18 N. R. 12 W Sec. 1	Jmw	SJ-109	Table w (see ~~[illegible]~~ for historic pumpage) • assume dewatering wells produced from Jmw for 1 year (mid 1980 → mid 1981) until shaft #1 was completed; • assume project will start up in 1990 according to the schedule in the attached. table (from Guyton report)	(4) Guyton & Associates, 1978	mine dewatering avg. depth to top of Jmw at mines is 3,220 ft.
Conoco, Inc. Crownpoint project — Borrego Pass project	T. 17 N. R. 13 W. Sec. 24 SE¼ SE¼ & NE¼ SE¼ — T. 16 N. R. 10 W. Sec. 7 SE¼ SW¼ & SW¼ SW¼	Jmw	SJ-125	• diversion of water from Jmw from underground mines + dewatering wells • anticipated depth: 2,200' • water rights application as amended by letter of 1/23/81 applies for 7,500 AFY each from Crownpoint + Borrego Pass • mine life from 18 to 22 years - assume start date 1990	4 Science Applications, Inc., 1981	mine dewatering Conoco's plans are vague.

from: Guyton, 1978 [July 1978 - 12 mine system]

Dewatering

The following paragraphs discuss mine locations and configurations, sequential events in mining that relate to dewatering of the Westwater Canyon in which the uranium ore is found, and estimated pumping rates required for dewatering. Information on mine locations, configurations, and sequential events was provided by Phillips Uranium Corporation personnel.

Mine Locations. Locations of the 12 mine sites given in Phillips' application to the State Engineer are listed below and shown on the map of Figure 2. The present study applies to dewatering at these sites.

Mine Number	Location
1	NW 1/4, NW 1/4, Sec. 30, T19N-R11W
2	SW 1/4, NW 1/4, Sec. 30, T19N-R11W
3	SW 1/4, SW 1/4, Sec. 36, T19N-R12W
4	NW 1/4, SW 1/4, Sec. 36, T19N-R12W
5	NW 1/4, NE 1/4, Sec. 30, T19N-R11W
6	SE 1/4, NE 1/4, Sec. 30, T19N-R11W
7	SW 1/4, SW 1/4, Sec. 17, T19N-R11W
8	NW 1/4, SW 1/4, Sec. 17, T19N-R11W
9	SE 1/4, NE 1/4, Sec. 10, T19N-R11W
10	NW 1/4, NE 1/4, Sec. 10, T19N-R11W
11	SE 1/4, NW 1/4, Sec. 1, T18N-R12W
12	SW 1/4, NE 1/4, Sec. 1, T18N-R12W

Conditions for Mining. Conditions related to the physical layout of the mines such as the depth, position, and configuration of ore bodies within the Westwater Canyon vary appreciably from one mine site to another. Therefore, as an aid in making calculations for estimating pumping for the 12-mine system, Phillips developed a mining program for a typical mine. The following discussion generally applies to conditions for this average or typical mine.

A vertical production shaft having an outside diameter of about 22 feet will be sunk through the Westwater Canyon and into the underlying Recapture shale. The average depth to the top of the Westwater Canyon at the mines is about 3,220 feet and the average depth to the top of the Recapture is about 3,430 feet. A ventilation shaft also will be sunk concurrently a few hundred feet from the production shaft. Both shafts will be lined with concrete as they are sunk.

From: Guyton, 1978

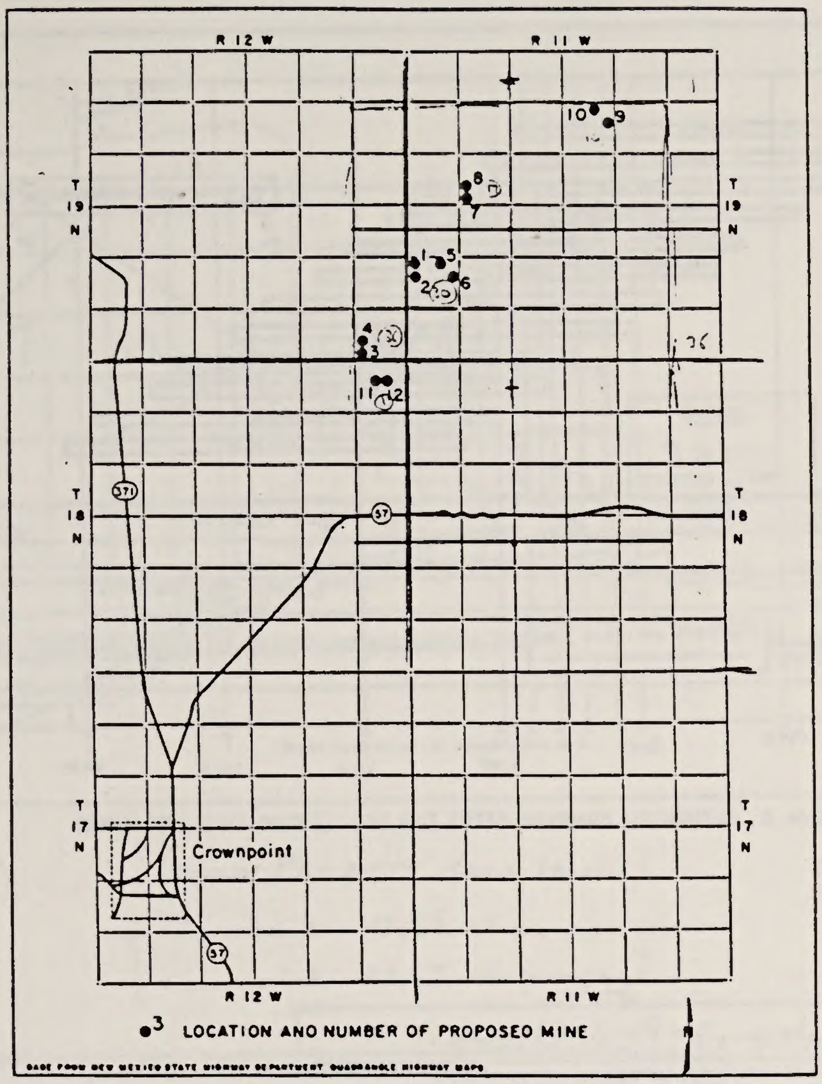


Figure 2. LOCATIONS OF PHILLIPS' PROPOSED MINES

The estimated amount of water produced from drainage was added to the amount computed to be produced by lowering of artesian pressures to obtain the estimated total amount of water pumped to the surface. The amount drained from the pore space of the aquifer will have relatively little effect upon conditions in the artesian part of the aquifer away from the mines during mining operations, but it will cause an effect after mining stops. When mining stops, production of water to the surface will stop, but flow into the mine through the artesian system will continue and will delay normal water-level recovery until the volume of void space created during mining is filled up. The net effect will be the same as though pumping from the aquifer continues after mining stops, and this will affect pumping rates at other mines. This was taken into consideration in estimating the pumping rates which were used in calculating the effects on the aquifer system.

From: Guyton, 1978

12' (revised from May '78 version)

Estimated elevations at the mines and the times that mining will start and stop for the eight mines used in making the calculations for estimating pumping rates are listed below.

Mine	Estimated Elevations for Westwater Canyon[1/]: Water Level	Formation: Top	Formation: Bottom	Time of Mining: Start		Stop	(*)
1	6,520	3,185	3,013	1979	1990	1993	2004
2	6,520	3,204	2,995	1980	1991	1994	2005
3	6,520	3,405	3,222	1982	1993	1996	2007
4	6,520	3,348	3,147	1983	1994	1997	2008
5	6,520	3,113	2,999	1985	1996	1999	2010
6	6,520	3,163	2,999	1986	1997	2000	2011
7	6,515	3,022	2,765	1988	1999	2002	2013
8	6,515	3,022	2,765	1989	2000	2003	2014
9	6,510	2,817	2,559	1991	2002	2005	2016
10	6,510	2,817	2,559	1992	2003	2006	2017
11	6,520	3,460	3,276	1994	2005	2008	2019
12	6,520	3,460	3,276	1995	2006	2009	2020

← 3350 → ← 203 → (3553)

1/ Elevations are in feet above sea level.

Estimated total pumping rates for dewatering the Westwater Canyon aquifer at Phillips' mines based on the above calculations are shown

(*) Note: Generalized layout of Phillips mine is 8000' by 800'. It would take ~3 years to complete the mine drifts for each mine.

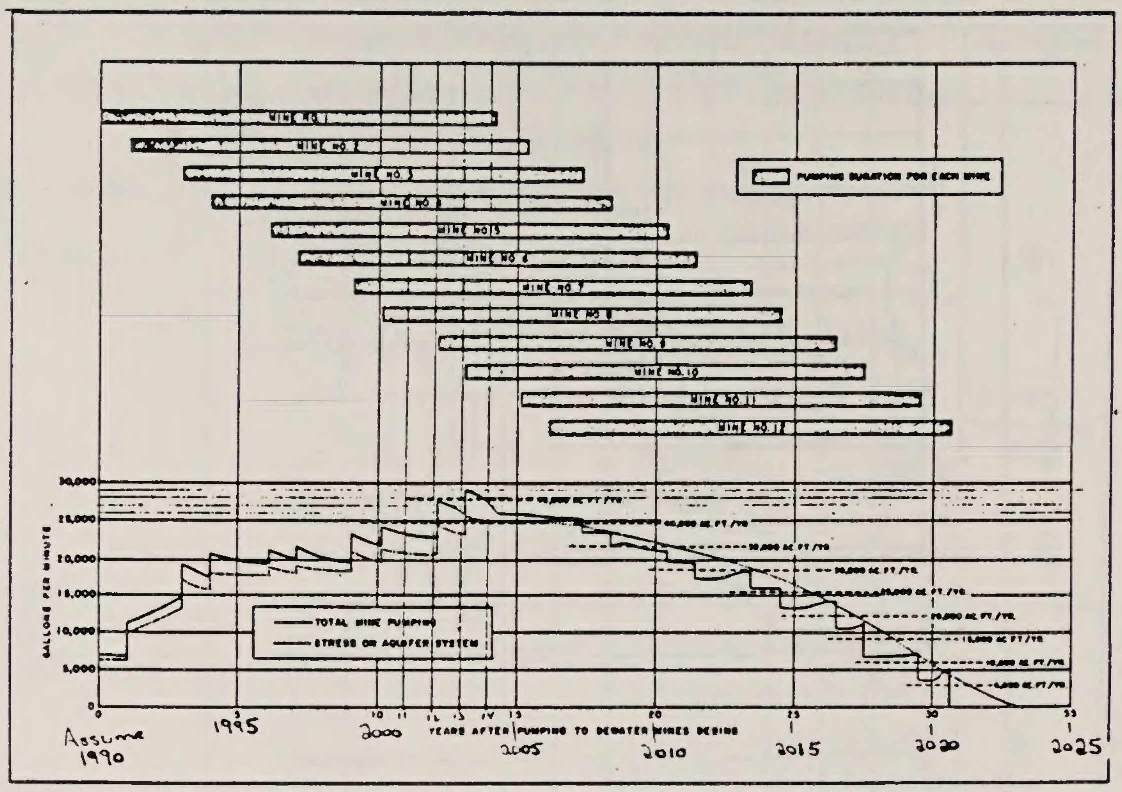


Figure 3. ESTIMATED PUMPING RATES FOR DEWATERING PHILLIPS' MINES

(life of each mine = 14 years) (from: Guyton, 1978)

Category 2 - Prior Users

TABLE E-2 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE + RATE of PRODUCTION	SOURCE OF INFO.	COMMENTS
Mobil Oil Corp. Monument Project	T.17N. R.12W. secs. 27 + 28	Jmw	SJ-146 and SJ-146-S	• one discharge center (#2 on attached map) • maximum depletion 330 AFY	(4) + Camp, Dresser + McKee, Inc., 1981	in-situ leach depth of wells for injection + extraction ≈ 2,200'
Crownpoint Project	T.17N. R.13W. secs. 3,4,5,6,7, 8,9,11,12,14,15, 16,17,18,21,22, 23,24 T.17 N. R.14W. Secs. 1+12		SJ-147 and SJ-147-S	• seven discharge centers (see attached map) • maximum depletion 2798 AFY (400 AFY each) • life of projects is 32 years • assume project will start up in 1990 according to the schedule in the attached figures (from Mobil Plan of Replacement) in the proportion of: 10.5% Monument (330/3128) 89.5% Crownpoint (2798/3128)	Camp, Dresser, and McKee, Inc., 1981	
Crownpoint Project	T.17N. R.13W. secs. 4+8	Jmw	SJ-1495 through SJ-1498 (declarations)	• declaration for 48 AFY from 4 flowing wells • assume 1990 to 2022 • combine this pumping center (#4) above	(4)	drilling, dust supression + domestic use

From: Camp, Dresser + McKee, 1981, "Mobil Plan of Replacement"

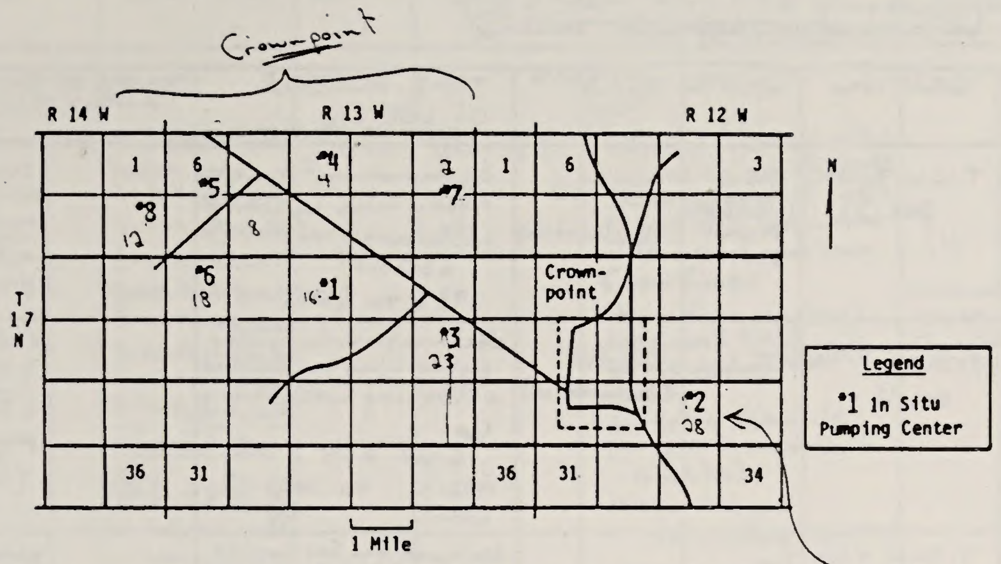


Figure 2.20. Location of Mobil's in situ project pumping centers.

Monument 10.5% of pumpage
Crownpoint 89.5% of pumpage

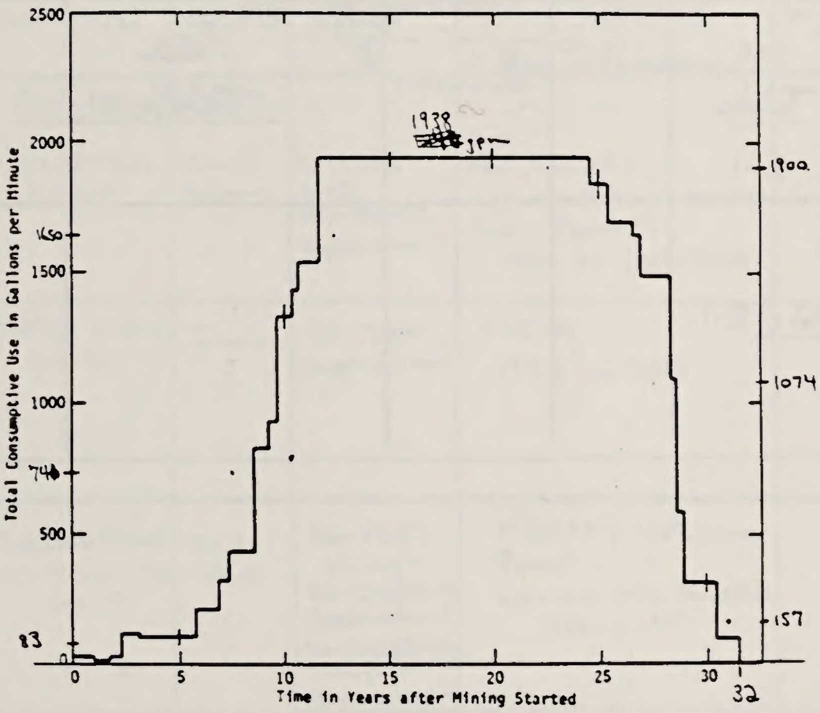


Figure 2.21. Total consumptive water use for Mobil's in situ solution mining operations versus time.

Year	Average Pumpage at each project pumpage center (for x-year increment starting in year shown): centers 1,3,4,5,6,7 & 8 (gpm)	center 2 (gpm)
1990	74.3	8.7
1995	663	77.8
2000	1477	173
2005	1734	204
2010	1700	200
2015	961	113
2020	140	16.5

Category 2 - Prior Users

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
Chaco Energy Co. South Hospah Mine	T.16 N. R.10 W. sec. 2	Jmw (total depth of well 2807 ft.)	SJ-120 (declaration)	declaration for water rights filed by Cherokee + Pittsburg Coal Mining Co. 650 AFY 1983 to 2013	(4)	surface mining + reclamation a Future 1 project (D.13)
Alamito Coal Co. Gallo Wash Mine	T.21 N. R.9 W. sec. 16	Jmw	SJ-118 (declaration)	declaration for water rights filed by Cherokee + Pittsburg Coal Mining Co. 650 AFY 1982-92 (start) to 2022-32 (end)	(4)	Surface mining + reclamation a Future 1 project (D.6)
Chaco Energy Co. Star Lake Mine.	T.20 N. R.6 W. sec. 32; T.20 N. R.7 W. sec. 22	Jmw + Je	SJ-119 (declaration)	declaration for water rights filed by Cherokee + Pittsburg Coal Mining Co. 800 AFY from Jmw 1,200 AFY from Je time schedule unknown assume 1995 to 2025	(4)	surface mining + reclamation a Future 2 project (G.2)
Bureau of Land Management Bisti well	T.23 N. R.13 W. sec. 9	Jmw	SJ-1243. (application)	claim for Federal reserved right - priority of 12/1/74 325 AFY assume 1985 → future	4.	public water hole (domestic, stock, irrig., fire + erosion control)
• Crownpoint • Gallup • Gallup - Gamerco Coal Co. • Navajo tract well 14T-515	see Table E-1		historic users G-9 (declaration) historic user	see Table E-1		

Notes:

(1)
(2) } see Table E-1
(4)

Table E-3. USE OF WESTWATER CANYON MEMBER FOR NEW MEXICO GENERATING STATION

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. 2	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
Public Service Co. of New Mexico Paragon Resources, Inc.	T.23N. R.12W. well no. 1 - SW¼ NW¼ sec.9 2 - NE¼ NE¼ sec.12 3 - NE¼ NE¼ sec.24 4 - NW¼ NW¼ sec.14 5 - NW¼ NW¼ sec.26 6 - NW¼ NW¼ sec.34 7 - NW¼ NW¼ sec.21 8 - SW¼ SW¼ sec.29 T.23N. R.13W. well no. 9 - SE¼ SE¼ sec.26 10 - SW¼ SW¼ sec.28 11 - NW¼ NW¼ sec.14 12 - SW¼ SW¼ sec.23 13 - NE¼ SE¼ sec.13 14 - SE¼ SE¼ sec.24 T.22N. R.12W. well no. 15 - SW¼ SW¼ sec.6 16 - SE¼ SE¼ sec.4	Jmw	SJ-189	• assume well field will be used as an alternate water supply if add'l. 15,000 AFY cannot be obtained from San Juan River • therefore, earliest date well field will be needed is for unit 3 • pumping schedule (in gpm from each of 16 wells) 1995 - 976 gpm (total pumpage 6250 AFY) 1998 - 2344 gpm (total pumpage 15,000 AFY) 2031 - 976 gpm (total pumpage 6250 AFY) 2033 - end	(4) + Woodward-Clyde Consultants, 1981	power plant cooling dates units are assumed to be on line are: unit 1 - 1990 unit 2 - 1993 unit 3 - 1995 unit 4 - 1998 economic life of each unit of plant assumed to be 40 years (1990 → 2038)

Table E-4. BLM BASELINES 1 AND 2 USERS OF WESTWATER CANYON MEMBER AQUIFER SYSTEM

USER	LOCATION	AQUIFER 1	WATER RIGHTS PERMIT No. 2	TIME SCHEDULE OF USE + RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Future 1 Projects					
Plains Electric Generating and Transmission Corp. Escalante Generating Station	T.15N. & T.16N. R.10W.	Jmw + Dalton ss.	SJ-886 + well RG-32002 (application)	20,000 AFY (proportion of pumpage from Jmw ?) 1984 to 2019-2024	(4)	for power plant cooling project no. A.2
Consolidation Coal Co. Con Paso-Burnham Mine	T.25N. R.16W. Sec.36	Jmw	SJ-1300 (application)	540 AFY 1982 to 2018	(4)	for surface mining + irrigation for reclamation project no. D.4
Sohio Western Mining Co. - Reserve Oil + Minerals Corp L-Bar Mill	Cebolleta Grant (nr. T.11N. R.5W. sec.13)	Kd + Jmw	RG-27627 through RG-27627-S-11 (declaration) RG-27627-S-12 through S-19 (application)	1450 AFY (90% from Jmw) assume 1990 to 2020 (30 yr. life)	(4)	uranium mill project no. E.29 [see Table w]
Bokum Resources Co. Marquez mill	T.12N. R.7W. sec.29	Jmw	RG-29300 (declaration)	application for declaration of water rights 1872 AFY for mill 40 AFY for mine assume 1990 to 2020	4	mining + milling project no. E:30 [see Table E-1]

Category 4- BLM Baseline Projects

Table E-1 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE & RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Future 1 Projects (continued)					
Kerr-McGee Church Rock #1 & #1E mines	T.17N. R.16W. Sec.35 (#1E mine in sec.36)	Jmw	—	1981 to 2005-2010 (combined pumpage 3800 gpm in 1980)	(3), (4) & Umshler, 1979	mine dewatering [see Table E-1] project no. E.1 & E.2
Ranchers Exploration & Development Co. Johnny M mine	T.13N. R.8W. sec.7 & 18	Jmb (Poison Canyon ss.)	—	1981 to 2005 (assumed life of 30 yrs) (900 to 1100 gpm in 1980)	(3) & (4)	mine dewatering [see Table E-1; project no E.6
Gulf Oil Corp. Mariano Lake Mine	T.15 N. R.14W. sec.12	Jmb (Poison Canyon ss.)	—	1981 to 1982 (pumpage of 200 to 230 gpm in 1980) (reserves depleted 1982)	(3) & (4)	mine dewatering [see Table E-1] project no. E.7
Gulf Oil Corp. Mt. Taylor mine	T.13 N. R.8W. Sec.24	Jmw	—	1981 to 2010 (assumed life of 30 yrs) (pumpage 4,000 gpm in 1980)	(3) & (4)	mine dewatering [see Table E-1] project no. E.8
United Nuclear Corp. N.E. Church Rock	T.17N. R.16W. sec.35	Jmw	G-11 & G-12 (declaration for ~3000 AFY)	1981 to 2005-2010 (1,200 gpm in 1980)	(3), (4)	mine dewatering [see Table E-1] project no. E.9 & E.10
Old Church Rock	T.16N. R.16W. sec.17	Jmw		1981 to 2005-2010 (225 gpm in 1980)	Umshler, 1979	
Anaconda Co. P-10 mine	T.10N. R.5W. sec.4	Jmb (Jackpile ss.)	—	1981 to 1982 (pumpage of 95 gpm in 1980) (Anaconda plans to close all mining by March, 1982)	(3) & (4)	mine dewatering [see Table E-1] project no. E.11
Kerr-McGee Corp. & Philadelphia Electric Co. Lee Mine (Roca Honda)	T.13N. R.8W. sec.17	Jmb, Jmw	B-851-DW-3 (application) [B-851 is total of 2660.7 AFY from 2 aquifers]	1983 to 2015 (assume 30 yr. life of mine) (water rights application to pump 2593 AFY from Jmw for mine dewatering)	(3) & (4)	mine dewatering [see Table E-1] project no. E.12
Kerr-McGee Corp. "sections 19, 22, 30, 30W & 33 mines"	T.14N. R.9W. & R.10W. secs. 19, 22, 30 & 33	Jmw	—	• secs. 17, 22, 24, 30, 30W & 33 - assume 1981 to 1992 • sec. 19 assume 1981 to 2005 combined pumpage of 2,500 gpm [includes mines in secs. 17 & 24 - (Future 2)]	(3)	mine dewatering [see Table E-1] project nos. E.17, E.18, E.2 E.22 & E.24
	T.14N. R.10W. sec.22	Jmw	B-363 B-373 (2 wells)	application for 177 AFY (additional pumpage 1981 to 2005)	(4)	for drilling, mine development & testing
Homestake Mining Co. (formerly UN-HP) "Secs. 23, 25 & 32 mines"	T.14N. R.10W. secs. 23 & 25 T.14N. R.9W. sec.32	Jmw	—	1981 to 1986 (combined pumpage of 400 to 600 gpm in 1980)	(3)	mine dewatering [see Table E-1] project nos. E.19, E.20 & E.23

Category 4 - BLM Baseline Projects

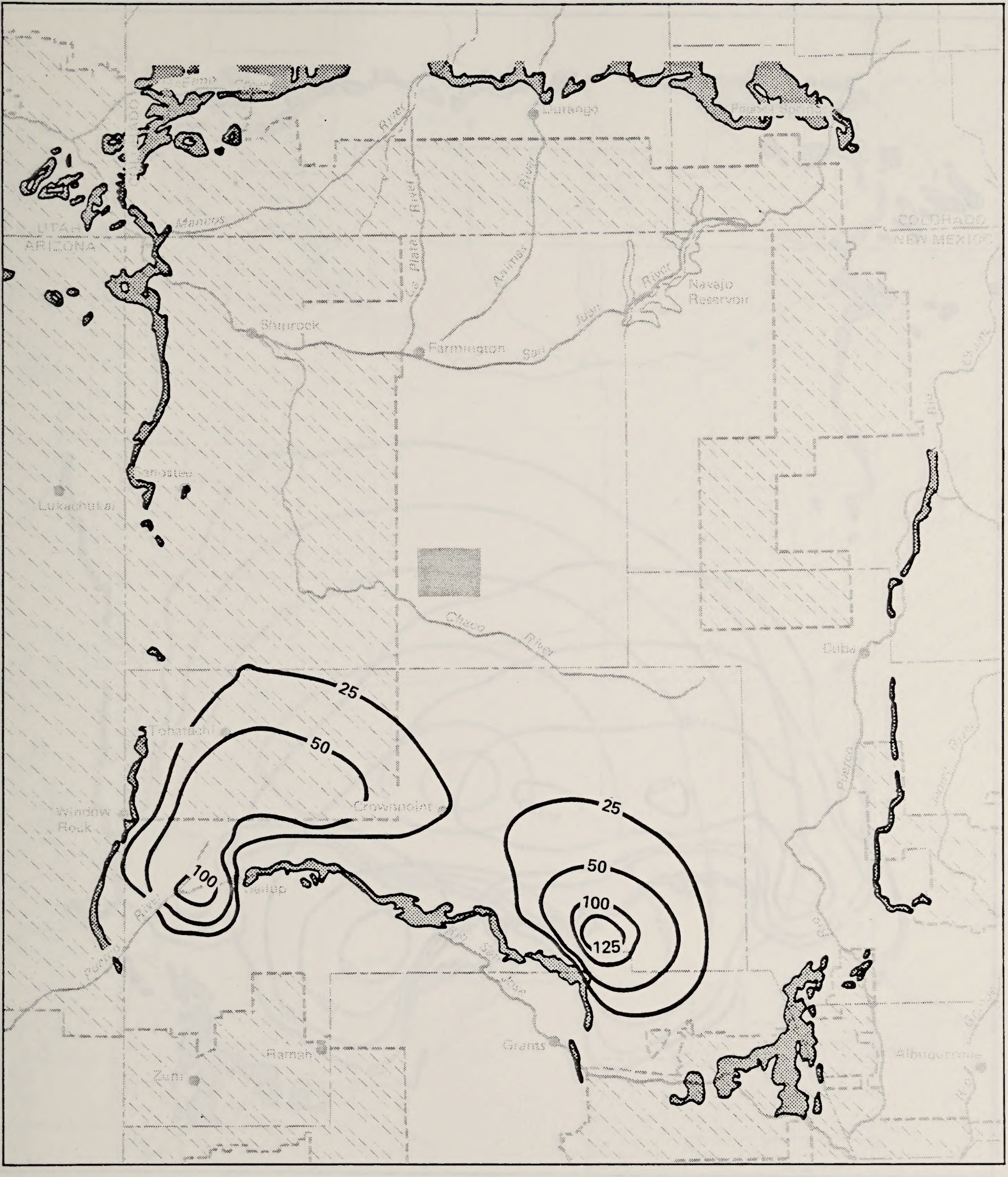
Table E4 (continued)

USER	LOCATION	AQUIFER (1)	WATER RIGHTS PERMIT No. (2)	TIME SCHEDULE OF USE & RATE OF PRODUCTION	SOURCE OF INFO.	COMMENTS
	Future Projects (continued)					
Star Lake Railroad Co. Star Lake-Bisti Railroad	T.14N. R.9W. Sec. 31	Jmw	B-680 (application for Kerr-McGee wastewater - not an additional appropriation)	300 AFY for construction 1982 to 1985	4)	source of water from mine dewatering project no. F.3
Kerr-McGee Uranium Co. secs. 35 & 36 mines	T.14N. R.9W. Sec. 35 & Sec. 36	Jmw	—	• assume 1981 to 2005 • each mine pumping 1450 to 1600 gpm in 1980	3) & Kelly, et al, 1980	mine dewatering [see Table E-1] project nos. E.25 & E.26
Chaco Energy Co. Star Lake Mine	T.21N. R.9W. Sec. 15	Je	SJ-549 (application)	1,000 AFY schedule unknown assume 2000 to 2030	4	for surface mining & reclamation
	T.19N. R.7W. Sec. 2	Jmw	SJ-673 (application)	500 AFY schedule unknown assume 2000 to 2030		project no. G.2
Sohio Western Mining Co. - Reserve Oil & Minerals Corp. JJ #1 mine	T.11N. R.5W. Sec. 13	Jmb (Jackpile ss.)	—	shut down at present assume 1990 to 2020	3 & 4	mine dewatering [see Table E-1] project no. H.8
United Nuclear Co. St. Anthony Mine	T.11N. R.4W. Sec. 19 & 30 (pit) T.11N. R.5W. sec. 24 (shaft)	Jmb (Jackpile ss.)	—	• mines are shut down at present • dewatering 20 gpm from shaft & 20 gpm from pit in 1979 • use too small to consider in model	(3)	mine dewatering [see Table E-1] project no. H.24
Bokum Resources Co. Marquez mine	T.13N. R.5W. Sec. 36 (Land Grant)	Jmw	—	assume 1600 gpm from Jmw 1990 to 2020 (assumed life) (in Nov. 1979, estimated inflow from Jmw of 800 gpm)	3 & 4	mine dewatering [see Table E-1] project no. H.19
Kerr-McGee Corp. Rio Puerco Mine	T.12N. R.4W. Sec. 24 (mill location)	Jmw & Jmb	RG-28782 (declaration)	1990 to 2020 (assumed life) 200 AFY (application is to change location of use of well based on Declaration)	3 & 4	mine dewatering [see Table E-1] project no. H.16
	T.12N. R.3W. sec. 18	Jmw & Jmb (10%)	RG-28727 (application)	application for 850 AFY (assumed pumpage) (dewatering 1,422 gpm during shaft sinking in 1979)		
Kerr-McGee Nuclear Corp. Secs. 17 & 24 mines	T.14N. R.9W. Sec. 17 T.14N. R.10W. sec. 24	Jmw	—	mines are shut down at present (mine water recirculation) • assume these mines do not reopen	3	mine dewatering [see Table E-1] project nos. H.20 & H.21

Notes: (1) (2) (3) (4) } [see Table E-1]

APPENDIX F

CALCULATED DRAWDOWNS IN THE WESTWATER CANYON MEMBER AQUIFER SYSTEM



LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

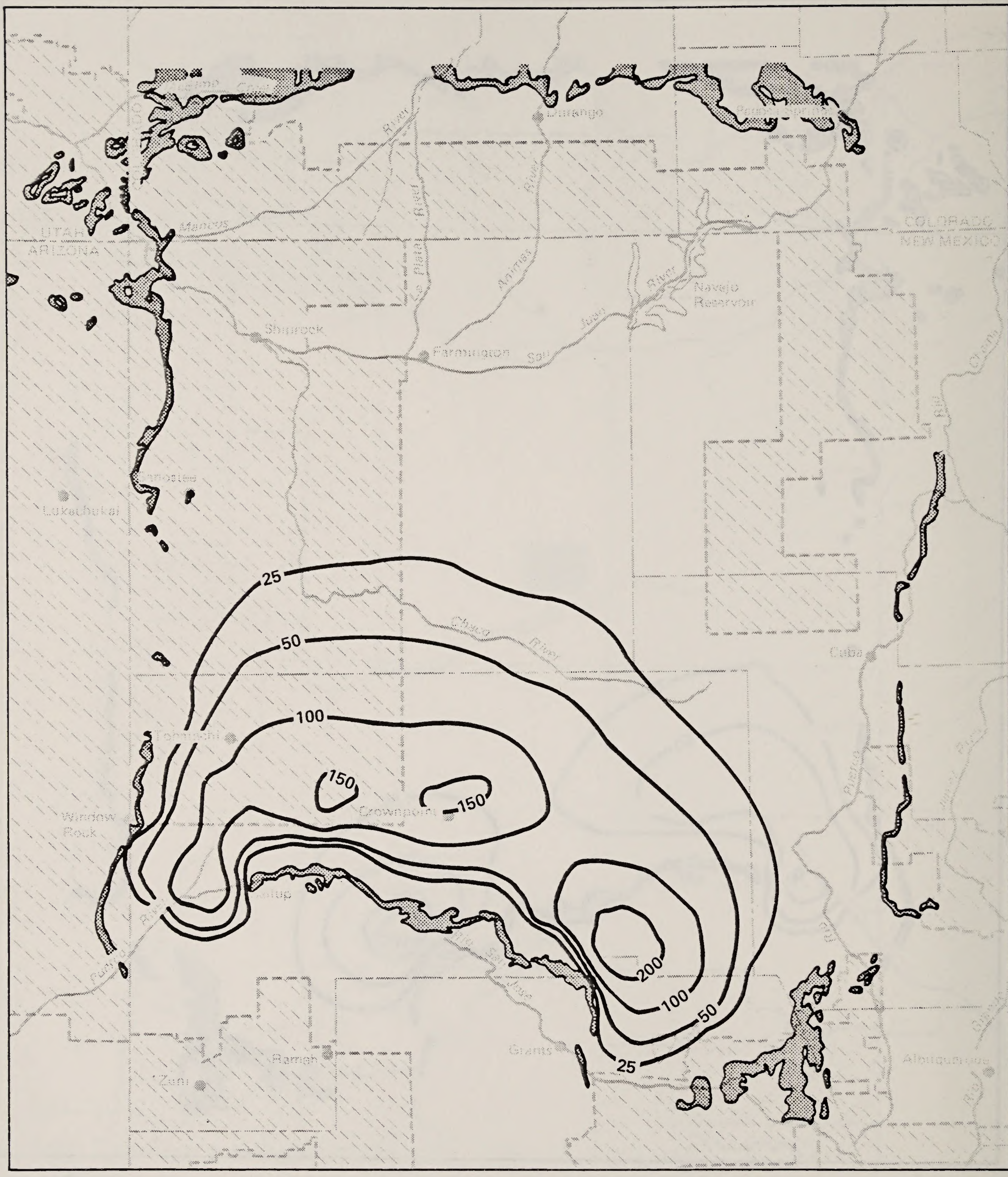
NMGS Well Field

Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

0 10 20
miles

Map F-1. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 1980



LEGEND

Indian Reservations

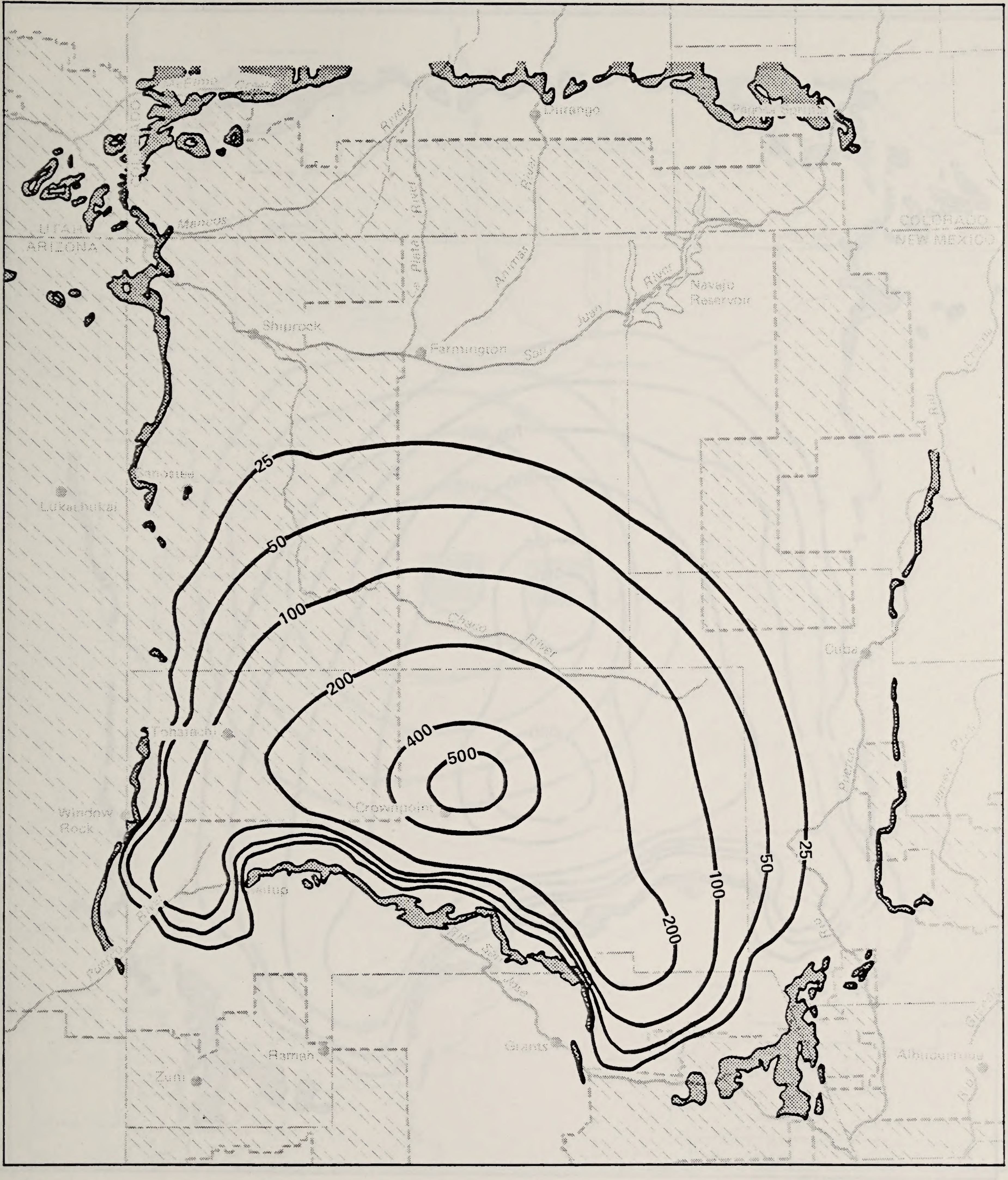
—100— Line of equal drawdown in feet

Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

0 10 20
miles

Map F-2. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 1995, CASE 1



LEGEND

Indian Reservations

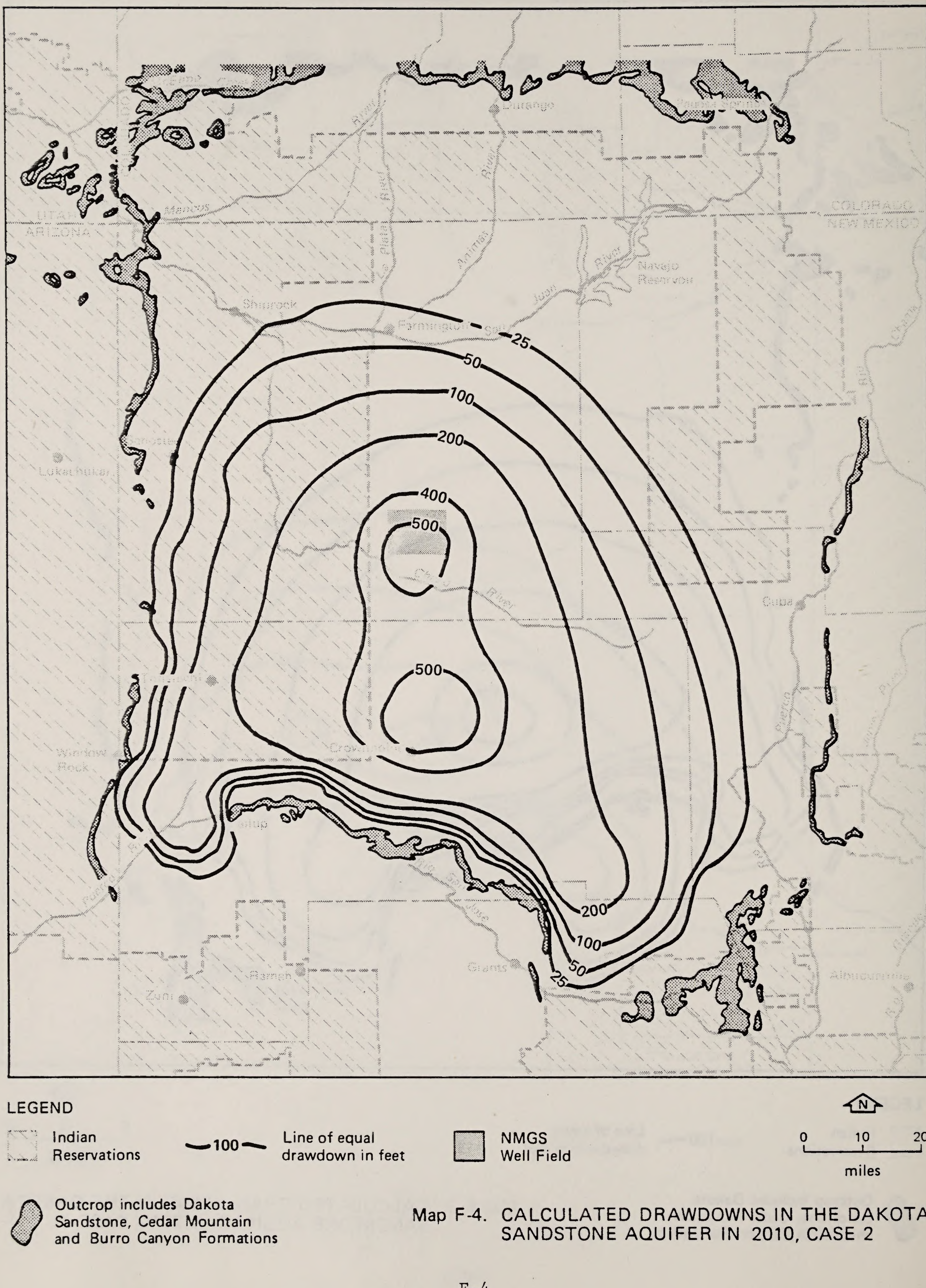
—100— Line of equal drawdown in feet

Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

0 10 20 miles

Map F-3. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 2010, CASE 1



Map F-4. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 2010, CASE 2

LEGEND

Indian Reservations

100 — Line of equal drawdown in feet

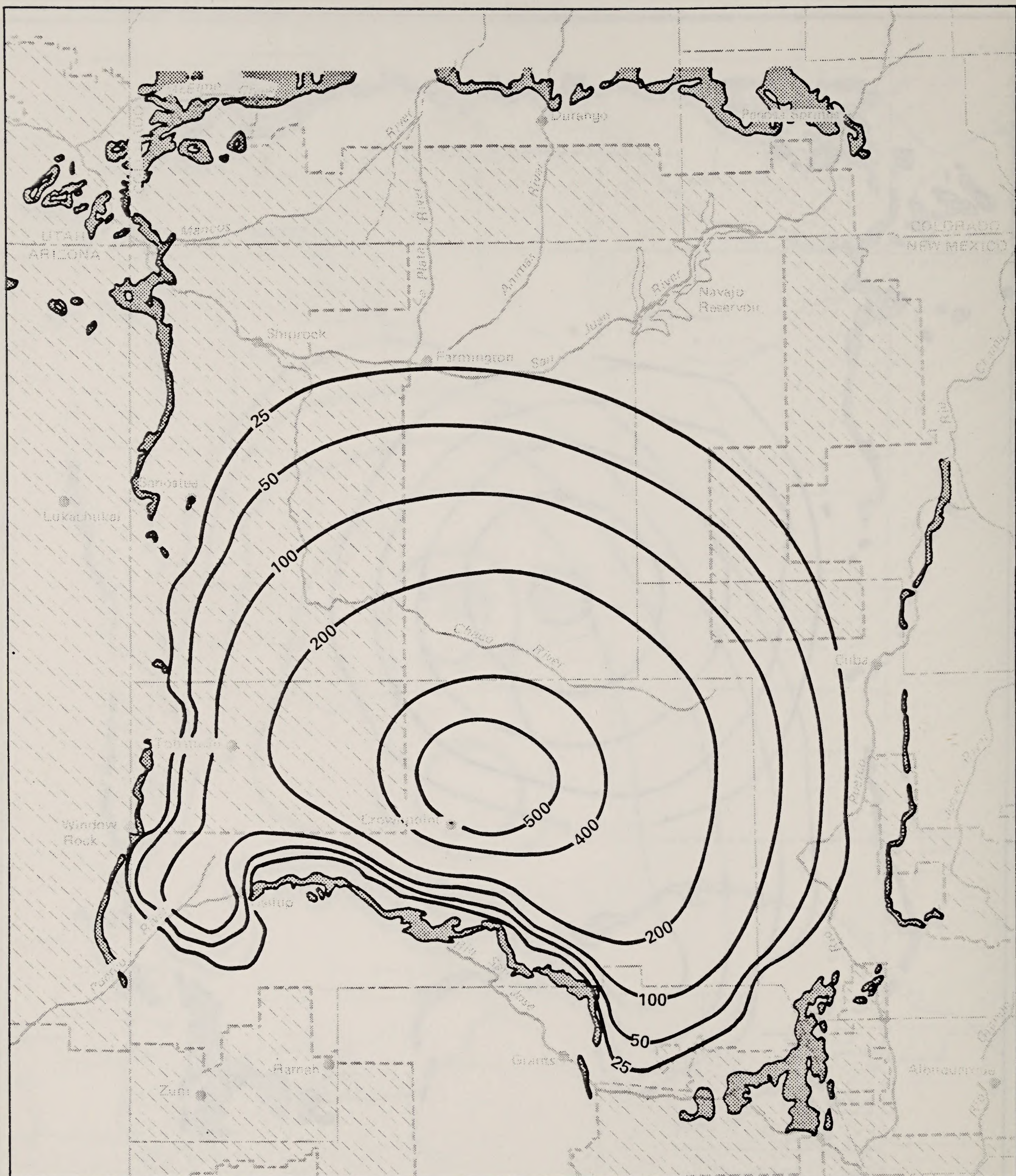
NMGS Well Field

Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

0 10 20 miles

Map F-5. CALCULATED DRAWDOWNS DUE TO NMGS IN THE DAKOTA SANDSTONE AQUIFER IN 2010



LEGEND

Indian Reservations

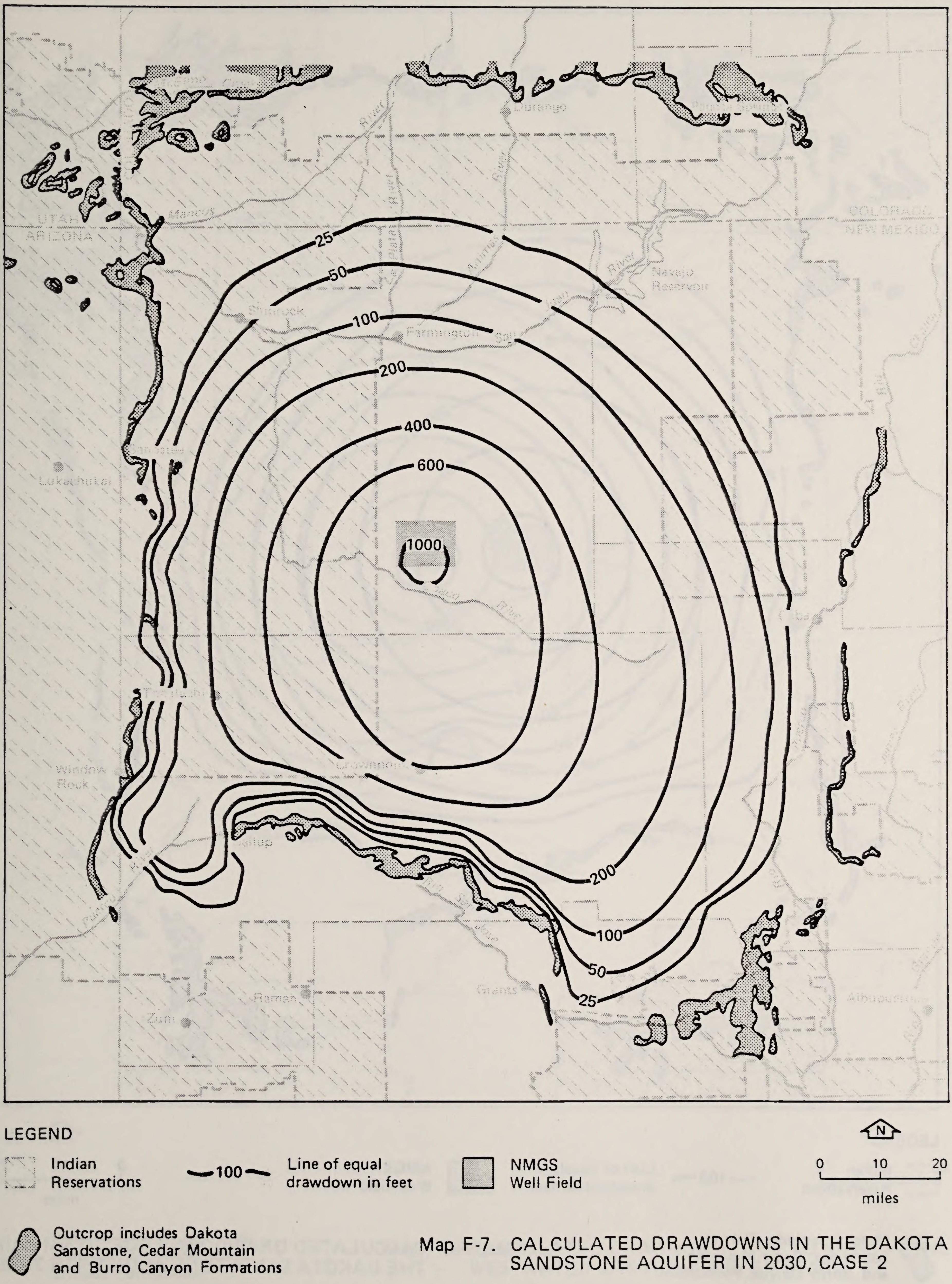
—100— Line of equal drawdown in feet

Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

0 10 20
miles

Map F-6. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 2030, CASE 1



Map F-7. CALCULATED DRAWDOWNS IN THE DAKOTA SANDSTONE AQUIFER IN 2030, CASE 2

LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

NMGS Well Field

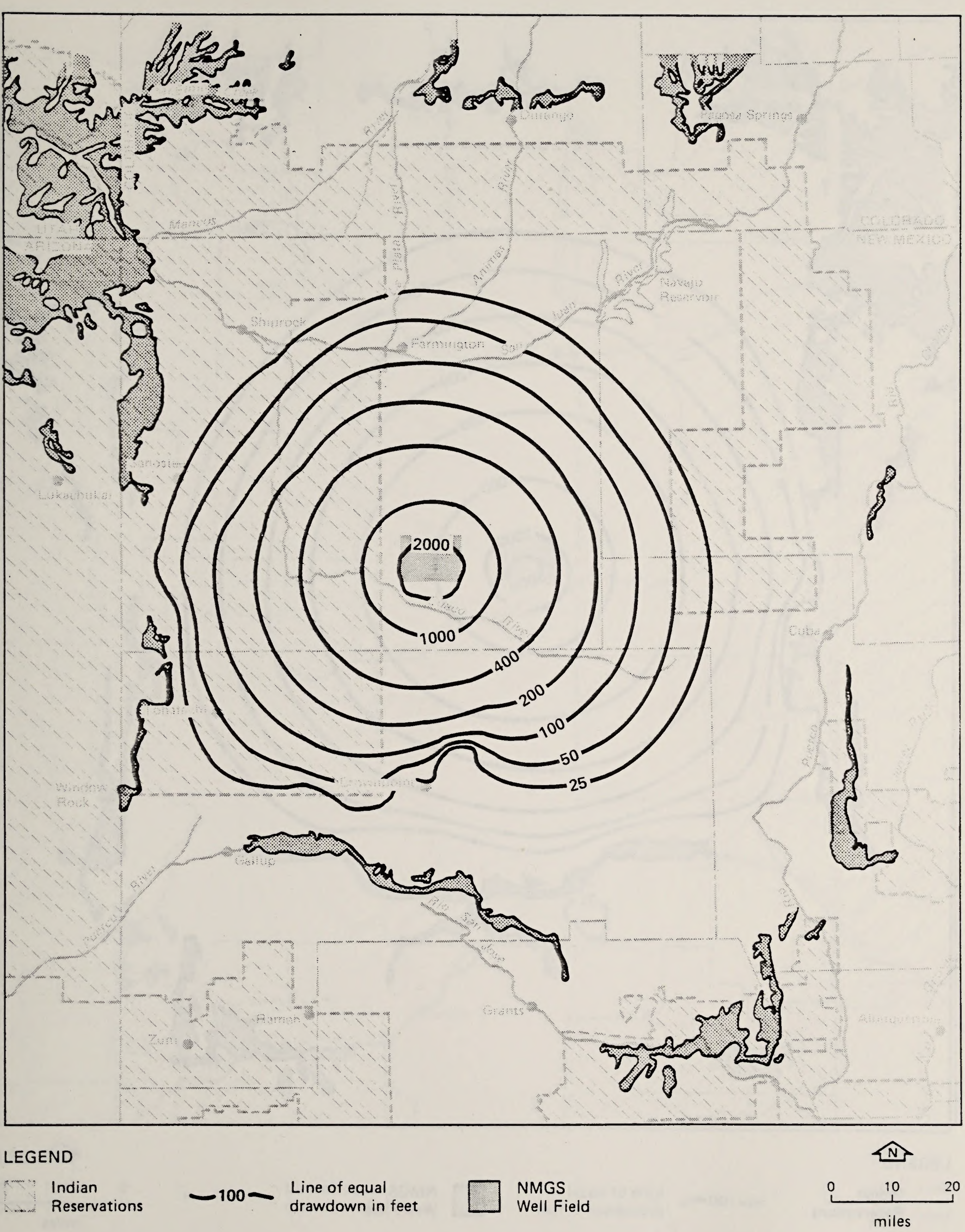
Outcrop includes Dakota Sandstone, Cedar Mountain and Burro Canyon Formations

N

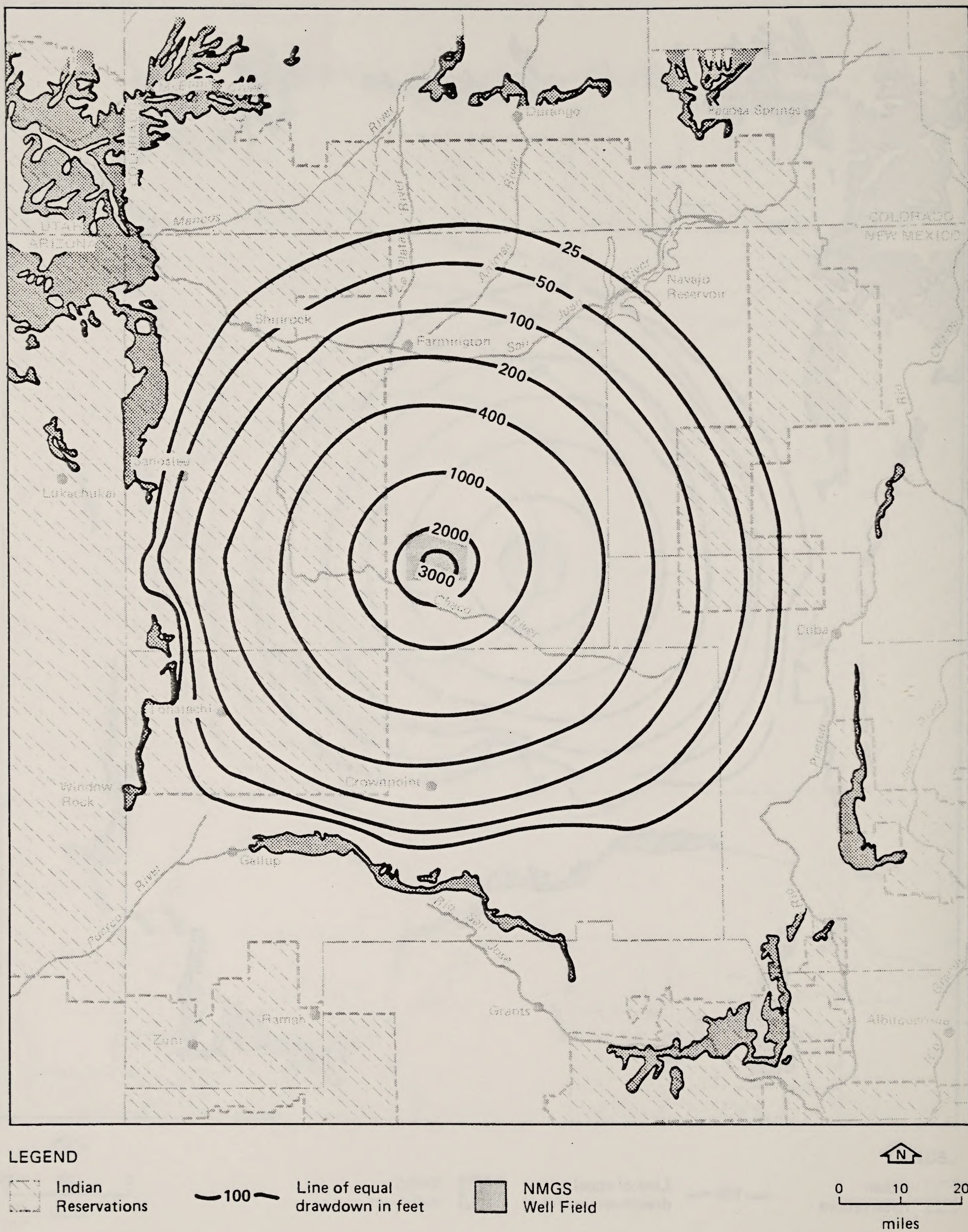
0 10 20

miles

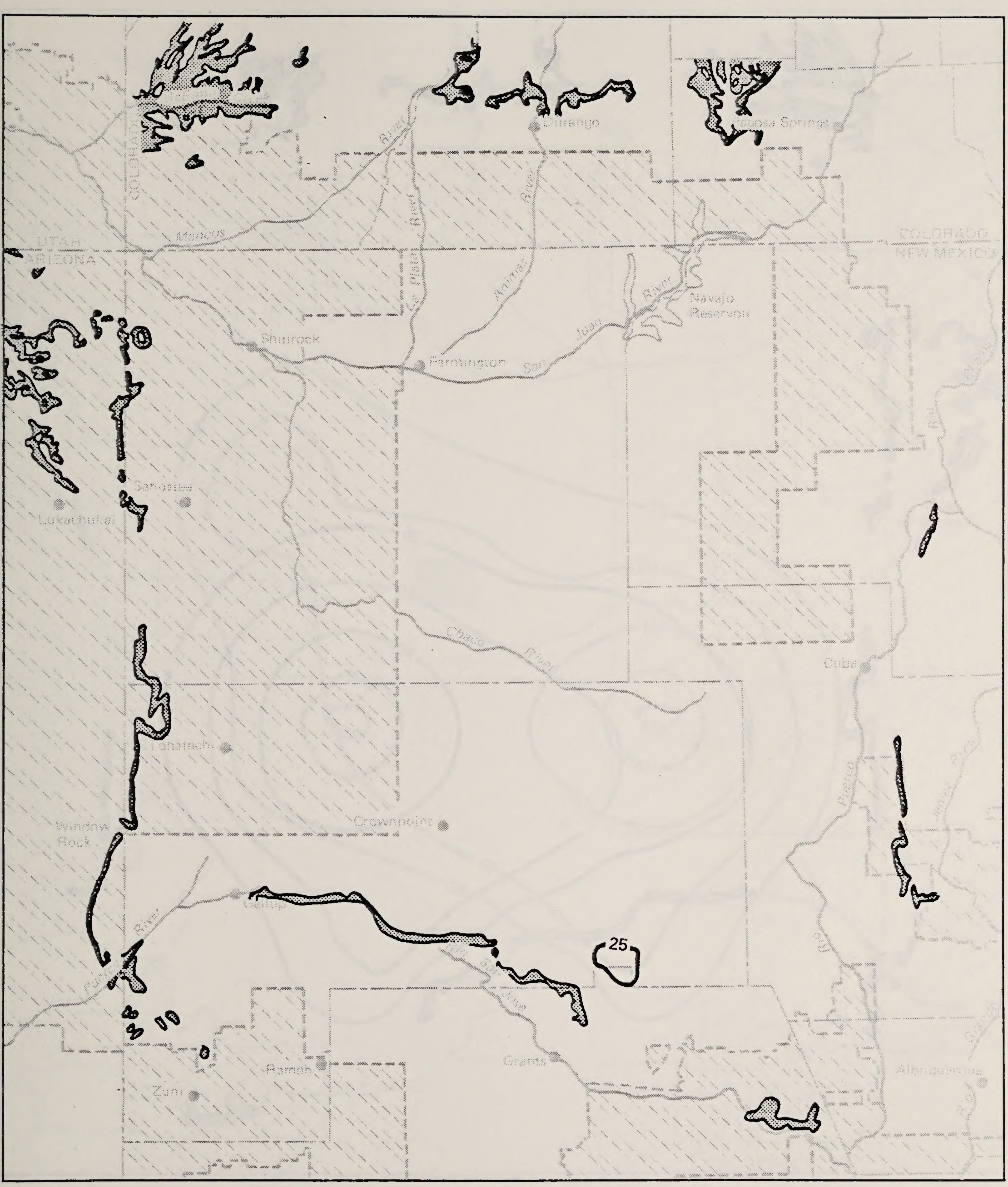
Map F-8. CALCULATED DRAWDOWNS DUE TO NMGS IN THE DAKOTA SANDSTONE AQUIFER IN 2030



Map F-9. CALCULATED DRAWDOWNS DUE TO NMGS IN THE WESTWATER CANYON AQUIFER IN 2010



Map F-10. CALCULATED DRAWDOWNS DUE TO NMGS IN THE WESTWATER CANYON AQUIFER IN 2030



LEGEND

Indian Reservations

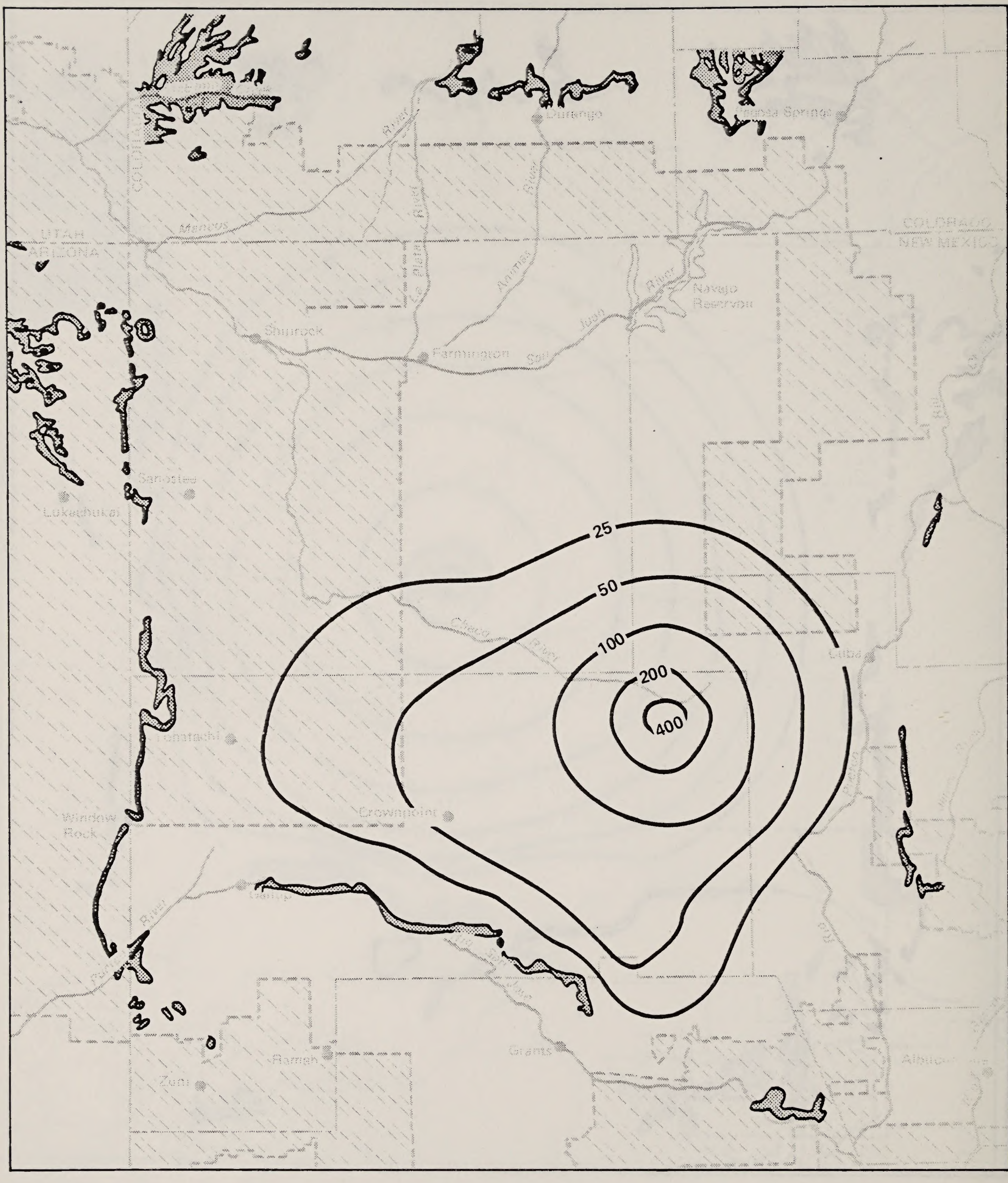
—100— Line of equal drawdown in feet

Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

N

0 10 20
miles

Map F-11. CALCULATED DRAWDOWNS IN THE ENTRADA SANDSTONE AQUIFER IN 1995, CASE 1



LEGEND

Indian Reservations

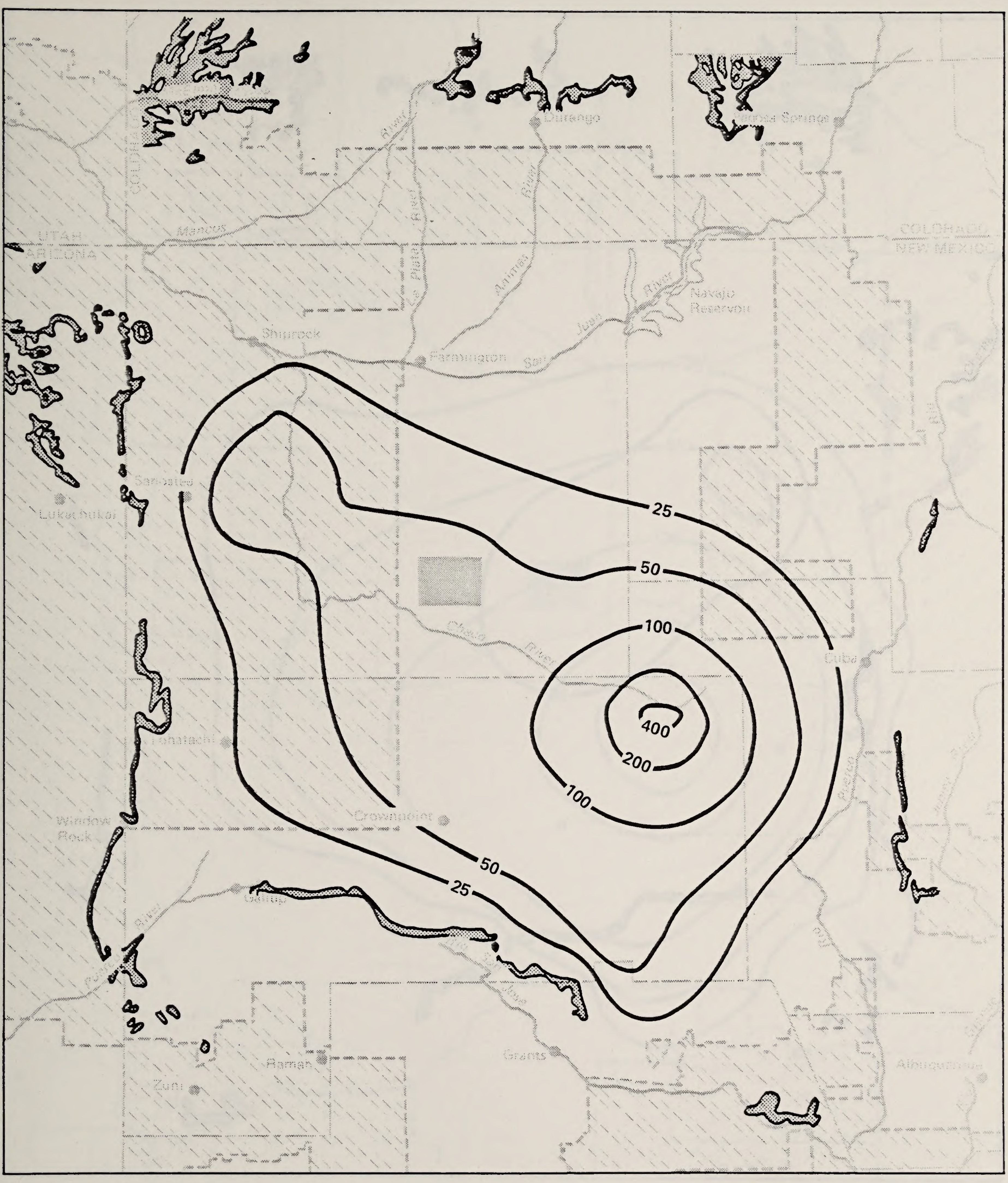
—100— Line of equal drawdown in feet

Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

N

0 10 20 miles

Map F-12. CALCULATED DRAWDOWNS IN THE ENTRADA SANDSTONE AQUIFER IN 2010, CASE 1



LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

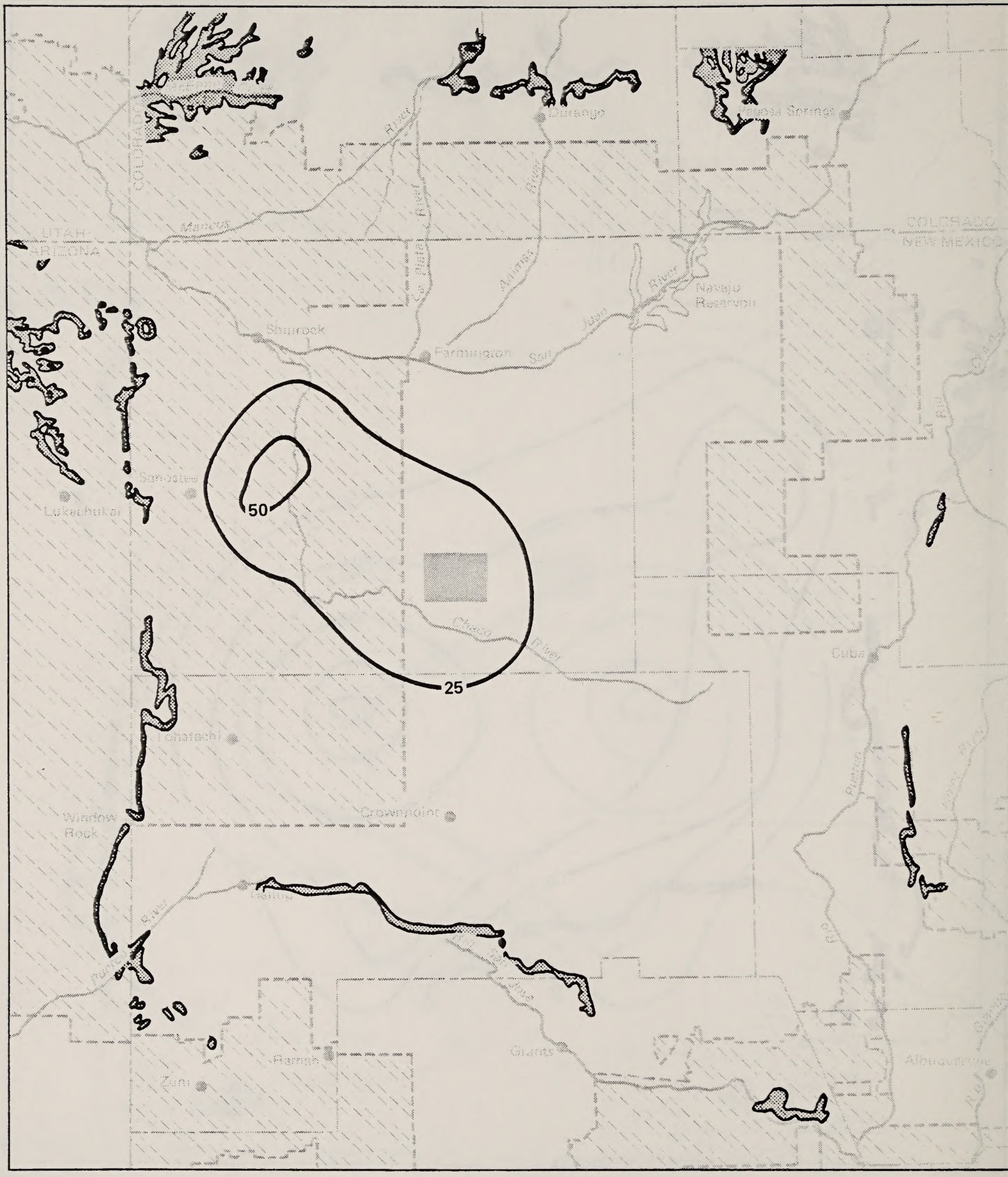
NMGS Well Field

Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

N

0 10 20 miles

Map F-13. CALCULATED DRAWDOWNS IN THE ENTRADA SANDSTONE AQUIFER IN 2010, CASE 2



LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

NMGS Well Field

0 10 20 miles

Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

Map F-14. CALCULATED DRAWDOWNS DUE TO NMGS IN THE ENTRADA SANDSTONE AQUIFER IN 2010

LEGEND

Indian Reservations

—100— Line of equal drawdown in feet

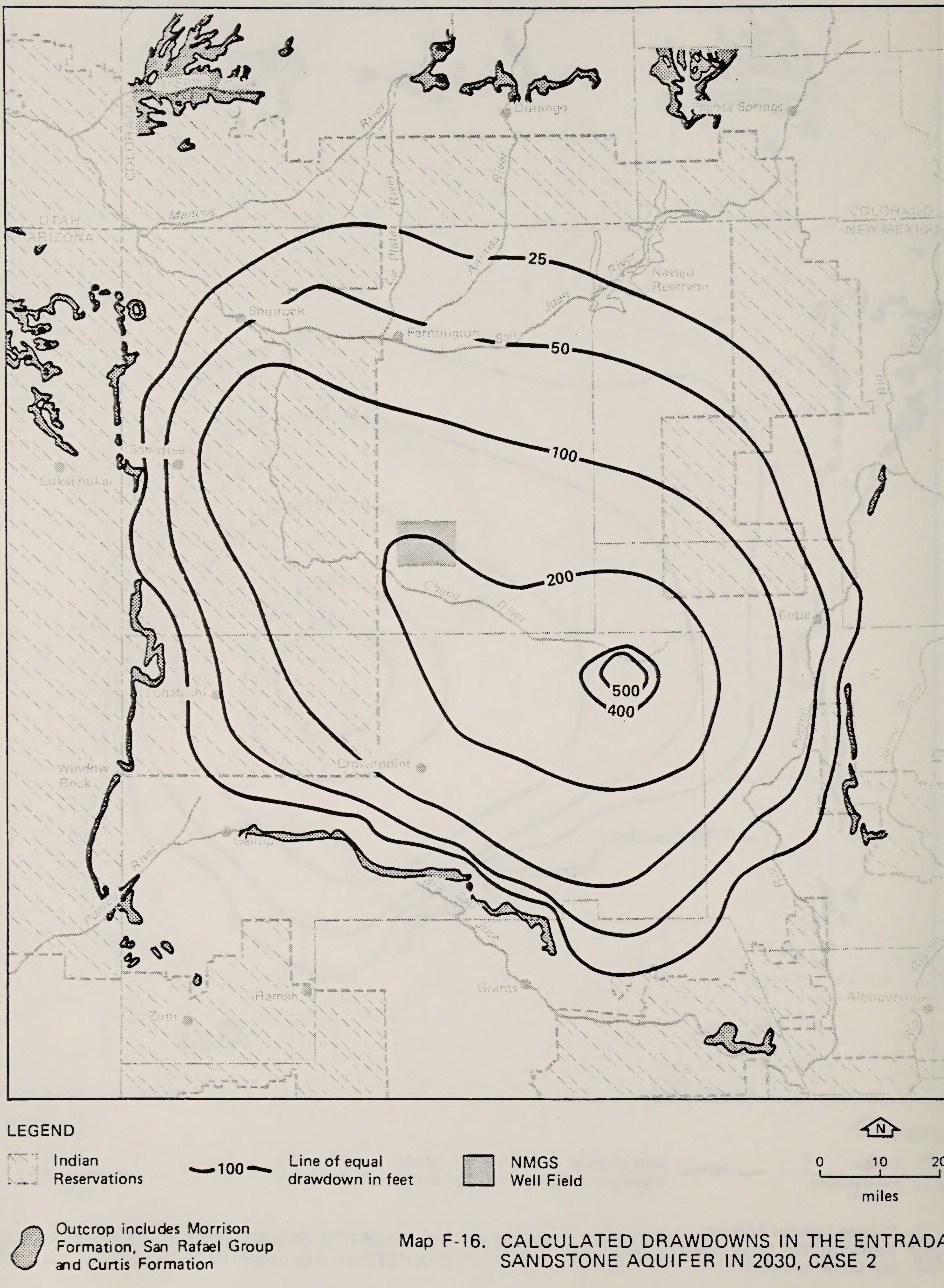
NMGS Well Field

Outcrop includes Morrison Formation, San Rafael Group and Curtis Formation

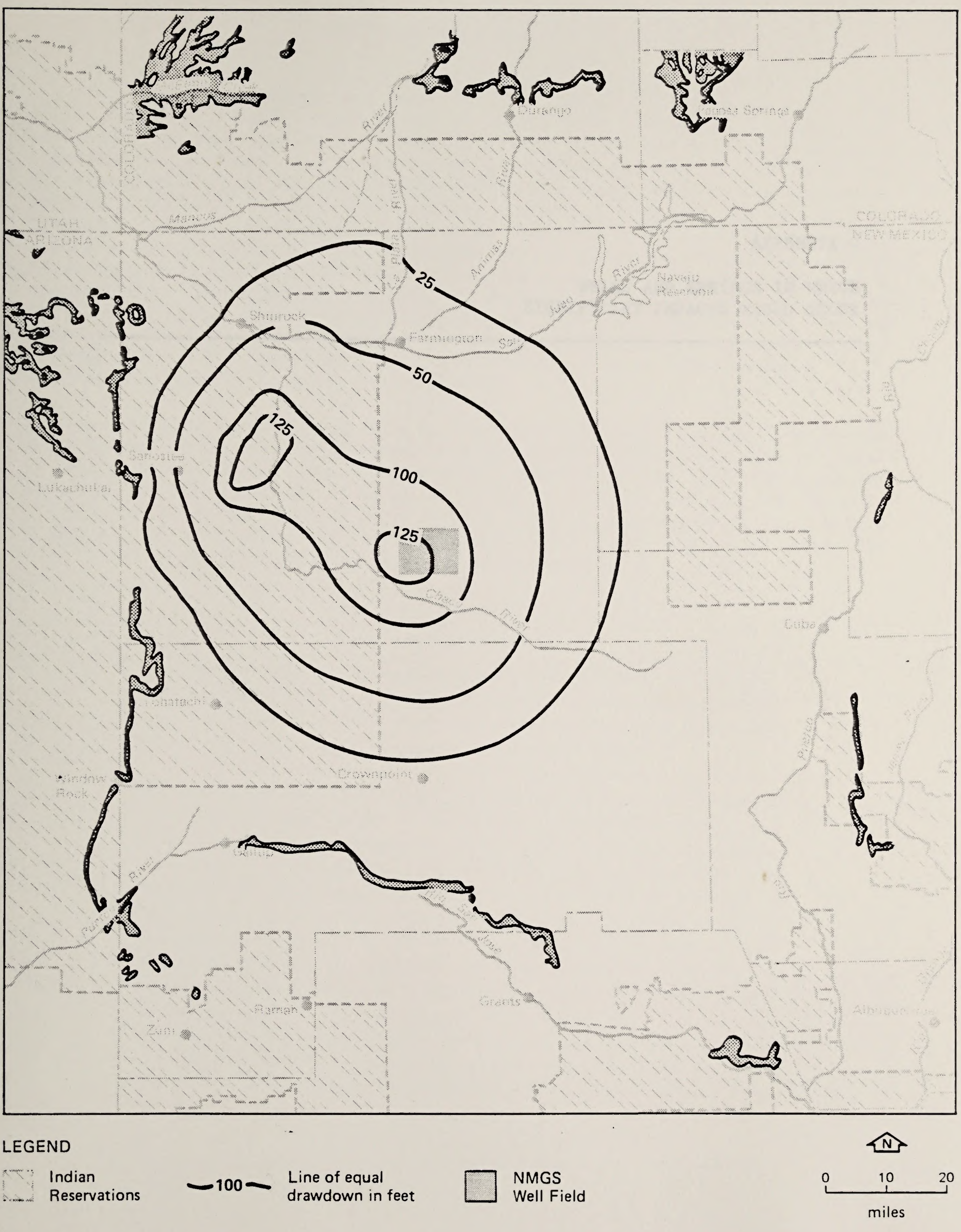
N

0 10 20
miles

Map F-15. CALCULATED DRAWDOWNS IN THE ENTRADA SANDSTONE AQUIFER IN 2030, CASE 1



Map F-16. CALCULATED DRAWDOWNS IN THE ENTRADA SANDSTONE AQUIFER IN 2030, CASE 2



Map F-17. CALCULATED DRAWDOWNS DUE TO NMGS IN THE ENTRADA AQUIFER IN 2030

APPENDIX G

WELLS AND SPRINGS IN WHICH SIGNIFICANT IMPACTS WOULD OCCUR

Well-numbering systems

Two numbering systems are used in this report to locate a well. The first uses the common subdivision of lands into townships, ranges, and sections. In this system, the location number is divided into four segments separated by periods. The first segment indicates the township north of the New Mexico Base Line, and the second denotes the range west of the New Mexico Principal Meridian. The third segment indicates the section within the township; and the fourth segment indicates the tract within which the well is located. To determine the fourth segment of the location number, the section is divided into quarters numbered 1, 2, 3 and 4 for the NW¼, NE¼, SW¼ and SE¼ respectively. Each quarter section is further subdivided into as many as four subdivisions depending on how closely the well was located. As an example, a well with a location number 21.07.28.2134 is located in the southeast ¼ of the southwest ¼ of the northwest ¼ of the northeast ¼ of section 28, Township 21 North, Range 7 West.

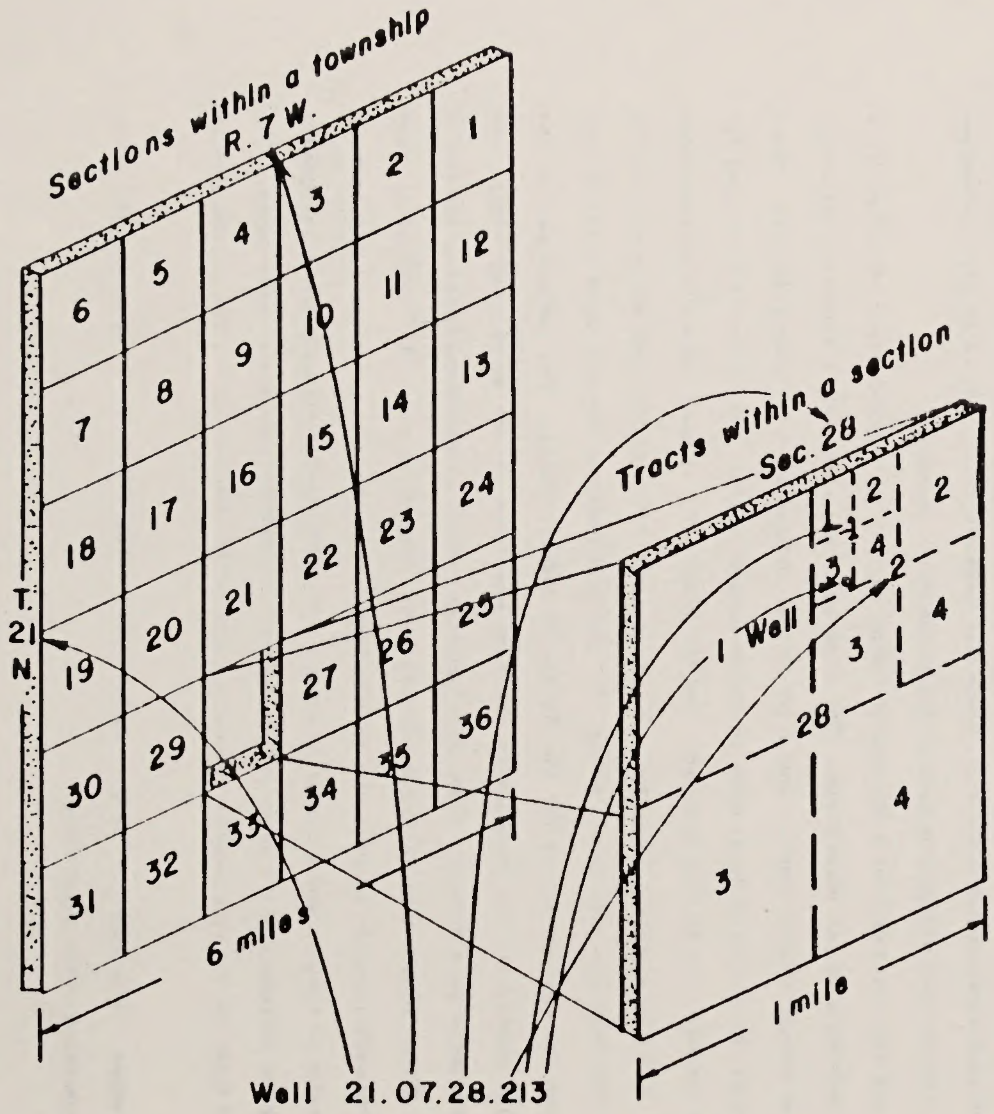
A different numbering system is used for the main part of the Navajo Reservation. This area is divided into 15-minute quadrangles, each of which is assigned a number. The well number consists of the quadrangle number followed by the distance in miles from the east line and the distance in miles from the north line, in that order. Thus, a well numbered 32 - 3.65 x 17.05 is in quadrangle number 32, 3.65 miles from the east line and 17.05 miles from the north line as shown in Figure G-1.

Bureau of Indian Affairs Field Number

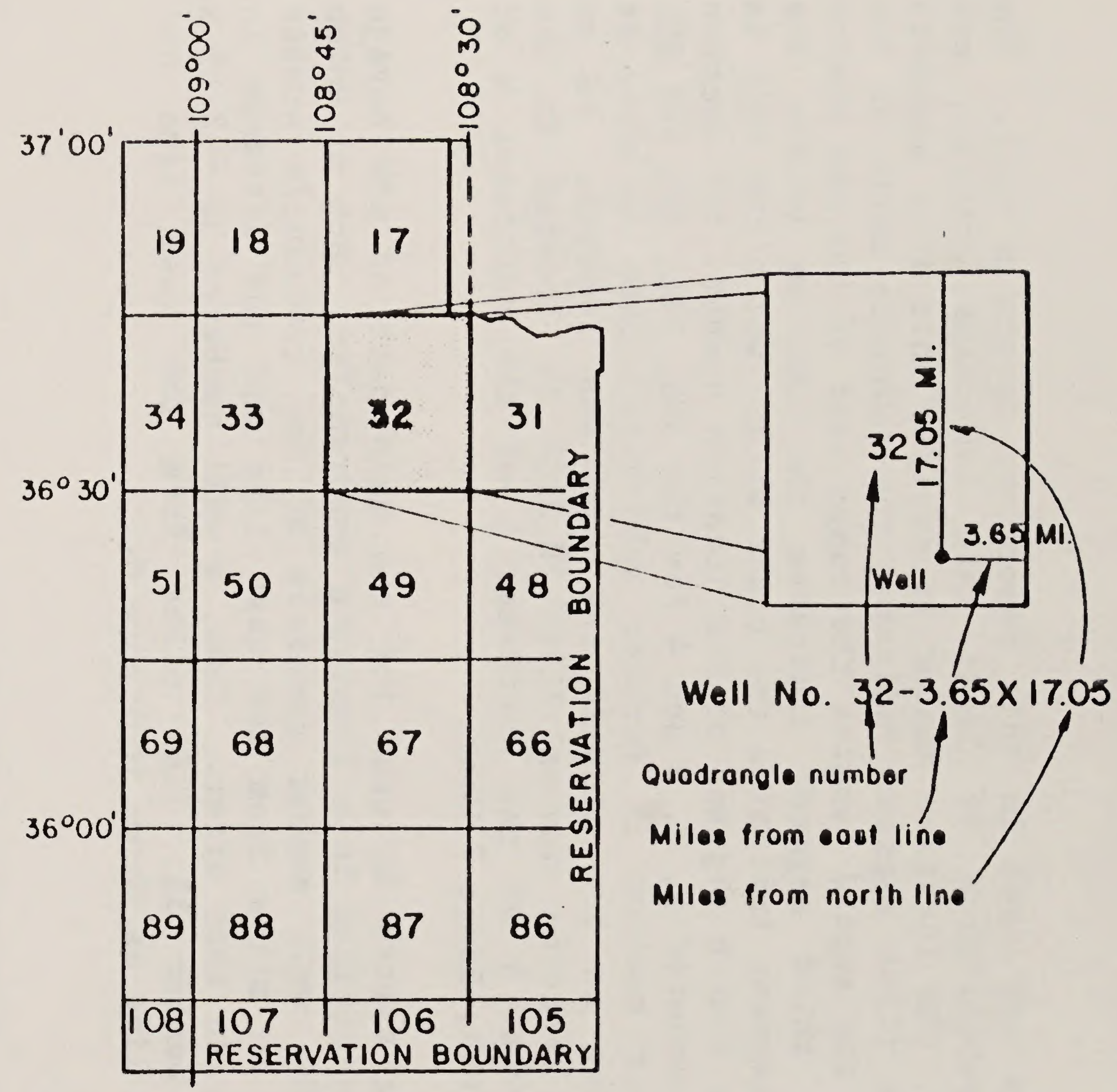
The ground-water and surface-water developments were inventoried during the 1930's by personnel of the Bureau of Indian Affairs. The water developments, regardless of type, were numbered consecutively within each administrative district. Since this field inventory, new water developments—principally drilled wells—were assigned a number and added to the inventory.

The wells and springs assigned a Bureau of Indian Affairs field number are identified by a compound number consisting of two main parts. The first part is divided into a numeral that designates the Bureau of Indian Affairs district and a letter that indicates one of several factors. Since about 1950, it denotes the source of funds used in the drilling of a well; the letter "K" is used for wells drilled under the Bureau's drilling program, and the letter "T" is used for wells drilled under the Navajo Tribal Well-Development Program. However, new wells drilled and all developments inventoried before 1950 may use instead of "K" or "T" the first letter of the last name of the person who first inventoried the well or spring for the Bureau of Indian Affairs. The second part of the Bureau field number represents the consecutive order in which the drilled wells, dug wells, and springs were inventoried in each district. Some developments contain an additional letter at the end of the field number. These letters are arranged consecutively, beginning with "A." Usually, these field numbers are obtained from the number of a nearby development that was inventoried previously.

Other dug wells or springs and a few drilled wells not inventoried previously were assigned a field number during the inventory of the early 1950's. This field number consists of three parts. The first part is formed from the district number and is followed by the letters "GS." The second part is the quadrangle number. The third part is the number representing the order in which the new developments were inventoried in the quadrangle.



System of numbering wells in New Mexico



System of numbering wells on the Navajo Indian Reservation

Source: Frenzel and others (1981).

Figure G-1. SYSTEMS OF NUMBERING WELLS AND SPRINGS IN NEW MEXICO

Table G-1. WELL WITH DRAWDOWNS OF 25 FEET OR GREATER IN ENTRADA SANDSTONE (Layer 1)

Source	Well Location Twp	Well Location Range	Well Location Section	Drawdown (ft)	Owner	Well Name	Date Completed	Aquifer	Final ID# No.[a]
USGS	21	09	16	90	Cherokee and Pittsburgh Coal & Mining Company	Gallo Wash Well #3		Je	E2
USGS	17 - 5.4 x 16.7[a]			70	-	OT-2 Stanolind		Je	E3
USGS	32 - 10.45 x 4.71[a]			70	-	12T-549		Je	E4
USGS	20	06	32	60	Cherokee & Pittsburgh Coal Mining Company	No. 1 Star Lake		Je, Jm	E5 (M33)
Guyton	50 - 6.70 x 5.30[a]			55	U.S. Bureau of Indian Affairs	12M-25	1925	Je, Jm	E6 (M105)
USGS	17 - 2.9 x 6.8[a]			45	-	-		Je and below	E7
USGS	17	12	28	45	-	Mobil Monument #132-2T		Je,Trw	E8 (M28)
Guyton	31N	16N	9	45	Atlantic Refining Company	-	3-64	Je	E9
USGS	19	05	31	40	-	NA1-SFPRR		Je	E10
USGS	17 - 7.5 x 3.05[a]			30	-	12T-565		Je(?)	E11
USGS	19	04	13	30	-	Filon 13C1		Je	E12
USGS	16	14	22	25	-	16T-595 (Mariano Lake)		Je,Jmw	E13 (M123)
USGS	16	14	27	25	-	16T-596 (Mariano Lake)		Je,Jmw	E14 (M141)

[a]Locations of wells are shown on Plate 1 (in pocket).

[b]BIA numbering system (see Figure G-1).

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a]

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
Guyton	23	13	9	1800	Apache No. 1 Foshay (Bisti Well)	1-72	Jmw	M1
Guyton	23	14	3	1200	Burnham Water Well No. 1	8-73	Jmw	M2 (D1)
N.M. State Eng. Off.	23	14	3	1200	23.14.130 Hiss.		Jmw	M3
USGS	48 - 4.0 x 16.9[c]			1125	EPNG Burnham		Jmw	M4
USGS	20	10	16	790	Chaco Canyon #15		Jmw(?)	M5
Guyton	21	9	16	760	No. 1 Gallo Wash	4-75	Jmw	M6
Guyton	17	13	2	700	-		Jmw	M7
Guyton	19	12	16	590	-		Jmw	M8
Guyton	19	13	16	580	-		Jmw	M9
Guyton	19	12	32	460	19-12-32-50		Jmw	M10
Guyton	19	11	31	450	Westwater Canyon Observation Well	1976	Jmw	M11
Guyton	18	12	1	420	18-12-1-157		Jmw	M12
N.M. State Eng. Off.	48 - 8.5 x 1.0[c]			390	22 Shell Oil Test		Kd,Jm	M13 (D8)
USGS	49 - 2.25 x 9.60[c]			375			Jm(?)	M14
USGS	49 - 2.3 x 9.0[c]			360	13T-511		Jm(?)	M15
USGS	17	13	4	300	15T-550		Kg(?),JM(?)	M16
USGS	17	13	9	265	9u214		Jm	M17
Guyton	17	12	17	250	-	12-75	Jmw	M18
N.M. State Eng. Off.	17	12	30	250	Crown Pt. Fire Station		Kd,Jm,Kg(?)	M19 (D18)

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
USGS	17	13	16	245	Mobil TW-1		Jmw	M20
Guyton	17	12	19	230	Crown Point P.M. 7	9-64	Jm	M21
USGS	28	13	16	230			Kmf,Kpl,Jm	M22
Guyton	17	12	20	225	Conoco Jmw Test	1974	Jmw	M23
Guyton	17	12	20	225	Crown Point P.M. 6	9-61	Jm	M24
N.M. State Eng. Off.	87 - 9.75 x 0.80[c]			220	14M-7 Dug Well		Kg,Jmw	M25
USGS	17	12	19	210	NTUA Crown Point #1		Kd,Jmn,Jcs(2)	M26 (D13)
USGS	86 - 12.95 x 16.70[c]			200	14T-529		Jmw	M27
USGS	17	12	28	195	Mobil Monument #132-2T		Jmw,Je,Trn	M28 (E8)
USGS	17	12	30	195	#3 15K-303		Kd,Jmw	M29 (D15)
USGS	17	12	30	195	P.M. 5		Kd,Jms,Jcs(?)	M30 (D16)
N.M. State Eng. Off.	87 - 9.0 x 8.0[c]			195	Pure Oil Co. #3		Jm	M31
N.M. State Eng. Off.	87 - 6.1 x 11.50[c]			190	14M-25A		Kd,Jmw,Kg	M32 (D17)
Guyton	20	06	32	180	No. 1 Star Lake	1975	Jmw	M33 (E5)
USGS	19	07	26	175	Villard & Reynolds		Jm	M34
USGS	87 - 12.60 x 7.06[c]			175	14A-10		Jmw(?)	M35
N.M. State Eng. Off.	87 - 12.6 x 7.0[c]			145	14N-102		Jmw	M36

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
USGS	87 - 3.30 x 15.60[c]			170	14T-573		Jmw	M37
USGS	87 - 9.65 x 13.30[c]			170	14T-583		Kg(?),Jmw(?)	M38
USGS	87 - 9.48 x 10.20[c]			165	14T-515		Kg,Kd,Jmw	M39 (D21)
Guyton	19	18	01	155	-		Jmw	M40
USGS	87 - 4.70 x 15.50[c]			155	14T-574		Jmw(?)	M41
N.M. State Eng. Off.	87 - 9.80 x 10.6[c]			155	14K-311		Kd,Jmw	M42 (D20)
Guyton	16	10	02	140	No. 1 South Hospah Water Well/C and P#1	4-75	Jmw	M43
USGS	19	05	08	140	Reynolds Mine		Jm	M44
USGS	87 - 5.35 x 16.10[c]			140	14T-559		Kd,Jmw,Kg	M45 (D22)
USGS	16	13	17	125	16T-558		Kd,Jmw	M46 (D24)
USGS	32 - 6.82 x 10.94[c]			125	12T-555		Jm(?)	M47
N.M. State Eng. Off.	29	16	33	125	Hogback Spring		Kg,Kd,Jmw	M48 (D31)
USGS	16	14	15	120	Hosta Butte 16T-323		Kd,Jmw	M49 (D32)
USGS	50 - 3.78 x 15.62[c]			120	-		Jm	M50
USGS	50 - 3.4 x 13.7[c]			110	-		Jm	M51
USGS	23	04	33	105	-		Jm	M52
Guyton	17	16	35	100	-	12-67	Jmw	M53
USGS	16	14	21	100	16T-555		Kd,Jmw	M54 (D44)
USGS	16	14	22	100	16T-595 (Mariano Lake)		Jmw,Je	M123

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
USGS	16	15	11	100	16T-509		Kd,Jmw	M55 (D35)
USGS	16	16	01	100	16-K-319		Kd,Jm(?)	M56 (D43)
USGS	17	16	35	100			Km,Kd,Jm	M57 (D36)
USGS	32 - 8.78 x 10.70[c]			100			Jmw,Jmr	M58
USGS	32 - 9.75 x 12.70[c]			100			Jm	M59
USGS	32 - 12.34 x 16.19[c]			100			Kd,Jm	M60 (D29)
USGS	32 - 5.6 x 3.6[c]			90			Kd(?),Jm(?)	M61 (D37)
USGS	106 - 9.32 x 2.95[c]			90	ERC 17-1		Kd, Jmw	M62 (D42)
USGS	32 - 13.20 x 13.05[c]			85	12K-320		Jmw	M63
USGS	33 - 0.1 x 15.5E[c]			85			Jm	M64
USGS	106 - 9.25 x 3.36[c]			85	ERC 17-2		Kg,Kd,Jmw	M65 (D41)
Guyton	16	11	33	85	P.M.3	9-72	Jmw	M66
USGS	16	14	27	85	16T-596 (Mariano Lake)		Jmw,Je	M141
USGS	32 - 7.56 x 2.47[c]			80	12T-630		Jmw,Jmr	M67
USGS	32 - 8.75 x 4.71[c]			80			Kd,Jm	M68 (D34)
USGS	32 - 12.76 x 10.50[c]			80			Jm	M69
USGS	50 - 1.95 x 0.85[c]			80	12R-85 Gypsy Oil		Jm(?)	M70
USGS	50 - 3.15 x 3.55[c]			80	12T-519		Kd,Jm	M71 (D39)

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
USGS	50 - 6.4 x 13.50[c]			80	12T-609		Kd,Jm	M72 (D62)
USGS	87 - 13.54 x 17.05[c]			80	14T-562		Kd,Jmw	M75 (D40)
Guyton	16	14	33	75	P.M. 3	4-58	Jm,Jcs	M74
Guyton	16	14	33	75	16T-507	6-60	Jmw,Jcs	M75
USGS	16	14	33	75	16K-528, P.M. 5	11-62	Jmw,Jcs	M76
USGS	16	14	33	75	16K-329, P.M. 2	3-52	Jmw,Jc	M77
USGS	16	14	33	75	P.M. 4		Jcs(?),Jmw(?)	M78
USGS	16	15	16	75			Kd,Jmw	M79 (D50)
USGS	33 - 2.03 x 16.88[c]			75	12R-84		Jmw	M80
N.M. State Eng. Off.	15	13	05	75	16K-318		Kd,Jm	M81 (D52)
N.M. State Eng. Off.	16	15	23	75	16T-535		Jmw,Kd	M82 (D64)
Guyton	15	12	03	70	16T-539 (Casamero Lake)	12-65	Jm	M83
USGS	30	16	10	70			Jmw	M84
USGS	32 - 11.17 x 4.79[c]			70	12K-309		Kd,Jmw(?)	M85 (D47)
Guyton	15	13	12	65	Blackjack No. 1 (Mine 2)	1958	Jb	M86
Guyton	15	13	12	65	Water Supply for Blackjack No. 1 Mine (1)	1958	Jb	M87

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
Guyton	33 - 4.00 x 15.55[c]			65	12T-508	7-59	Kd,Jb	M88 (D43)
USGS	30	16	04	65	-		Jmw	M89
USGS	31	15	23	65	-		Jm	M90
USGS	106 - 13.78 x 3.70[c]			65	14T-560		Jmw,Kd	M91 (D63)
N.M. State Eng. Off.	50 - 5.8 x 4.6[c]			65	12T-609		Kd,Jm	M92 (D53)
Guyton	16	16	15	60	16T-513	7-59	Jmw	M93 (D59)
USGS	31	16	34	60	-		Jm	M94
USGS	17 - 1.0 x 10.0[c]			60	-		Jm	M95
USGS	17 - 1.8 x 10.2E[c]			60	-		Jm, Pdc(?)	M96
USGS	17 - 3.2 x 9.4E[c]			60	-		Jm(?)	M97
Guyton	16	16	17	55	Church Rock Mine		Jm	M98
Guyton	15	13	17	55	16K-327		Jm(?)	M99
Guyton	15	12	17	55	16T-525A		Jmw	M100
USGS	15	12	17	55	Smith Lake Chap. Hse		Jmw	M101
USGS	15	12	17	55	16T-594 (Smith Lake)		Kd,Jm,Jc	M102 (D70)
USGS	15	12	17	55	16T-597 (Smith Lake)		Kd,Jm,Jc	M103 (D71)
Guyton	25	19	04	50	12T-512	9-59	Jm	M104
Guyton	50 - 6.70 x 5.30[c]			50	12M-25	1925	Jm,Je	M105 (E6)

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
Guyton	50 - 6.95 x 5.35[c]			50	12K-311	8-51	Jm	M106
Guyton	50 - 7.00 x 5.10[c]			50	Sanostee P.M. 3	5-65	Jmw,Jr,Kd	M107
Guyton	30	18	36	50	12T-520	2-61	Jm,Jb	M108
USGS	15	13	18	50	Blackjack 2		Jmw	M109
USGS	16	16	17	50	16T-532		Jmw	M110
USGS	17 - 2.50 x 6.80[c]			50	12T-559		Jm,Kd	M111 (D74)
USGS	17 - 3.5 x 8.3E[c]			50	-		Jm	M112
USGS	17 - 6.4 x 10.25[c]			50	12R-204		Kd,Jm,Kg(?)	M113
USGS	17 - 9.99 x 14.60[c]			50	12K-300A		Kd,Jm	M114 (D66)
USGS	17 - 10.5 x 14.75[c]			50	12K-300		Kd,Jm	M115 (D76)
USGS	17 - 10.85 x 15.45[c]			50	12T-520		Jm	M116
USGS	32 - 13.3 x 2.59[c]			50	-		Jm	M117
USGS	50 - 6.60 x 5.00[c]			50	12T-512		Jm	M118
USGS	50 - 6.8 x 5.4[c]			50	Sanostee		Jm	M119
USGS	50 - 7.90 x 10.15[c]			50	12T-507		Jm	M120
USGS	107 - 1.50 x 3.15[c]			50	14T-531 (North Twin Lakes)		Jm	M121
N.M. State Eng. Off.	15	12	20	50	Smith Lake T.P. Test		Jmw	M122
Guyton	15	12	19	45	Smith Lake T.P.		Jmw	M124
USGS	33 - 3.27 x 9.10[c]			45	-		Jmw,Jmr	M125

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
Guyton	26	19	05	40	12T-582		Jm	M126
Guyton	15	14	12	40	N-1136		Jmn, Jmb	M127
USGS	15	14	02	40	Gulf Mariano Well		Jmw	M128
USGS	50 - 8.76 x 5.75[c]			40	–		Jm	M129
Guyton	16	16	30	35	–	1949	Jm,Jcs	M130
Guyton	29	19	01	35	12R-50A	3-27	Jm	M131 (D98)
USGS	33 - 2.67 x 4.67[c]			35	12K-310		Kd,Jmw	M132 (D79)
USGS	33 - 4.90 x 9.45[c]			35	12R-98		Kg,Jm	M133
USGS	50 - 8.46 x 2.51[c]			35	12T-570		Jm	M134
USGS	33 - 7.40 x 16.45[c]			35	12T-582		Jm	M135
Guyton	16	17	21	30	16T-534	7-65	Jmw	M136
USGS	15	11	29	30	–		Jm	M137
USGS	16	18	07	30	–		Kg,Kd,Jmw	M138 (D97)
USGS	17 - 7.5 x 3.10[c]			30	12T-560		Jm(?)	M139
USGS	18 - 3.75 x 16.5[c]			30	12T-50B		Kd,Jm	M140 (D103)
Guyton	33 - 7.05 x 9.00[c]			25	New Red Rock Sch. P.M. 1	12-65	Kd,Jmw	M142
USGS	15	10	20	25	Gulf West Largo		Jmw	M143
USGS	16	16	30	25	Springstead T.P.		Jm,Jcs	M144

Table G-2. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN WESTWATER CANYON MEMBER (Layer 3)[a] (concluded)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[b]
USGS	16	16	30	25	Springstead T.P.		Jm,Jcs(?)	M145
USGS	18 - 0.5 x 6.8E[c]			25	-		Kd,Jm	M147
USGS	18 - 5.5 x 14.0[c]			25	Exxon Artesian		Jmw	M148
USGS	33 - 7.16 x 8.76[c]			25	New Red Rock P.M. 1		Jm	M149 (D100)
USGS	33 - 7.76 x 14.37[c]			25	12T-354		Jmw	M150
USGS	50 - 11.30 x 4.95[c]			25	12T-516		Kd,Jm	M151

[a]Also included are wells tapping undifferentiated Morrison Formation.

[b]Locations of wells are shown on Plate 1 (in pocket).

[c]BIA Numbering System

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
Guyton	23	14	3	>400	Burnham Water Well No. 1	8-73	Kd	D1
Guyton	20	10	30	330			Kd	D2
Guyton	24	9	1	300	Not-Ti-Nue-Wood		Kd	D3
Guyton	19	12	32	280	19-12-32-28		Kd	D4
Guyton	19	12	32	280	19-12-32-4	7-75	Kt	D5
Guyton	19	11	31	275	Hydrologic Test Well Hole 150	1976	Kd	D6
Guyton	19	11	31	275	Dakota Observation Well, Hole 178	1976	Kd	D7
N.M State Eng. Off.	48 - 8.5 x 1.0[b]			265	22 Shell Oil Test		Kd, Jm	D8 (=M13)
USGS	27	13	15	250	F.A. Schultz #1		Kd	D9
USGS	17	13	9	200	Mobil 9u 207		Kd	D10
USGS	19	10	33	200	Ruby Oil		Kg, Kd	D11
USGS	19	10	25	195	Tenneco Oil		Kd	D12
USGS	17	12	19	175	NTUA Crown Point #1		Kd, Jm, Jcs	D13 (=M20)
USGS	17	12	20	170	Crown Point P.M. 6		Kd, Jmw	D14 (=M20)
USGS	17	12	30	160	15K-303		Kd, Jmw	D15 (=M29)
USGS	17	12	30	160	Crown Point P.H. 5		Kd, Jms, Jcs(?)	D16 (=M30)
N.M. State Eng. Off.	87 - 6.1 x 11.50[b]			160	14M-25A		Kd, Jms, Kg	D17 (M32)

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5) (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
N.M. State Eng. Off.	17	12	30	155	Crown Pt. Site Station		Kd, Jm, Kd(?)	D18 (=M19)
USGS	17	09	01	140	Hancock #1		Knt(?),Kg, Kd	D19
N.M. State Eng. Off.	87 - 9.80 x 10.6[b]			135	14K-311		Kd, Jmw	D20 (M41)
USGS	87 - 9.48 x 10.20[b]			130	14T-515		Kg, Kd, Jmw	D21 (=M38)
USGS	87 - 5.35 x 16.10[b]			120	14T-559		Kd, Jmw, Kg	D22
Guyton	27	17	4	100	12T-547	6-62	Kd	D23
Guyton	49 - 13.75 x 2.20[b]			100	12T-590		Kd	D24
USGS	16	13	17	100	16T-558		Kd, Jmw	D25 (=M46)
USGS	32 - 2.6 x 4.9E[b]			100	Magnolia Navajo #1		Kg(?) Kd(?)	D26
USGS	32 - 3.60 x 4.59[b]			100	12T		Kd(?)	D27
USGS	32 - 7.4 x 9.8[b]			100	12T-547		Kd	D28
USGS	32 - 12.34 x 16.19[b]			100	Exxon		Kd, Jm	D29 (=M60)
USGS	32 - 3.38 x 3.61[b]			95	12B-75		Kd	D30
N.M. State Eng. Off.	29	16	33	95	Hogback Spring		Kg, Kd, Jmw	D31 (=M48)
USGS	16	14	15	90	Hosta Butte 16T-323		Kd, Jmw	D32 (=M49)
USGS	32 - 3.60 x 2.60[b]			90	Amoco-Byeback		Kd	D33
USGS	32 - 8.75 x 4.71[b]			90	Exxon		Kd, Jm	D34 (=M68)
USGS	16	15	11	80	16T-509		Kd, Jmw	D35 (=M55)

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5) (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
USGS	17	16	35	80	United Nuclear Corp.		Km, Kd, Jm	D36 (=M57)
USGS	32 - 5.6 x 3.6[b]			80	-		Kd(?), Jm(?)	D37 (=M61)
Guyton	29	17	1	75			Kd	D38
USGS	50 - 3.15 x 3.55[b]			75	12T-519		Kd, Jm	D39 (=M71)
USGS	87 - 13.54 x 17.05[b]			75	14T-562		Kd, Jmw	D40 (=M73)
USGS	106 - 9.25 x 3.36[b]			75	ERC 17-2		Kg, Kd, Jmw	D41 (=M65)
USGS	106 - 9.32 x 2.95[b]			75	ERC 17-1		Kd, Jmw	D42 (=M62)
Guyton	16	16	1	70	16K-319		Kd	D43 (=M56)
USGS	16	14	21	70	16T-555		Kd, Jmb	D44 (=M54)
USGS	17 - 5.0 x 16.5[b]			70	Pan Am Petr. Company		Kd	D45
USGS	106 - 7.80 x 4.25[b]			70	14T-540		Kg(?), Kd(?)	D46
Guyton	32 - 11.17 x 4.79[b]			60	12K-309	5-40	Kd	D47 (=M85)
Guyton	16	15	17	60	16T-348	11-57	Kd	D48
Guyton	16	15	17	60	16T-514	8-59	Kd	D49
USGS	16	15	16	60	Tidewater Oil Co.		Kd, Jmw	D50 (=M79)
USGS	106 - 3.71 x 2.13[b]			60	14T-561		Kg, Kd	D51
N.M. State Eng. Off.	15	13	5	55	16K-318		Kd, Jm	D52 (=M81)

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5) (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
N.M. State Eng. Off.	50 - 5.8 x 4.6[b]			55	12T-609		Kd, Jm	D53 (=M92)
Guyton	33 - 4.00 x 15.50[b]			50	12T-508	7-59	Kd, Jmb	D54
Guyton	33 - 1.60 x 8.90[b]			50	12P-357	7-57	Kd	D55
USGS	15	11	17	50	Q104, 193 x 14.72 16B - 37		Kd	D56
USGS	16	14	33	50	Red Willow Spring		Kd, Km	D57
USGS	16	15	21	50	W-2 Pinedale Test		Kd	D58
USGS	16	16	15	50	16T-513		Kd, Jmw	D59 (=M93)
USGS	17 - 9.99 x 14.60[b]			50	12K-300A		Kd, Jm	D60 (=M114)
USGS	33 - 0.3 x 7.72[b]			50	12P-347		Kd, Kg(?)	D61
USGS	50 - 6.4 x 13.50[b]			50	12T-609		Kd, Jm	D62 (=M72)
USGS	106 - 13.78 x 3.70[b]			50	14T-560		Jmw, Kd(?)	D63
N.M. State Eng. Off.	16	15	23	50	16T-535		Jmw, Kd	D64 (=M82)
Guyton	16	5	18	45	-	2-56	Kd	D65
USGS	15	14	12	45	16GS-105-5		Kd	D66
Guyton	15	14	12	45	-		Kd	D67
USGS	15	11	17	45	16B-37 (U.S. BIA)	1937	Kd	D69
USGS	15	12	17	45	Smith Lake #1 16T-594		Kd, Jm, Jc	D70 (=M102)

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5) (continued)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
USGS	15	12	17	45	Smith Lake #2 16T-597		Kd, Jm, Jc	D71 (=M103)
USGS	16	15	20	45	16K-355		Kd(?) Km(?)	D72
USGS	16	16	17	45	Church Rock Mine		Kd, Jmw	D73
USGS	17 - 2.50 x 6.80[b]			45	12T-559		Jm, Kd	D74 (=M111)
USGS	17 - 6.4 x 10.25[b]			45	12R-204		Kd, Jm, Kg(?)	D75
USGS	17 - 10.5 x 14.75[b]			45	12K-300		Kd, Jm	D76 (=M115)
USGS	50 - 7.20 x 6.15[b]			45	12T-543		Kd, Jm	D77
Guyton	30	17	5	40	No. 2-G Navajo		Kd	D78
Guyton	33 - 2.67 x 4.67[b]			40	12K-310	10-45	Kd	D79 (=M132)
Guyton	15	14	11	40	16GS-105-1		Kd	D80
USGS	15	06	03	40	Midwest		Kd	D81
USGS	16	17	15	40	16T-510		Kd	D82
USGS	24	02	20	40	Magnolia Ingerson #1		Kd	D83
USGS	17 - 8.2 x 1.0E[b]			40	2-G Navajo		Kd	D84
USGS	33 - 0.85 x 1.71[b]			40	-		Kd(?)	D85
Guyton	50 - 8.10 x 10.05[b]			35	12T - 507	7-59	Kd	D86
Guyton	68 - 10.30 x 12.50[b]			35	18T - 531	6-59	Qal, Kd(?)	D87
Guyton	16	15	27	35	16T - 560	7-71	Kt	D88
USGS	15	13	17	35	16K - 327		Kd,Jmw	D89

Table G-3. WELLS WITH DRAWDOWNS OF 25 FEET OR GREATER IN DAKOTA SANDSTONE (Layer 5) (concluded)

Source	Well Location Twp	Range	Section	Drawdown (Ft)	Well Name	Date Completed	Aquifer	Final ID No.[a]
USGS	15	13	17	35	Tidewater Oil Co.		Kd	D90
USGS	19	03	14	35	Magnolia Oil		Kd	D91
USGS	88 - 9.55 x 0.15[b]			35	14T - 517		Kd, Jmn	D92
Guyton	15	12	19	30	Smith Lake T.P.		Kd	D93
USGS	15	11	25	30	16T-501		Kd	D94
USGS	15	12	19	30	Smith Lake Mission		Kd	D95
USGS	15	12	22	30	Hassel Well		Kd	D96
USGS	16	18	07	30	J.B. Tanner		Kg, Kd, Jmw	D97 (=M138)
USGS	18 - 3.0 x 17.0[b]			30	12R-50A		Kd, Jm	D98 (=M131)
USGS	18 - 3.10 x 16.50[b]			30	12T-548		Kd	D99
Guyton	33- 7.05 x 9.00[b]			25	New Red Rock School P.H. 1	12-65	Kd, Jmn	D100 (=M149)
USGS	18 - 3.75 x 16.5[b]			25	12T-50B		Kd, Jm	D103 (=M140)

[a]Locations of wells are shown on Plate 1 (in pocket).

[b]BIA numbering system (see Figure G-1).

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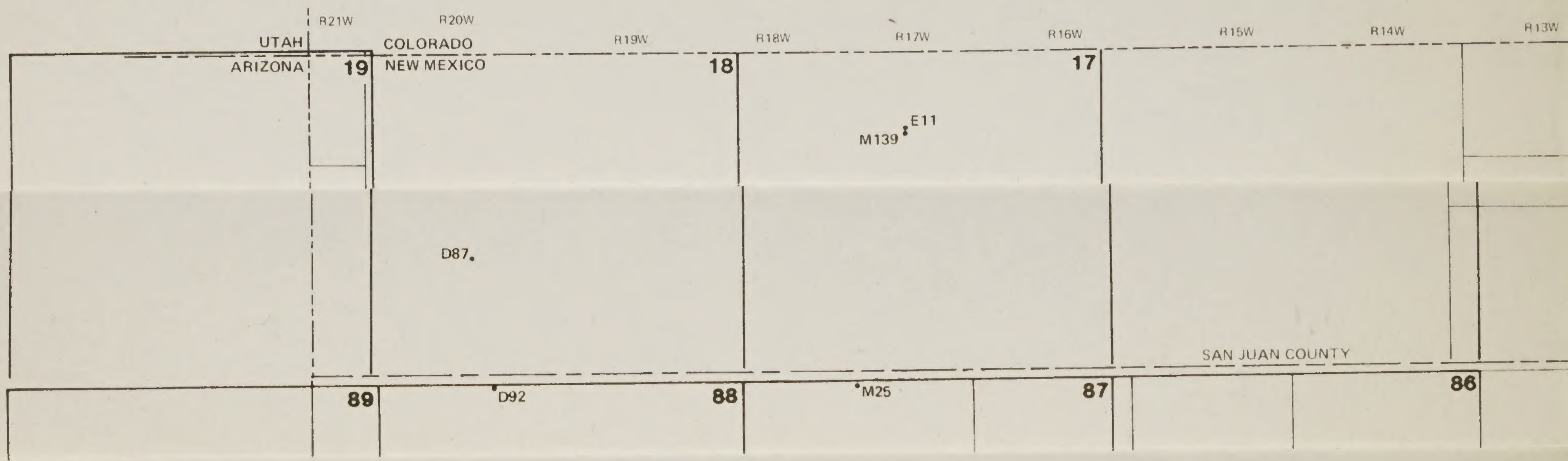
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R19W
R18W
R17W
R16W
R15W
R14W
R13W
UTAH
ARIZONA
COLORADO
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D92
88
M25
87
86

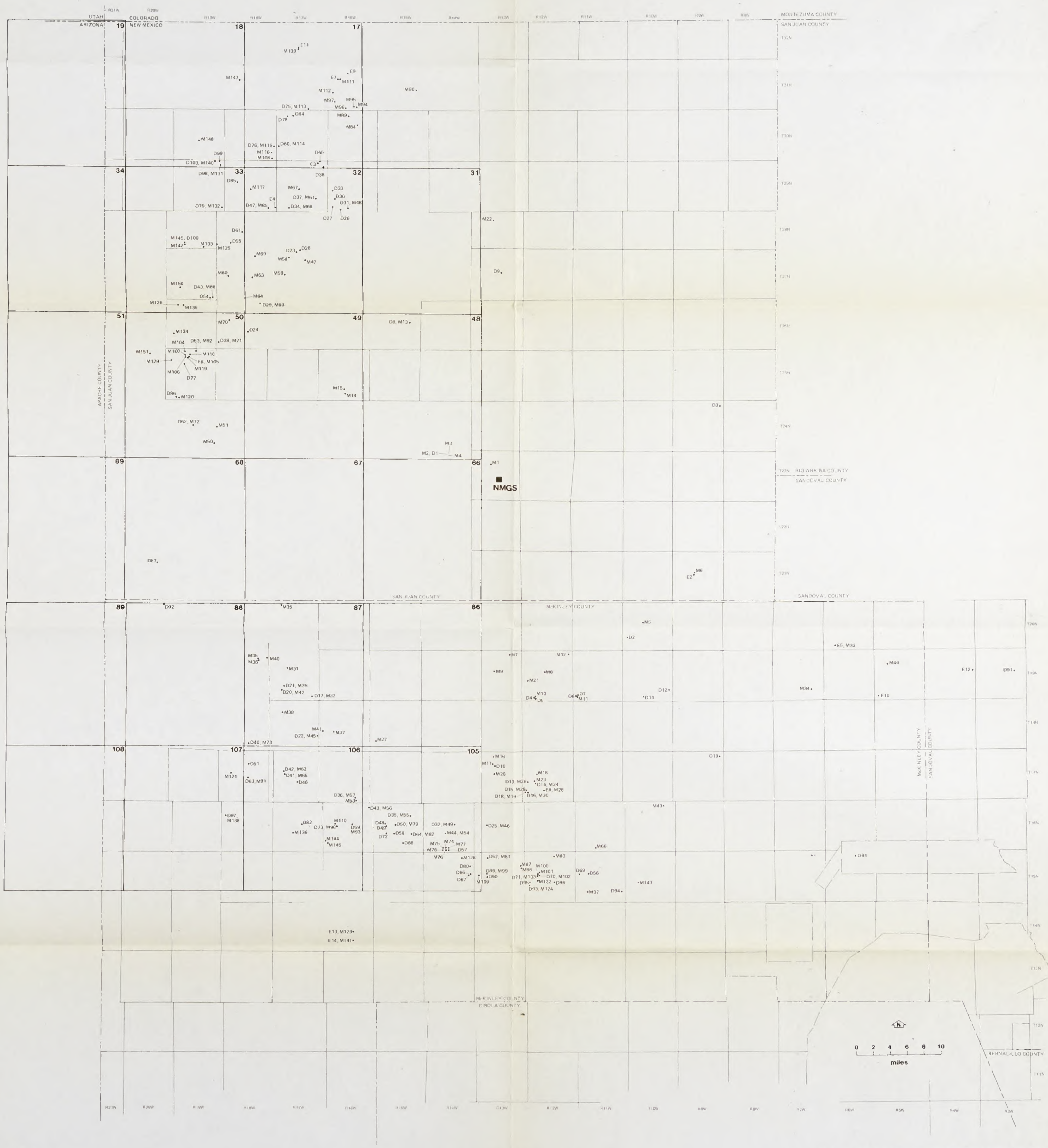

Plate 1. WELL LOCATIONS AROUND THE PROPOSED NMGS FACILITY