1 of 5

**Salt Lake City Area Integrated Projects
Electric Power Marketing
Draft Environmental Impact Statement**

Volume 2: Sections 1-16

U.S. Department of Energy
Western Area Power Administration

February 1994

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

COVER SHEET

Title: Salt Lake City Area Integrated Projects Electric Power Marketing Draft Environmental Impact Statement

Cooperating Agencies: U.S. Fish and Wildlife Service, the National Park Service, and the Bureau of Reclamation

Lead Agency: Western Area Power Administration

Written comments on this environmental impact statement (EIS) should be addressed to:

Mr. David Sabo
Western Area Power Administration
Salt Lake City Area Office
P.O. Box 11606
Salt Lake City, Utah 84147-0606
Telephone: (801) 524-5392

For general information on the U.S. Department of Energy EIS process, contact:

Ms. Carol Borgstrom, Director
Office of NEPA Oversight (EH-25)
U.S. Department of Energy
Room 3E-080 Forrestal Building
1000 Independence Ave., S.W.
Washington, D.C. 20585
Telephone: (202) 586-4600

ABSTRACT

The Salt Lake City Area Office of the Western Area Power Administration (Western) markets electricity produced at hydroelectric facilities operated by the Bureau of Reclamation. The facilities are known collectively as the Salt Lake City Area Integrated Projects (SLCA/IP) and include dams equipped for power generation on the Green, Gunnison, Rio Grande, and Colorado rivers and on Deer and Plateau creeks in the states of Wyoming, Utah, Colorado, Arizona, and New Mexico. Of these facilities, only the Glen Canyon Unit, the Flaming Gorge Unit, and the Aspinall Unit (which includes Blue Mesa, Morrow Point, and Crystal dams) are influenced by Western power scheduling and transmission decisions. The EIS alternatives, called commitment-level alternatives, reflect combinations of capacity and energy that would feasibly and reasonably fulfill Western's firm power marketing responsibilities, needs, and statutory obligations. The viability of these alternatives relates directly to the combination of generation capability of the SLCA/IP with energy purchases and interchange. The economic and natural resource assessments in this environmental impact statement (EIS) include an analysis of commitment-level alternatives. Impacts of the no-action alternative are also assessed. Supply options, which include combinations of electrical power purchases and hydropower operational scenarios reflecting different operations of the dams, are also assessed. The EIS evaluates the impacts of these scenarios relative to socioeconomics, air resources, water resources, ecological resources, cultural resources, land use, recreation, and visual resources.

DOCUMENT CONTENTS

VOLUME 1

Summary

VOLUME 2

Summary

Section 1	Introduction
Section 2	Alternatives, Including No Action
Section 3	Affected Environment
Section 4	Environmental Consequences
Section 5	Cumulative Impacts of Commitment-Level Alternatives and Operational Scenarios
Section 6	Unavoidable Adverse Impacts
Section 7	Relationship between Short-Term Use of the Environment and Long-Term Productivity
Section 8	Irreversible and Irretrievable Commitment of Resources
Section 9	Environmental Statutes, Regulations, Executive Orders, and Permit Requirements
Section 10	Consultation, Coordination, and Public Involvement
Section 11	References
Section 12	List of Preparers
Section 13	Acronyms, Abbreviations, and Units of Measure
Section 14	Glossary
Section 15	Index
Section 16	List of Recipients

VOLUME 3

Appendix A Socioeconomics

VOLUME 4

Appendix B	Air Resources
Appendix C	Water Resources for Flaming Gorge Dam and the Aspinall Unit
Appendix D	Ecological Resources

CONTENTS — VOLUME 2

COVER SHEET	V2 - iii
DOCUMENT CONTENTS	V2 - v
FIGURES — VOLUME 2	V2 - xi
TABLES — VOLUME 2	V2 - xiv
SUMMARY	S-1
S.1 Background	S-1
S.2 Western's Responsibilities and Mission	S-1
S.3 Public Involvement	S-2
S.4 Alternatives	S-2
S.5 Hydropower Operational Scenarios	S-3
S.6 Affected Environment	S-4
S.6.1 Socioeconomics	S-8
S.6.2 Air Resources	S-10
S.6.3 Water Resources	S-10
S.6.4 Ecological Resources	S-11
S.6.5 Cultural Resources	S-12
S.6.6 Land Use	S-12
S.6.7 Recreation	S-13
S.6.8 Visual Resources	S-13
S.7 Environmental Consequences of Commitment-Level Alternatives	S-13
S.8 Environmental Consequences of Hydropower Operational Scenarios	S-17
S.8.1 Glen Canyon Dam	S-17
S.8.2 Flaming Gorge Dam	S-22
S.8.3 Aspinall Unit	S-23
S.9 Cumulative Environmental Consequences	S-23
1 INTRODUCTION	1-1
1.1 Need for Agency Action	1-1
1.2 Purpose of Agency Action	1-1
1.3 Description of the Proposed Action	1-1
1.4 Western Responsibilities and Mission	1-2
1.5 Recent History of Marketing Criteria Development	1-4
1.6 Relationship of this EIS to Other Actions	1-5
1.6.1 EPAMP EIS	1-5
1.6.2 Glen Canyon Dam EIS	1-6
1.6.3 Biological Opinion on Operation of the Glen Canyon Dam	1-6
1.6.4 Biological Opinion on Operation of the Flaming Gorge Dam	1-6
1.6.5 Gunnison River NEPA Documentation	1-7

CONTENTS — VOLUME 2 (Cont.)

1.6.6	Biological Opinion on Operation of the Aspinall Unit	1-8
1.6.7	Integration of Provo River Project with SLCA/IP	1-8
1.7	Public Involvement	1-9
1.8	Content of this EIS	1-9
2	ALTERNATIVES, INCLUDING NO ACTION	2-1
2.1	Introduction	2-1
2.2	Commitment-Level Alternatives	2-1
2.2.1	Selection of Commitment-Level Alternatives	2-2
2.2.2	Description of Commitment-Level Alternatives	2-5
2.2.3	Comparison of Impacts of Commitment-Level Alternatives	2-8
2.3	Hydropower Operational Scenarios	2-9
2.3.1	Background	2-9
2.3.2	Hydropower Operations, Purchases, and Exchanges	2-12
2.3.3	Selection and Description of Hydropower Operational Scenarios	2-13
2.3.4	Comparison of Impacts of Hydropower Operational Scenarios	2-17
3	AFFECTED ENVIRONMENT	3-1
3.1	Socioeconomics	3-1
3.1.1	Regions of Influence	3-1
3.1.2	Socioeconomic Baseline	3-4
3.1.3	Electric Power Marketing Baseline	3-8
3.2	Air Resources	3-12
3.2.1	Climate and Meteorology	3-12
3.2.2	Air Quality	3-13
3.2.3	Acoustic Environment	3-14
3.3	Water Resources	3-14
3.3.1	Glen Canyon Dam	3-15
3.3.2	Flaming Gorge Dam	3-26
3.3.3	Aspinall Unit	3-37
3.4	Ecological Resources	3-45
3.4.1	Glen Canyon Dam	3-45
3.4.2	Flaming Gorge Dam	3-60
3.4.3	Aspinall Unit	3-80
3.5	Cultural Resources	3-89
3.5.1	Glen Canyon Dam	3-89
3.5.2	Flaming Gorge Dam	3-92
3.5.3	Aspinall Unit	3-95
3.6	Land Use	3-96
3.6.1	Glen Canyon Dam	3-96
3.6.2	Flaming Gorge Dam	3-99
3.6.3	Aspinall Unit	3-101

CONTENTS — VOLUME 2 (Cont.)

3.7	Recreation	3-104
3.7.1	Glen Canyon Dam	3-105
3.7.2	Flaming Gorge Dam	3-106
3.7.3	Aspinall Unit	3-115
3.8	Visual Resources	3-118
3.8.1	Glen Canyon Dam	3-119
3.8.2	Flaming Gorge Dam	3-119
3.8.3	Aspinall Unit	3-120
4	ENVIRONMENTAL CONSEQUENCES	4-1
4.1	Consequences of Commitment-Level Alternatives	4-1
4.1.1	Socioeconomics	4-1
4.1.2	Air Resources	4-25
4.1.3	Other Resources	4-30
4.2	Consequences of Hydropower Operations	4-33
4.2.1	Socioeconomics	4-34
4.2.2	Air Resources	4-41
4.2.3	Water Resources	4-43
4.2.4	Ecological Resources	4-67
4.2.5	Cultural Resources	4-108
4.2.6	Land Use	4-113
4.2.7	Recreation	4-114
4.2.8	Visual Resources	4-123
4.3	Summary of Impacts of Commitment-Level Alternatives and Hydropower Operational Scenarios	4-126
4.3.1	Commitment-Level Alternatives	4-126
4.3.2	Hydropower Operational Scenarios	4-132
4.4	Mitigation and Monitoring	4-142
4.4.1	Potential Mitigation for Commitment-Level Alternatives	4-142
4.4.2	Potential Mitigation for Hydropower Operational Scenarios	4-143
4.4.3	Potential Monitoring	4-144
5	CUMULATIVE IMPACTS OF COMMITMENT-LEVEL ALTERNATIVES AND OPERATIONAL SCENARIOS	5-1
5.1	Socioeconomics	5-2
5.2	Air Resources	5-2
5.3	Water Resources	5-2
5.4	Ecological Resources	5-3
5.5	Cultural Resources	5-5
5.6	Land Use	5-5
5.7	Recreation	5-6
5.8	Visual Resources	5-6

CONTENTS — VOLUME 2 (Cont.)

6	UNAVOIDABLE ADVERSE IMPACTS	6-1
7	RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY	7-1
8	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES	8-1
9	ENVIRONMENTAL STATUTES, REGULATIONS, EXECUTIVE ORDERS, AND PERMIT REQUIREMENTS	9-1
9.1	Clean Air Act	9-1
9.2	Noise Control Act of 1972	9-2
9.3	Water Quality and Water Resource Requirements	9-2
9.3.1	Clean Water Act	9-2
9.3.2	Rivers and Harbors Appropriations Act of 1899	9-4
9.3.3	Safe Drinking Water Act	9-4
9.3.4	Wild and Scenic Rivers Act	9-5
9.3.5	Executive Order 11988 — Floodplain Management; Executive Order 11990 — Protection of Wetlands	9-6
9.4	Ecological Resources	9-7
9.4.1	Endangered Species Act of 1973	9-7
9.4.2	Migratory Bird Treaty Act	9-8
9.4.3	Bald and Golden Eagle Protection Act	9-8
9.4.4	Fish and Wildlife Coordination Act	9-9
9.4.5	DOE Order 4300.1C — Real Property Management, Chapter V: Management of Natural Resources	9-9
9.5	Historical, Archaeological, and Cultural Resource Requirements	9-10
9.5.1	National Historic Preservation Act and Archaeological and Historic Preservation Act	9-10
9.5.2	American Indian Religious Freedom Act	9-10
9.5.3	DOE Order 4300.1C — Real Property Management, Chapter V: Management of Natural Resources	9-11
9.5.4	Wilderness Act of September 3, 1964	9-11
9.6	Management of Wastes and Hazardous Materials	9-12
10	CONSULTATION, COORDINATION, AND PUBLIC INVOLVEMENT	10-1
10.1	Consultation and Coordination	10-1
10.1.1	Socioeconomics	10-1
10.1.2	Air Resources	10-1
10.1.3	Water Resources	10-2
10.1.4	Ecological Resources	10-3
10.1.5	Cultural Resources	10-5
10.1.6	Land Use	10-6

CONTENTS — VOLUME 2 (Cont.)

10.1.7	Recreation	10-8
10.1.8	Visual Resources	10-9
10.2	Public Involvement	10-10
10.2.1	Scoping Process	10-10
10.2.2	Alternatives Development	10-14
11	REFERENCES	11-1
12	LIST OF PREPARERS	12-1
13	ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE	13-1
14	GLOSSARY	14-1
15	INDEX	15-1
16	LIST OF RECIPIENTS	16-1

FIGURES — VOLUME 2

S.1	Affected Environment for Socioeconomics	S-8
S.2	Affected Environment for Natural and Cultural Resources	S-9
1.1	Locations of Power Plants in the Salt Lake City Area Integrated Projects	1-3
2.1	Commitment-Level Boundaries for Marketable Firm Energy and Capacity at the SLCA/IP	2-4
2.2	Affected Environment for Socioeconomics	2-9
2.3	Affected Environment for Natural and Cultural Resources	2-19
3.1	Metropolitan and Rural Subregions in the Regional Economic Analysis	3-3
3.2	Colorado River between Glen Canyon Dam and Lake Mead	3-16
3.3	Drainage Basin for the Colorado River	3-17
3.4	Historical Daily Flows at Lees Ferry	3-18
3.5	Maximum and Minimum Daily Flows for Moderate-, Low-, and High-Release Years for the Glen Canyon Dam	3-20

FIGURES — VOLUME 2 (Cont.)

3.6	Maximum Daily Fluctuations for Glen Canyon Dam	3-21
3.7	Hourly Releases from Glen Canyon Dam for a Typical Day Having High, Moderate, and Low Fluctuations	3-21
3.8	Separation, Reattachment, and Channel Margin Deposits in the Colorado River below Glen Canyon Dam	3-23
3.9	Recirculation Zone below a Debris Fan in the Colorado River below Glen Canyon Dam	3-23
3.10	Green River Basin	3-27
3.11	Historical Flows at Greendale, Utah, 1951-1989	3-29
3.12	Maximum and Minimum Daily Water Releases for Power Generation at Flaming Gorge Dam for Moderate, Dry, and Wet Years	3-30
3.13	Maximum Daily Fluctuations at Flaming Gorge Dam for Moderate, Dry, and Wet Years	3-31
3.14	Flow-Exceedance Curves for Moderate, Normal, Dry, and Wet Years at Flaming Gorge Dam	3-31
3.15	Releases from Flaming Gorge Dam, February 1987	3-32
3.16	Green River from Flaming Gorge Dam to Jensen, Utah	3-33
3.17	Cumulative Sediment Load as a Function of Flow at Browns Park for Moderate, Dry, and Wet Years	3-36
3.18	Green River Water Temperature at Greendale and Jensen, Utah, and in the Yampa River, 1989	3-36
3.19	Location of Dams in the Aspinall Unit	3-38
3.20	Drainage Area for the Aspinall Unit	3-38
3.21	Maximum and Minimum Daily Releases at Blue Mesa Dam for Moderate, Dry, and Wet Years	3-41
3.22	Maximum and Minimum Daily Releases at Morrow Point Dam for Moderate, Dry, and Wet Years	3-42
3.23	Maximum and Minimum Daily Releases at Crystal Dam for Moderate, Dry, and Wet Years	3-43

FIGURES — VOLUME 2 (Cont.)

3.24	Maximum Daily Release Fluctuations at Blue Mesa, Morrow Point, and Crystal Dams for Moderate, Dry, and Wet Years	3-44
3.25	Generalized Representation of Riparian Vegetation Zones and Their Relationship to Flow Levels	3-50
3.26	Pre- and Post-Dam Flows in the Green River at Greendale and Jensen, Utah	3-61
3.27	Land Use in the Vicinity of the Glen Canyon Dam	3-98
3.28	Land Use in the Vicinity of the Affected Segment of the Green River	3-100
3.29	Land Use in the Vicinity of the Aspinall Unit	3-103
3.30	Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 1	3-109
3.31	Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 2	3-110
3.32	Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 3	3-111
3.33	Recreational Resources and Facilities in Dinosaur National Monument	3-113
3.34	Recreational Resources in Blue Mesa Reservoir	3-116
3.35	Recreational Resources in Crystal and Morrow Point Reservoirs	3-117
4.1	Components of the Economic Impact Analysis	4-3
4.2	Schematic Representation of the Relationship between Percentage Change in Average Retail Rates and Percentage Reliance on Long-Term Firm Capacity and Energy from Western	4-7
4.3	Components of Air Quality Impact Assessment	4-28
4.4	Maximum and Minimum Flows under the Year-Round High Fluctuating Flow Scenario	4-52
4.5	Maximum and Minimum Flows under the Seasonally Adjusted High Fluctuating Flow Scenario	4-54
4.6	Maximum and Minimum Flows under the Seasonally Adjusted Moderate Fluctuating Flow Scenario	4-55

FIGURES — VOLUME 2 (Cont.)

4.7	Flows under the Seasonally Adjusted Steady Flow Scenario	4-56
4.8	Maximum and Minimum River Stages under the Year-Round High Fluctuating Flow Scenario	4-58
4.9	Maximum and Minimum River Stages under the Seasonally Adjusted High Fluctuating Flow Scenario	4-59
4.10	Maximum and Minimum River Stages under the Seasonally Adjusted Moderate Fluctuating Flow Scenario	4-60
4.11	River Stages under the Seasonally Adjusted Steady Flow Scenario	4-61
4.12	Water Surface Elevations below Morrow Point Dam	4-66

TABLES — VOLUME 2

S.1	Electric Power Marketing EIS Commitment-Level Alternatives	S-4
S.2	Hydropower Operational Scenarios for Glen Canyon Dam	S-5
S.3	Hydropower Operational Scenarios for Flaming Gorge Dam	S-6
S.4	Hydropower Operational Scenarios for the Aspinall Unit	S-7
S.5	Relative Impacts of the Commitment-Level Alternatives	S-15
S.6	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam	S-18
S.7	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam	S-20
S.8	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources Associated with the Aspinall Unit	S-21
2.1	Electric Power Marketing EIS Commitment-Level Alternatives	2-6
2.2	Relative Impacts of the Commitment-Level Alternatives	2-10
2.3	Hydropower Operational Scenarios for Glen Canyon Dam	2-14

TABLES — VOLUME 2 (Cont.)

2.4	Hydropower Operational Scenarios for Flaming Gorge Dam	2-16
2.5	Hydropower Operational Scenarios for the Aspinall Unit	2-18
2.6	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam	2-21
2.7	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam	2-23
2.8	Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources Associated with the Aspinall Unit	2-25
3.1	Estimated Baseline Statistics: Population, Employment, Disposable Income, and Gross Regional Product	3-5
3.2	Irrigated Acreage in Six-State Region in 1987	3-8
3.3	Agriculture Output for Selected Crops in 1984	3-9
3.4	Power Marketing Utility Categories	3-10
3.5	Average Retail Rates by State and Utility Size — 1993, 2000, 2008	3-11
3.6	Baseline Coverage Ratio by Reliance Level	3-12
3.7	Computed Colorado River Sand Loads for Steady and Fluctuating Flows	3-25
3.8	Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Glen Canyon Dam	3-54
3.9	Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Glen Canyon Dam	3-57
3.10	Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Flaming Gorge Dam in the Green River	3-70
3.11	Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Flaming Gorge Dam on the Green River	3-75
3.12	Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species in the Vicinity of the Aspinall Unit Reservoirs on the Gunnison River	3-87

TABLES — VOLUME 2 (Cont.)

3.13	Land Use Planning and Management Documents Pertaining to the Glen Canyon Dam Area	3-99
3.14	Land Use Planning and Management Documents Pertaining to the Flaming Gorge Dam Area	3-102
3.15	Land Use Planning and Management Documents Pertaining to the Aspinall Unit Area	3-105
3.16	Annual Visitation and Overnight Use at Dinosaur National Monument, 1988-1991	3-114
4.1	Financial Impacts of Alternative/Operational Scenario Combinations	4-8
4.2	Predicted Retail Rates and Percentage Change from No-Action Alternative by State and Utility Category: Supply Option A	4-9
4.3	Predicted Retail Rates and Percentage Change from No-Action Alternative/Supply Option A by State and Utility Category: Supply Option B	4-12
4.4	Predicted Retail Rates and Percentage Change from No-Action Alternative/Supply Option A by State and Utility Category: Supply Option C	4-15
4.5	Coverage Ratio by Utility Category and Commitment-Level Alternative in 2008	4-18
4.6	Average 1991 Electricity Retail Rates by State and End-User Class	4-19
4.7	Maximum Estimated Impacts of Commitment-Level Alternatives and Supply Options on Population, Gross Regional Product, Disposable Income, and Employment	4-23
4.8	Maximum Estimated Impacts of Commitment-Level Alternative/ Supply Option Combinations on Agricultural Output and Net Revenues in the SLCA/IP Service Area in 2008	4-25
4.9	Maximum Estimated Impacts of Commitment-Level Alternative/ Supply Option Combinations on Irrigated Acreage Planted, Surface Water Use, and Groundwater Use in the SLCA/IP Service Area in 2008	4-26
4.10	Summary of Recreation Use Values Associated with Each Operational Scenario at Glen Canyon Dam	4-37

TABLES — VOLUME 2 (Cont.)

4.11	Summary of Recreation Use Values Associated with Each Operational Scenario at Flaming Gorge Dam	4-41
4.12	Summary of Projected Daily Fluctuations and Maximum Releases from Glen Canyon Dam	4-45
4.13	Summary of Daily Maximum Stage above the Minimum Water Elevation below Glen Canyon Dam	4-47
4.14	Summary of Sediment Impacts for Glen Canyon Dam	4-48
4.15	Summary of Sand Load in Browns Park for Different Hydropower Operational Scenarios	4-62
4.16	Maximum Daily Surface Fluctuations for a Moderate Year at the Aspinall Unit Reservoirs under the Seasonally Adjusted High Fluctuating Flow Scenario	4-65
4.17	Summary of Impacts to Trout and Native Fish below Glen Canyon Dam under the Different Operational Scenarios	4-68
4.18	Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Glen Canyon Dam	4-72
4.19	Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Glen Canyon Dam	4-73
4.20	Summary of Potential Impacts to, and Overall Population Status of, the Humpback Chub, Razorback Sucker, and Flannelmouth Sucker below Glen Canyon Dam under Different Operational Scenarios	4-75
4.21	Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Glen Canyon Dam	4-79
4.22	Summary of Impacts to Trout and Native Fish below Flaming Gorge Dam under Different Hydropower Operational Scenarios	4-83
4.23	Summary of Impacts to Riparian Vegetation below Flaming Gorge Dam under Different Hydropower Operational Scenarios	4-86
4.24	Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Flaming Gorge Dam	4-88
4.25	Summary of Impacts to Threatened, Endangered, Candidate, and Sensitive Fish Species below Flaming Gorge Dam under Different Operational Scenarios	4-90

TABLES — VOLUME 2 (Cont.)

4.26	Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Flaming Gorge Dam	4-96
4.27	Summary of Impacts of Hydropower Operational Scenarios on Vegetation along the Aspinall Unit Reservoirs	4-102
4.28	Summary of Impacts of Hydropower Operational Scenarios on Wildlife at the Aspinall Unit Reservoirs	4-103
4.29	Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species at the Aspinall Unit Reservoirs	4-105
4.30	Archaeological Sites and Historic Structures Downstream of Flaming Gorge Dam that Could Be Affected by Hydropower Operational Scenarios	4-110
4.31	Summary of Impacts of Hydropower Operational Scenarios on Cultural Resources below Flaming Gorge Dam	4-111
4.32	Summary of Impacts to Recreational Activities below Glen Canyon Dam under Nine Hydropower Operational Scenarios	4-116
4.33	Summary of Impacts to Recreational Activities on the Green River below Flaming Gorge Dam under Moderate Hydrological Conditions	4-119
4.34	Relative Impacts of the Commitment-Level Alternatives	4-127
4.35	Summary of Impacts of Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam	4-134
4.36	Summary of Impacts of Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam	4-137
4.37	Summary of Impacts of Operational Scenarios on Natural and Cultural Resources in the Vicinity of the Aspinall Unit	4-140

SUMMARY

S.1 BACKGROUND

The Western Area Power Administration (Western) proposes to change the level of its commitment (sales) of long-term firm electrical capacity and energy from the Salt Lake City Area Integrated Projects (SLCA/IP) hydroelectric power plants. Because this change could be a major Federal action with potentially significant impacts to the human environment, this environmental impact statement (EIS) is being prepared in compliance with the National Environment Policy Act of 1969 (NEPA) and associated implementing regulations.

S.2 WESTERN'S RESPONSIBILITIES AND MISSION

Western, a power marketing administration within the Department of Energy, was created with the passage of the Department of Energy Organization Act of 1977 (DOE Act). The DOE Act transferred the power marketing and transmission functions from the Secretary of the Interior (Bureau of Reclamation [Reclamation]) to the Secretary of Energy, acting through Western.

Western's mission is to sell and deliver electricity that is in excess of project uses (power that is required for the operation of the project) generated from power plants that were built as part of certain Federal water projects. Most of the power plants included in this EIS are located on the Upper Colorado River and its tributaries. Western's Salt Lake City Area Office (SLCAO) is responsible for marketing of power from the Colorado River Storage Project (CRSP), Collbran Project, Rio Grande Project, and Provo River Project. On October 1, 1987, the Colorado River, Collbran, and Rio Grande projects were integrated for marketing and rate-making purposes and are collectively known as the SLCA/IP.

Western's power marketing responsibility begins at the switchyard of Federal hydroelectric power facilities and includes the transmission lines to interconnected utility systems. The hydroelectric projects in Western's 15-state area are operated by Reclamation, the Army Corps of Engineers, and the International Boundary and Water Commission. These agencies manage and release water in accordance with the various acts authorizing specific projects and with other enabling legislation. Western's capacity and energy sales must be in conformance with the laws that govern its sale of electrical power. Further, Western's hydropower operations at each facility must comply with minimum and maximum flows and other constraints set by Reclamation or other operating agencies, acting in accord with law or policy.

The 1902 Reclamation Act provided for the use of revenue from the sale of Federal land to develop irrigation projects. The Reclamation Project Act of 1939 further defined the responsibility of Reclamation in irrigation development and directed that revenues from the sale of electricity generated at the Federal facilities be used to repay some of the irrigation

investment, as well as all costs incurred in developing the hydroelectric facilities. The principal purposes of these projects are irrigation, flood control, and navigation. About 90% of all revenues received from these projects are from power sales.

An important provision of the Reclamation Project Act was to give preference in the sale of Federally generated electricity to municipalities, other public corporations or agencies, cooperatives, and other nonprofit organizations financed under the Rural Electrification Act of 1936. Western also requires that a preference entity must own and control their distribution system, be willing and able to purchase and distribute electricity, and be responsible for supplying the entire electrical load to customers in its service area. Western sells firm power to nonpreference customers only if the available supply exceeds the demands of interested and eligible preference customers. Preference is an important issue because the price of Western's firm power (the long-term firm capacity and energy rate) is limited to cost recovery at a rate that currently places it below market levels.

S.3 PUBLIC INVOLVEMENT

Public comments and opinions from interested groups, Federal and state agencies, customers, and the general public are an integral part of the decision-making process. To date, Western has received comments on the scope of this EIS, on the purpose and need statement (which was developed after the scoping process), on the alternatives, and on the hydropower operational scenarios. In addition, this EIS reflects comments by cooperating and coordinating agencies. The cooperating agencies are the Bureau of Reclamation, the National Park Service, and the U.S. Fish and Wildlife Service. The coordinating agencies are the states of Utah, Wyoming, New Mexico, Colorado, and Arizona.

S.4 ALTERNATIVES

Western could market the electricity produced at the SLCA/IP in a variety of ways. To fulfill its mission and statutory responsibilities, Western markets hydroelectricity supplemented with energy purchased from and exchanged with other utilities. By purchasing and exchanging power with other utilities, Western is able to increase its level of long-term firm sales and enhance the value of the hydrogeneration resources.

Western's principal marketing program is the sale of long-term firm capacity and energy at long-term firm power rates. The amount of capacity and energy sold under long-term contract is called the level of commitment. The alternatives examined in this EIS are based upon different levels of long-term firm commitments and are called commitment-level alternatives.

The commitment-level alternatives evaluated in this EIS are defined on the basis of a specified level of both capacity (which is equivalent to the instantaneous output of a generator, usually stated in megawatts [MW]) and energy (the amount of power generated over a period of time, usually stated in megawatt-hours [MWh] and limited by generator

capacity). The combination of capacity and energy commitment, plus other elements of the power marketing contracts, are used to define a resource that is used to meet a customer's load requirements. Normally, this allows for a higher energy use during daytime (on-peak) hours and a lower use during nighttime (off-peak) hours. Western, in coordination with Reclamation, schedules and releases water on an hourly and daily basis from the SLCA/IP and Western makes purchases and exchanges to meet its contractual commitments defined by the alternatives. Together these factors affect hydropower operations at SLCA/IP facilities.

The commitment-level alternatives considered in this EIS span the range of commitments necessary for Western to fulfill its statutory obligations. These alternatives were presented in draft to the general public for comment and were discussed with specific environmental and customer groups. Seven combinations of capacity and energy commitments are considered as representative of the entire range of commitments that could be offered by Western. Capacity commitments range from a low of 550 MW (less than 40% of the historical commitment) to a high of 1,450 MW. Energy commitments range from a low of 3,300 MWh (less than 60% of the historical commitment) to a high of 6,200 MWh.

The major characteristics of the commitment-level alternatives considered in this EIS are described in Table S.1. These alternatives were selected on the basis that, as a group, the combinations of capacity and energy incorporated into these alternatives represent the reasonable bounds of capacity and energy available to Western given currently available resources. In addition to two moderate capacity-moderate energy alternatives (3 and 6), the alternatives include high capacity and energy (alternative 1), low capacity and energy (alternative 4), high capacity and low energy (alternative 2), and low capacity and high energy (alternative 5) combinations. As of this time, Western has not selected a preferred alternative.

S.5 HYDROPOWER OPERATIONAL SCENARIOS

In addition to analyzing the commitment-level alternatives, this EIS evaluates the impacts of hydropower operations at the three SLCA/IP facilities that provide most of the hydropower marketed by Western — Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. The array of potential dam operations — referred to as operational scenarios — ranges from historical high fluctuations, to no fluctuation (baseload or steady flows) at each facility. Operational scenarios considered here are presented in Tables S.2, S.3, and S.4. These hydropower operational scenarios were submitted in draft to the public and to specific interest groups for review.

This EIS addresses a set of actions that could be considered in separate NEPA documents. By considering both commitment-level alternatives and operational scenarios together, examination of a full range of operations and commitment levels and their combined impacts is possible. Actual hydropower operations within the range of scenarios examined

TABLE S.1 Electric Power Marketing EIS Commitment-Level Alternatives

Alternative	Capacity Commitment (MW)	Energy Commitment (GWh)	Load Factor (%)	Minimum Schedule Requirement (%)	Description
No action	1,291	5,700	50	35	Moderate capacity and high energy (the 1978 marketing program commitment level)
1	1,449	6,156	48.5 ^a	35	High capacity and high energy (the post-1989 commitment level)
2	1,450	3,300	26	10	High capacity and low energy
3	1,225	4,000	37	15	Moderate capacity and moderate energy
4	550	3,300	68	52	Low capacity and low energy
5	625	5,475	100	100	Low capacity and high energy
6	1,000	4,750	54	33	Moderate capacity and moderate energy

^a This load factor differs slightly from that published in the Post-1989 Marketing Criteria (50.2%) because of a difference between calculating this number annually versus seasonally.

may come about as a result of management decisions by Western or Reclamation. Reclamation determines operational constraints for hydropower facilities, and Western makes operational decisions within these constraints.

S.6 AFFECTED ENVIRONMENT

The Upper Colorado River and its tributaries provide the principal supply of surface water for western Colorado, Utah, and Arizona. More than 50 impoundments are located on the Upper Colorado and its tributaries, with a combined storage capacity equivalent to three years of flow (33 million acre-feet). These impoundments provide some or all of the requirements for flood control, irrigation and municipal water supply, recreation, and hydropower generation. The impoundments have supported agricultural, municipal, and recreational development that would otherwise not have been possible. The environment

TABLE S.2 Hydropower Operational Scenarios for Glen Canyon Dam

Parameter	Continuation of Historical Flows	Maximum Power Plant Capacity	Restricted Fluctuating Flows				Steady Flows		
			High	Moderate	Modified Low	Interim Low	Existing Monthly Volume	Seasonally Adjusted	Year-Round
Minimum releases ^a (cfs)	1,000 Labor Day-Easter 3,000 Easter-Labor Day ^b	1,000 Labor Day-Easter 3,000 Easter-Labor Day ^b	3,000, 5,000, 8,000, depending on monthly volume, firm load, and market conditions	5,000	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000	8,000 Oct-Nov ^c 8,500 Dec 11,000 Jan-Mar 12,500 Apr 18,000 May-Jun 12,500 Jul 9,000 Aug-Sep	Yearly volume prorated ^d
Maximum releases (cfs)	31,500	33,200	31,500	31,500 ^f	20,000 ^f	20,000	Monthly volumes prorated	18,000 ^f	Yearly volume prorated ^d
Allowable daily change in flow (cfs/24 hours)	30,500 Labor Day-Easter 28,500 Easter-Labor Day	32,200 Labor Day-Easter 30,200 Easter-Labor Day	15,000 to 22,000	±45% of mean flow for the month not to exceed ±6,000	5,000, ^g 6,000, or 8,000	5,000, ^g 6,000, or 8,000	±1,000 ^h	±1,000 ^h	±1,000 ^h
Allowable scheduled ramping (cfs/h)	Unrestricted	Unrestricted	Unrestricted up 5,000 or 4,000 down	4,000 up 2,500 down	2,500 up 1,500 down	2,500 up 1,500 down	2,000 cfs/d between months	2,000 cfs/d between months	2,000 cfs/d between months
Elements common to restricted fluctuating and steady flow alternatives	None	None	Adaptive management including long-term monitoring and research, monitoring and protection of cultural resources, flood frequency reduction measures, beach/habitat-building flows, new population of humpback chub, further study of selective withdrawal, emergency exception criteria						

^a In high volume release months, the allowable daily change would require higher minimum flows.

^b Releases each weekday during recreation season (Easter to Labor Day) would average not less than 8,000 cfs for the period from 8 a.m. to midnight.

^c Based on an 8.23 million acre-feet year; in higher release years, additional water would be added equally to each month, subject to an 18,000 cfs maximum.

^d For an 8.23-million acre-feet year, steady flow would be about 11,400 cfs.

^e Maximums represent normal or routine limits and may necessarily be exceeded during high water years.

^f May be exceeded during habitat-maintenance flows.

^g Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-feet; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet and 8,000-cfs for monthly volumes over 800,000 acre-feet.

^h Adjustments would allow for small power system load changes.

Source: Adapted from Reclamation (1993).

TABLE S.3 Hydropower Operational Scenarios for Flaming Gorge Dam^a

Parameter	Year-Round High Fluctuating Flows	Seasonally Adjusted Flows		
		High Fluctuating	Moderate Fluctuating	Steady
Minimum releases (cfs)	800	800 Oct-Jan 2,380 Feb-Mar 800 Apr-May 4,700 Jun 1-21 800 Jun 22-Jul 9 890 Jul 10-31 990 Aug 1,070 Sep	800 Oct 2,220 Nov-Jan 2,380 Feb-Mar 2,440 Apr 2,740 May 4,700 Jun 1-21 2,770 Jun 22-30 1,860 Jul 1-Jul 9 976 Jul 10-31 1,080 Aug 1,160 Sep	800 Oct 2,380 Nov-Mar 2,600 Apr 3,390 May 4,700 Jun 1-21 3,740 Jun 22-30 2,020 Jul 1-9 1,060 Jul 10-31 1,160 Aug 1,240 Sep
Maximum releases (cfs)	4,700	800 Oct 4,700 Nov-Jan 2,380 Feb-Mar 4,700 Apr-Jul 9 2,900 Jul 10-31 3,000 Aug 3,100 Sep	800 Oct 4,170 Nov-Jan 2,380 Feb-Mar 4,390 Apr 4,700 May-Jun 3,810 Jul 1-9 1,980 Jul 10-31 2,080 Aug 2,160 Sep	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,900	0 Oct 3,900 Nov-Jan 0 Feb-Mar 3,900 Apr-May 0 Jun 1-21 3,900 Jun 22-Jul 9 2,010 Jul 10-Aug 2,030 Sep	0 Oct 1,950 Nov-Jan 0 Feb-Mar 1,950 Apr-May 0 Jun 1-21 1,950 Jun 22-Jul 9 1,000 Jul 10-Sep	0
Allowable scheduled ramping (cfs/h)	3,900	3,900	1,950	0

^a For a moderate hydrological year.

TABLE S.4 Hydropower Operational Scenarios for the Aspinall Unit^a

Parameter	Seasonally Adjusted High Fluctuating Flows			Seasonally Adjusted Steady Flows		
	Blue Mesa	Morrow Point	Crystal	Blue Mesa	Morrow Point	Crystal
Minimum release (cfs)	1,750 Jun 0 Others	0 Oct-Mar 557 Apr 1,830 May 2,440 Jun 1,070 Jul 0 Aug-Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,250 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep	1,570 Oct 1,200 Nov 1,050 Dec 500 Jan-Mar 1,600 Apr 2,370 May 3,050 Jun 2,350 Jul 1,750 Aug-Sep	1,700 Oct 1,280 Nov 1,100 Dec 570 Jan-Mar 1,970 Apr 2,890 May 3,320 Jun 2,480 Jul 1,770 Aug 1,820 Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,250 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep
Maximum release (cfs)	3,700	5,300 Oct-Mar 2,680 Apr 3,420 May 3,770 Jun 3,190 Jul 5,300 Aug-Sep	Same as minimum releases	Same as minimum releases	Same as minimum releases	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,700 Oct-May 1,950 Jun 3,700 Jul-Sep	5,300 Oct-Mar 2,120 Apr 1,590 May 1,330 Jun 2,120 Jul 5,300 Aug-Sep	0	0	0	0
Allowable scheduled ramping (cfs/h)	3,700	5,300	0	0	0	0

^a For a moderate hydrological year

potentially affected by the commitment-level alternatives and the hydropower operational scenarios varies among resources (Figures S.1 and S.2). Socioeconomics are treated first in this EIS because commitment-level alternatives vary considerably in their impact on socioeconomics but differ little in their effects on the natural environment.

S.6.1 Socioeconomics

Western's SLCAO serves about 183 customers, including utilities, Federal installations, state universities, irrigation districts, and others. In turn, Western's utility customers serve end-users in 192 counties in 12 states. Part of the socioeconomic analysis of the commitment-level alternatives assessed the impacts that a change in Western's long-term firm commitments could have on its utility customers. Specific attention was focused on the financial viability of these customers and the retail rates charged to their end-users. For analytical purposes, utilities were classified according to whether they are municipally or cooperatively owned and the degree to which they rely on Western for the power they sell. Utilities that receive less than 25% of their total energy from Western were classified as low reliance; 55% of Western's customers fall into this category. The remaining 45% of Western's customers were classified as high reliance. On this basis, high-reliance municipals are most dependent on Western — an average of 47% of the load served by utilities in this category

FIGURE S.1 Affected Environment for Socioeconomics

FIGURE S.2 Affected Environment for Natural and Cultural Resources

is provided by Western. At the other extreme, an average of 6% of the load served by low-reliance municipals is provided by Western.

In addition, the impact of commitment-level alternatives on conservation and renewable energy programs was evaluated by examining the impacts on consumption efficiency and load management activities by long-term firm sale utility customers.

To facilitate the analysis of regional economic impacts, the combined service territory of these utilities was subdivided into six metropolitan subregions and three rural subregions. Within the metropolitan subregions, economic activity, as measured by employment, is concentrated in the wholesale, retail, business, and public service sectors. In the three rural subregions, economic activity is more dispersed, with no one sector accounting for more than 25% of the total employment in each subregion. Population, employment, and output are most heavily concentrated in the metropolitan subregions.

The impacts on agricultural production were analyzed on a state-by-state basis. The six-state region that includes Arizona, Colorado, New Mexico, Nevada, Wyoming, and Utah produces a variety of crops, such as alfalfa, cotton, and wheat. About 24% of the total acreage in this region that is used in agriculture is irrigated with use of electric pumps.

S.6.2 Air Resources

The affected environment for air resources was defined as the area encompassing the states of Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. This region is semiarid to arid and encompasses many major population centers, including Phoenix and Tucson, Arizona; Denver and Colorado Springs, Colorado; Albuquerque, New Mexico; Las Vegas, Nevada; and Salt Lake City, Utah. These population centers and some of their suburbs are designated as *nonattainment areas*¹ with respect to one or more of the National Ambient Air Quality Standards. The electric utility industry is a major contributor to the overall air pollutant emissions within the region, particularly with regard to sulfur dioxide, nitrogen oxides, and carbon dioxide. Despite this situation, ambient air quality in the region as a whole is generally considered good, and visibility is currently the best in the contiguous United States.

S.6.3 Water Resources

The affected environment for water resources and other natural resources evaluated in this EIS was defined as the areas associated with the hydroelectric facilities that are influenced on an hourly and daily basis by Western to produce power (Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit). Other facilities where operations are dictated by irrigation demands, municipal and industrial uses, flood control, or other nonpower

¹ This designation means that the air in the area exceeds the concentration limits established for the specified pollutant.

purposes were not considered because, although Western markets power produced at these facilities, Western does not affect power production at them.

The area affected by hydropower operations at Glen Canyon Dam included the area along the Colorado River between the dam and Lake Mead. This area includes the Grand Canyon National Park. The affected area for Flaming Gorge Dam was the area along the Green River between the dam and Jensen, Utah; and the affected area for the Aspinall Unit was the reservoirs of the unit (Blue Mesa, Morrow Point, and Crystal reservoirs).

Existing conditions in the affected environment of these three facilities have been shaped by hydropower operations occurring since the facilities were built in the early 1960s. Compared with pre-dam conditions, the Colorado River below Glen Canyon Dam and the Green River below Flaming Gorge Dam generally exhibit larger daily fluctuations in flow and less seasonal fluctuations in flow, are much clearer (carry less sediment), are more erosive of existing sediment deposits, and are colder. Flow, stage, water temperature, and sediment transport are considered the most important characteristics of water resources downstream of these facilities.

The affected environment of the Aspinall Unit was limited to the reservoirs themselves because the lowermost dam of the unit (Crystal Dam) is a reregulation dam and would eliminate hydropower-induced fluctuations in flow in the Gunnison River below the unit. The water resources of the affected environment of the Aspinall Unit are characteristic of western reservoirs (cold, clear, minimal flow). Sediment is not an important resource of the Aspinall Unit because the shores of the reservoirs are mostly bare rock. The largest of the reservoirs, Blue Mesa, experiences relatively minor hydropower-induced daily fluctuations, while the elevations of Morrow Point and Crystal reservoirs can exhibit larger fluctuations within a day because of steep canyon walls and limited storage volume.

S.6.4 Ecological Resources

The current conditions of ecological resources in and along the Colorado and Green rivers below Glen Canyon Dam and Flaming Gorge Dam, respectively, and the reservoirs of the Aspinall Unit reflect the effects of approximately 30 years of dam operations.

Certain ecological resources below Glen Canyon and Flaming Gorge dams are similar. Both rivers support high-quality trout fisheries in the areas immediately below the dams where waters are clearest and coldest. Farther downstream, native fish that rely on warm water are more common, and each river supports several fish species that are Federally listed as endangered. The humpback chub and the razorback sucker occur in the Colorado River between Glen Canyon Dam and Lake Mead. No reproduction of the razorback sucker is known to occur in the area, while the humpback chub population is maintained almost exclusively by reproduction in the Little Colorado River. This population is the largest known remaining population of humpback chub in the Colorado River system. The Green River below Flaming Gorge Dam supports populations of razorback sucker, humpback chub, and Colorado squawfish. Little or no successful reproduction by the razorback sucker has

been observed in the Green River, and this population is declining. The Colorado squawfish and humpback chub successfully reproduce in the Green River, and populations may be stable. The bonytail chub may be extirpated from the Green River above Jensen, Utah. No verified specimens of this species have been collected from this portion of the Green River Basin since 1979.

Riparian vegetation and some wildlife species have increased substantially along the rivers in response to regulated flows. The endangered peregrine falcon commonly breeds along both the Colorado and Green rivers below the dams, and the endangered bald eagle winters in the downstream corridors. Other Federally listed terrestrial species that are either known to occur or could occur in the affected environment of these two facilities include Ute ladies-tresses (Flaming Gorge), Mexican spotted owl (Glen Canyon and Flaming Gorge), and the whooping crane (Flaming Gorge).

The ecological resources of the Aspinall Unit reservoirs are very different from those below Glen Canyon and Flaming Gorge dams. The cold, nutrient-poor waters of the reservoirs support few aquatic resources with the exception of an important introduced kokanee salmon population. Little riparian vegetation occurs in the vicinity of any of the reservoirs, and most shoreline areas consist of bare rock. Federally listed endangered species that could occur in the vicinity of the reservoirs include the peregrine falcon, bald eagle, and the whooping crane. Only the bald eagle is relatively common in the area.

S.6.5 Cultural Resources

The affected environment for cultural resources, including archaeological, historical, and Native American resources, includes the area along the Colorado River below Glen Canyon Dam, the Green River below Flaming Gorge Dam, and the area around the Aspinall Unit reservoirs. The regional prehistory and ethnohistory for the three sites is relatively similar. Numerous archaeological sites, but fewer historical structures, are present in the river corridors below Glen Canyon and Flaming Gorge dams. The paucity of historical remains reflects the relatively minor degree of Euro-American settlement and activity that has occurred in the area. Most sites in the area of the Aspinall Unit are located along Blue Mesa Reservoir and consist of archaeological sites, although some historic sites also occur. Native American tribes that have identified or may identify cultural resources in the areas include the Havasupai, Hopi, Hualapai, Navajo, Southern Paiute, and Zuni for the Glen Canyon Dam area; and the San Juan Southern Paiute, Southern Ute Tribe, Ute Mountain Tribe, and Ute Indian Tribe for the Flaming Gorge Dam and the Aspinall Unit areas.

S.6.6 Land Use

Most of the land in areas along the Colorado River below Glen Canyon Dam, along the Green River below Flaming Gorge Dam, and in the vicinity of the Aspinall Unit reservoirs is publicly owned and consists primarily of national parks, monuments, forests,

and reservation lands. Recreation is a key component in the management of the region's public lands.

S.6.7 Recreation

The affected areas of the Glen Canyon, Flaming Gorge, and Aspinall Unit facilities support important water-based recreational activities. These activities include white-water boating, angling, and riverside camping downstream of both the Glen Canyon and Flaming Gorge dams and boating and angling in the Aspinall Unit reservoirs.

S.6.8 Visual Resources

Visual resources in the affected areas are of high quality and are dominated by the prominent geological features characteristic of each area. Dam operations in these areas, through their effects on stream flow and shoreline vegetation, have relatively minor influence on visual resources.

S.7 ENVIRONMENTAL CONSEQUENCES OF COMMITMENT-LEVEL ALTERNATIVES

Commitment-level alternatives were analyzed for their potential impacts on the financial viability of Western's utility customers, the retail rates charged to the end-users of electricity marketed by Western, regional economic variables (including population, employment, disposable income, and gross regional product), agricultural production, and the use value of recreational activities. In addition, the analysis considered the potential effects that a change in Western's commitment levels could have on the mix of generation options used to supply electricity to the affected region and the resulting impacts on local and regional air quality. Impacts on natural and cultural resources were assessed in the context of changes in operational scenarios at each of the affected sites. With this approach, it was possible to identify the range of impacts that could result from implementation of any one of the commitment-level alternatives.

Hydropower operational scenarios could also affect socioeconomics and air resources through their effects on purchases and exchanges and the resultant cost of electricity. Thus, it was necessary to specify both an operational scenario and a commitment-level alternative to assess socioeconomic and air resource impacts. Commitment-level alternatives were paired with specific supply options, which consisted of combinations of operational scenarios at each of the three facilities considered in this EIS, combined with power purchases. These supply options were defined as follows:

- *Supply Option A:* Continuation of historical operations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit, combined with all necessary power purchases;

- *Supply Option B:* Low fluctuations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit, combined with all necessary power purchases;
- *Supply Option C:* Seasonally adjusted steady flows at Glen Canyon, Flaming Gorge, and the Aspinall Unit, combined with all necessary power purchases.

The supply options are obtainable through actions by both Western and Reclamation.

The socioeconomic impacts determined for these supply options capture the full range of impacts that could occur given any possible combination of operational scenarios. Combinations of operational scenarios whose impacts approximate those of supply option A include any combination that incorporates a continuation of historical operations, maximum power plant capacity, or restricted high fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit. Combinations whose impacts approximate those of supply option B include any combination that incorporates moderate fluctuations or low fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit. Finally, combinations whose impacts approximate those of supply option C include any combination consisting of seasonally adjusted steady flows, existing monthly steady flows, or year-round steady flows at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge; and either of the operational scenarios at the Aspinall Unit.

The predicted impacts attributable to the combinations of commitment-level alternatives and supply options considered in this EIS are summarized in Table S.5. The analyses indicated that none of the combinations of commitment-level alternatives and supply options would have a statistically significant effect on any of the four socioeconomic variables mentioned above (i.e., the estimated impacts are not statistically different from zero), and only slight impacts are likely on conservation and renewable energy programs as measured in terms of consumption efficiency and load management. This result is partly a reflection of the fact that the power marketed by Western accounts for only about 10% of the total electricity consumed in the affected region. In addition, much of the affected region has an excess supply of generating capacity. This excess capacity would serve to offset the adverse price effects of a reduction in the amount of Western's long-term firm commitment of capacity and energy and thus blunt the regional economic impacts of any increase in electricity prices.

The analysis also indicates that a change in Western's long-term firm commitments would have, at most, a very small effect on agricultural production, as measured by net income to the agricultural sector at the state level. At the state level, most of the impacts would consist of shifts from irrigated to dryland farming methods for individual crops and some substitution among crops. However, the largest impact indicated by the analysis was a decrease in net agricultural income by about 1.2% in Utah in the final year of the forecast

TABLE S.5 Relative Impacts of the Commitment-Level Alternatives

Commitment-Level Alternative	Financial Viability and Retail Rates	Regional Economic Activity	Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
No action (1978 Marketing Criteria)	Slight impacts on financial viability of Western's customers and the retail rates charged to end-users.	No impacts on the levels of population, employment, income or output.	No impacts on agricultural production.	No impacts on local or regional air quality or noise.	Impacts dependent on dam operations (see Tables S.6, S.7, and S.8).
Commitment-level alternative 1	No impact on financial viability; slight impact on retail rates.	Estimated impacts on population, employment, income, and output are not statistically different from zero.	Slight impact on agricultural production.	Same as above.	Same as above.
Commitment-level alternative 2	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 3	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 4	No impact on financial viability; moderate or large impacts on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 5	Slight impact on financial viability; moderate to large impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 6	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.

period. Furthermore, this impact would occur under the commitment-level alternative representing the lowest long-term firm commitment of capacity and energy and, therefore, the lowest supply risk.

Results of the analysis suggest that the different combinations of commitment-level alternatives and supply options could affect the financial viability of Western's utility customers and the retail rates charged to end-users. The combination of commitment-level alternative 2 and unrestricted dam operations at the three affected sites — Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit — would leave the financial viability of affected utilities unchanged. In addition, many of Western's utility customers would experience a decline in their retail rates. However, the remaining combinations of commitment-level alternatives and operational scenarios could result in adverse impacts. Maximum adverse impacts to financial viability would result from the combination of commitment-level alternative 4 and steady flows at each of the hydropower facilities. However, this impact is considered moderate. Less than 12% of the utilities included in the financial analysis would experience a decrease in financial viability under this combination of commitment-level alternative and supply option. All of the other alternatives and operational scenarios would result in smaller impacts on financial viability.

With the exception of alternative 2, retail rates would generally increase as a result of a change in Western's commitment levels. Changes in rates would vary by alternative, state, and the characteristics of the affected utilities. Commitment-level alternatives 4 and 5 combined with steady flows at each dam would result in the largest weighted average increase in rates (15%) across affected utilities. The combination of alternative 4 and steady flows would also result in the largest rate increase, as measured for state and utility categories. Under these conditions, it is estimated that the retail rates charged by municipal utilities in Utah that rely on Western for more than 25% of their supply (high reliance) would increase by 41%.

Overall, high-reliance utilities — primarily municipals — in Utah and New Mexico would experience the largest retail rate impacts under each of the commitment-level alternatives. In contrast, utility customers in Wyoming would be largely unaffected. Utility customers in Arizona, Colorado, and Nevada would experience slight to moderate effects under most alternatives.

Even with lack of any statistically significant regional economic impacts, the fact that retail rates would increase under most combinations of commitment-level alternatives and supply options suggests that there are likely to be localized impacts to employment and income. However, the areas in which such impacts are likely to occur are small relative to the subregions that were constructed to conduct the regional analysis. Consequently, any impacts that might occur at the local level could be undetected when impacts were measured at the regional level.

The analysis of impacts to air resources led to the conclusion that local and regional air quality and noise levels would not be affected by any of the commitment level alternatives.

The impacts of commitment-level alternatives on water resources, ecological resources, cultural resources, and recreation would depend on the operational scenarios implemented at the hydropower facilities under consideration. In addition to the direct impacts of hydropower operations, indirect impacts could result from fulfilling the need for additional generating capacity under each commitment-level alternative. This need for additional capacity could be met by building new power plants, by expanding or retrofitting existing ones, or by purchases and exchanges. Construction and operation of power plants to meet additional capacity needs could result in additional impacts to natural and cultural resources in the vicinities of any new or expanded facilities. A detailed assessment of specific impacts is not presented here because the significance and nature of any such impacts would depend on the specific plans and locations for the new expanded facilities — information that is not available at this time.

S.8 ENVIRONMENTAL CONSEQUENCES OF HYDROPOWER OPERATIONAL SCENARIOS

Hydropower operations are only weakly linked to commitment levels. To assess the potential impacts associated with hydropower operations, ranges of operational scenarios were specified for each of the three affected sites. Nine operational scenarios were considered at Glen Canyon Dam; four scenarios were considered at Flaming Gorge Dam, and two scenarios were considered for the Aspinall Unit. Impacts are described below by facility and are summarized in Tables S.6, S.7 and S.8.

S.8.1 Glen Canyon Dam

Continuation of historical operations and maximum power plant capacity operational scenarios would have impacts on most resources similar to those that have occurred since the dam was completed in 1963. Past operations have determined existing conditions for water resources, ecological resources, and recreational activities. Impacts identified for these scenarios included impacts to existing cultural resources, riparian vegetation, humpback chub, and recreation.

Restricted high fluctuations would result in moderate reductions in erosion rates and slight benefits to most ecological resources and recreation. For this scenario, slight adverse impacts were identified for the humpback chub. Adverse impacts could also occur to cultural resources because of erosion.

Moderate and low fluctuating flow operational scenarios would produce benefits for water resources (substantially reduced erosion rates), terrestrial ecology (moderate increases in woody riparian vegetation), cultural resources, and white-water boating. These operational scenarios could result in slight or moderate benefits to trout, native fish, peregrine falcon, bald eagle, southwestern willow flycatcher, and angling. Slight adverse impacts could occur to the humpback chub. Marsh vegetation could decrease under these scenarios.

TABLE S.6 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Continuation of historical flows	No change from current conditions.	Slight adverse impact to humpback chub; no change from current conditions for other resources.	Adverse impact because of high erosion rate.	No impact.
Maximum power plant capacity	Same as above.	Slight adverse impact to humpback chub and southwestern willow flycatcher; no impact to other resources.	Same as above.	Slight adverse impact to angling and white-water boating.
Restricted high fluctuating flows	Moderate benefit; decreased sediment load and erosion rate.	Slight adverse impact to humpback chub; slight benefit to aquatic resources; no impact to terrestrial resources.	Same as above.	Slight benefit to angling and white-water boating.
Moderate fluctuating flows	Large benefit; decreased sediment load and erosion rate.	Slight adverse impact to humpback chub; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; slight benefit to aquatic resources; moderate benefit to terrestrial resources.	Benefit because of reduced erosion rates.	Same as above.
Modified low fluctuating flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; slight to moderate benefit to aquatic resources; moderate benefit to terrestrial resources.	Same as above.	Moderate benefit to white-water boating; slight benefit to angling.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.	Same as above.
Existing monthly steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.

TABLE S.6 (Cont.)

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Seasonally adjusted steady flows	Same as above.	Slight to moderate benefit to humpback chub; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to white-water boating; moderate benefit to angling.
Year-round steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, and peregrine falcon; moderate benefit to southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 30 years of operations. No impacts to air resources, land use, or visual resources were identified.

TABLE S.7 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Year-round high fluctuating flows	Slight impact; increase in erosion rate.	Slight to moderate adverse impacts to aquatic resources; slight adverse impacts to terrestrial resources.	Adverse impact because of high erosion rate.	Slight adverse impact to angling; no impact on white-water boating.
Seasonally adjusted high fluctuating flows	Same as above.	Slight to moderate benefits to native fish and endangered fish; slight to moderate adverse impacts to trout; slight adverse impact to terrestrial resources; moderate adverse impact to bald eagle.	Adverse impact because of high erosion rate.	Large adverse impact to angling in spring and early summer; large benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.
Seasonally adjusted moderate fluctuating flows	Slight benefit; decrease in erosion rate.	Slight to moderate benefit to native fish and endangered fish; moderate adverse impact to bald eagle; slight adverse impact to Ute ladies-tresses; slight adverse impact to terrestrial resources.	Moderate benefit because of reduced erosion rate.	Moderate to large adverse impact to angling in spring and early summer; moderate benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.
Seasonally adjusted steady flows	Same as above.	Moderate to large benefit to native fish and endangered fish; slight benefit to trout; slight benefit to terrestrial resources; moderate adverse impact to bald eagle and Ute ladies-tresses; slight benefit to peregrine falcon.	Same as above.	Same as above.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 30 years of operations. No impacts to air resources, land use, or visual resources were identified.

TABLE S.8 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources Associated with the Aspinall Unit^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Seasonally adjusted high fluctuating flows				
Blue Mesa Reservoir	Slight impact; daily fluctuations same as historical but monthly release volumes change.	No impact to any resources.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.	Same as above.
Crystal Dam Reservoir	Same as above.	No impacts to aquatic resources; slight benefit to terrestrial resources.	Same as above.	Same as above.
Seasonally adjusted steady flow				
Blue Mesa Reservoir	Large impact; daily fluctuations eliminated and monthly release volumes change.	No impact to aquatic or terrestrial resources; slight adverse impact to bald eagle.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Same as above.	No impact to aquatic resources; slight benefit to terrestrial resources; slight adverse impact to bald eagle.	Same as above.	Same as above.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 28 years of operation. No impacts to air resources, land use, or visual resources were identified.

Although steady flow scenarios could result in benefits to a number of resources, some benefits would require the proposed occasional high flows to build beaches and maintain fish habitats. Benefits could occur for water resources (reduced erosion rates), aquatic ecology (trout and native fish), terrestrial ecology (increase in woody riparian vegetation), cultural resources, and recreation (angling and white-water boating). Benefits would be expected for the humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher. Marsh vegetation could decrease.

S.8.2 Flaming Gorge Dam

The year-round high fluctuating flow operational scenario for Flaming Gorge Dam features higher maximum releases and greater daily flow fluctuations than occurred under historical operations. These higher flows and daily fluctuations could result in adverse impacts to some ecological resources, including trout, native fish, endangered fish, and woody riparian vegetation. Since this scenario has a higher erosion rate than steady flows, adverse impacts to cultural resources would be expected.

The remaining three operational scenarios at Flaming Gorge Dam are seasonally adjusted; that is, they feature shifts in monthly volumes to meet requirements of the U.S. Fish and Wildlife Service Biological Opinion issued for the facility. These scenarios exhibit a high sustained flow in May or June, reduced fluctuations and lower flows in summer and autumn, and steady flows when ice cover is present on the river (February and March). These flows are intended to be protective of endangered fish in the system and could result in benefits to these species, as well as to other resources. Some adverse impacts could result from seasonal adjustment, however. The spring peak in flows would result in large adverse impacts to anglers. The bald eagle and over-wintering waterfowl could be adversely affected by steady flows in February and March. With steady flows, less open ice-free water would be available for these species.

Seasonally adjusted high fluctuations would have moderate effects on flow and stage, but would have erosion rates similar to those of year-round high fluctuations. Slight to moderate benefits are expected to native fish (including the endangered humpback chub, bonytail chub, Colorado squawfish and razorback sucker) because of improved nursery habitat conditions and increased overwinter survival. This scenario would result in large benefits to angling in mid-summer through autumn (when lower flows are maintained) and moderate benefits to white-water boating during the spring peak in flows. Slight adverse impacts are expected to terrestrial ecology because of the inundation of some woody riparian vegetation. Slight adverse impacts are also expected to trout as under year-round high fluctuations. Because erosion rates would be higher than under steady flows, cultural resources would be adversely affected by this operational scenario.

Seasonally adjusted moderate and steady flows are relatively similar in their impacts to most resources. Both scenarios would have moderately reduced erosion rates and, thus, would benefit water resources and cultural resources. Slight benefits to trout and moderate to large benefits to native and endangered fish, angling, and white-water boating are also

expected under these scenarios because of reduced daily fluctuations. Slight to moderate adverse impacts to the threatened plant Ute ladies-tresses could occur if these scenarios resulted in lower soil moisture levels in the alluvial meadows where the species occurs.

Seasonally adjusted moderate fluctuations are expected to have slight adverse impacts on terrestrial resources because some existing woody riparian vegetation would be inundated and lost. The steady flow scenario would result in slight benefits to terrestrial resources by allowing an increase in woody riparian vegetation.

S.8.3 Aspinall Unit

Because Crystal Dam reregulates flows from the Aspinall Unit, flows in the Gunnison River below the Unit and the resources that depend on those flows would not be affected by hydropower operations. Slight to moderate impacts to flow and stage in Blue Mesa and Morrow Point reservoirs would occur because of seasonal adjustments in releases and daily fluctuations. Despite these changes in flow and stage, neither operational scenario is expected to result in impacts to sediment, most ecological resources (aquatic ecology, threatened and endangered species), cultural resources, recreation, land use, or visual resources. Both scenarios would result in slight benefits to terrestrial resources in the headwaters of Crystal Reservoir in the form of an increase in woody riparian vegetation. Slight adverse impacts to the bald eagle are expected under the seasonally adjusted steady flow scenario because the reservoirs would freeze earlier in the winter with reduced fluctuations.

S.9 CUMULATIVE ENVIRONMENTAL CONSEQUENCES

Past actions relevant to the cumulative impacts of commitment-level alternatives and hydropower operational scenarios include the construction and operation of existing hydropower facilities and thermal power plants, as well as other development activities. These past impacts and the impacts of ongoing activities were incorporated into the baseline conditions described under *Affected Environment* and, consequently, are considered in the assessment of impacts discussed under *Environmental Consequences*. Similarly, reasonably foreseeable future actions have been considered in the impact assessment wherever possible. Included are actions that might be implemented in association with findings or recommendations of the EIS for continued operation of Glen Canyon Dam, the Biological Opinion for operation of Flaming Gorge Dam, and the EIS for operations of the Aspinall Unit. These actions were incorporated into the impact assessment in the formulation of the hydropower operational scenarios considered.

The location of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit within the Colorado River Basin together with other hydroelectric facilities within the basin increases the potential for cumulative impacts on the hydrology of the basin. However, because of the distance between facilities and the number of intervening tributaries that

ameliorate the impacts of individual facilities on flow, sediment load, and water temperature, no cumulative impacts to resources are expected that have not already been considered in the individual assessments for each facility.

1 INTRODUCTION

1.1 NEED FOR AGENCY ACTION

The Western Area Power Administration (Western) needs to determine the level of long-term firm capacity and energy commitment from the Salt Lake City Area Integrated Projects (SLCA/IP) that Western will make available to its customers and that will form the basis for its SLCA/IP power marketing program.

1.2 PURPOSE OF AGENCY ACTION

The alternative commitment level selected by Western must be consistent with its statutory obligations and legal constraints. This necessity requires a weighing of economic, environmental, and other public considerations. Western's action will have to achieve a balanced mix of purposes as follows:

- Provide the greatest practicable amount of long-term firm capacity and energy.
- Provide for the meeting of firming requirements as practicable by purchases of capacity and energy.
- Provide long-term resource and contractual stability.
- Provide the greatest practical value of the power resource.
- Result in the least practicable associated adverse environmental impacts.
- Be responsive and adaptable to likely operations of SLCA/IP facilities.
- Be responsive to decisions from the Bureau of Reclamation's (Reclamation's) Glen Canyon Dam Environmental Impact Statement (EIS) (Reclamation 1993) and the Energy Planning and Management Program (EPAMP) EIS now being prepared by Western.

1.3 DESCRIPTION OF THE PROPOSED ACTION

Western proposes to establish its commitment level for sales of long-term firm electrical capacity and energy to its SLCA/IP customers. Western, a power marketing administration of the U.S. Department of Energy (DOE), has the mission to sell and deliver capacity and energy generated by hydroelectric power plants built as part of certain Federal water projects. The SLCA/IP power plants include facilities in the states of Wyoming, Utah,

Colorado, Arizona, and New Mexico. The facilities are located on the Colorado River and its tributaries and on the Rio Grande and its tributaries (Figure 1.1).

Power generated by the SLCA/IP facilities or purchased by Western from other sources is provided to Western's customers under contracts that establish the terms for how capacity (generation capacity) and energy (quantity of electrical energy) are to be sold. The contracts also specify amounts of capacity and energy that Western agrees to offer for long-term sale (greater than 12 months) to its customers. These amounts constitute Western's "commitment levels." The capacity and energy level is called "firm" when its availability is guaranteed to the customer.

Currently, Western's sale commitments from the SLCA/IP, including capacity and energy purchased from other sources, total approximately 1,200 megawatts (MW)¹ of long-term firm capacity and 5,700 gigawatt-hours (GWh)² of long-term firm energy. This commitment level was established in 1978 (1978 marketing program) for the period to 1989. As part of the development of its power marketing program for the period 1989 to 2004 (the post-1989 marketing program), Western proposed to increase these commitment levels to 1,449 MW of capacity and 6,156 GWh of energy.

This EIS has been prepared in accordance with Section 102(2)C of the National Environmental Policy Act of 1969 (NEPA), as implemented in regulations promulgated by the Council on Environmental Quality (CEQ) (40 CFR Parts 1500-1508) and DOE NEPA implementing regulations (10 CFR Part 1021).

1.4 WESTERN RESPONSIBILITIES AND MISSION

The Western Area Power Administration was established within the DOE pursuant to the Department of Energy Organization Act of 1977 (42 USC §§ 7101 *et seq.*) (DOE Act). This legislation provided for the transfer of Federal power marketing and power transmission functions from the Secretary of Interior through the Bureau of Reclamation to the Secretary of Energy. Western performs these functions in 15 western states: Arizona, California, Colorado, Iowa, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming. Western conducts its functions in conformance with certain laws, primarily the DOE Act, Section 5 of the Flood Control Act of 1944 (16 USC § 825s), Section 9(c) of the Reclamation Project Act of 1939 [43 USC § 485h(c)], and, in this case, the Colorado River Storage Project (CRSP) Act (43 USC §§ 620-620o). While Western took over the power marketing activities, Reclamation retained irrigation, water supply, and dam-operation functions at Federal water projects constructed by Reclamation.

¹ One megawatt equals 1,000,000 watts.

² One gigawatt-hour equals 1,000,000,000 watt-hours.

FIGURE 1.1 Locations of Power Plants in the Salt Lake City Area Integrated Projects

Western's Salt Lake City Area Office (SLCAO) markets power from the CRSP and the Collbran, Rio Grande, and Provo River Projects. The CRSP power plants are those authorized by the Colorado River Storage Project Act; specifically included are power plants at Glen Canyon Dam (the Glen Canyon Unit) on the Colorado River just below the Utah-Arizona border; at Flaming Gorge Dam (the Flaming Gorge Unit) on the Green River just below the Wyoming-Utah border; at Fontenelle Dam on the Green River; and at the Blue Mesa, Morrow Point, and Crystal dams (Aspinall Unit) on the Gunnison River in Colorado (Figure 1.1). On October 1, 1987, the CRSP hydropower facilities, the Collbran Project (Upper and Lower Molina dams), and the Rio Grande Project (Elephant Butte Dam) were integrated as the SLCA/IP for marketing and rate-making purposes. The Provo River Project has been functionally integrated in the CRSP since 1963, and Western has proposed to formally integrate the project. The hydroelectric facilities of the SLCA/IP are operated by Reclamation. Within the limits on dam operations set by Reclamation, Western coordinates water releases with Reclamation for hydropower generation and markets the capacity and energy so produced.

In marketing power in excess of project-use needs, Western sells both long-term and short-term firm power. This power is normally sold to what are known as "preference customers." This designation originates from the Reclamation Project Act of 1939, which requires Western to give preference in the sale of Federal power to municipalities, nonprofit corporations or agencies, cooperatives, and other nonprofit organizations financed under the Rural Electrification Act of 1936 (17 USC § 901 *et seq.*).

Western sells power to nonpreference customers, such as investor-owned utilities, only if the available supply exceeds the demands of interested and eligible preference customers, or if so required by unique legislation. The Reclamation Project Act of 1939 reiterated that revenues from the sale of electricity generated at the Federal facilities were to be used to repay the appropriate share of the costs incurred in developing the hydroelectric facilities and some of the investment in irrigation.

1.5 RECENT HISTORY OF MARKETING CRITERIA DEVELOPMENT

The SLCA/IP power marketing criteria specify terms and conditions for the long-term firm capacity and energy sales contracts. In 1980, Western began examining its marketing criteria for long-term capacity and energy from the SLCA/IP because the existing long-term firm contracts were to expire in 1989. Through this process, Western developed the proposed "Post-1989 Criteria." Western prepared an environmental assessment (EA) for implementation of the Post-1989 Criteria, and on January 8, 1986, a Finding of No Significant Impact (FONSI) was approved by DOE. The final Post-1989 Criteria were to supersede the existing "General Power Marketing Criteria" for the CRSP (1978 Criteria) and those governing sales of Collbran and Rio Grande resources. The Post-1989 Criteria included the terms by which Western would allocate long-term firm capacity and energy from the SLCA/IP during the period October 1, 1989, through September 30, 2004.

On December 20, 1988, the National Wildlife Federation (NWF) and others filed suit against Western regarding the adequacy of Western's 1986 EA and FONSI (*National Wildlife Federation, et al. vs. Western Area Power Administration, et al.*, Docket No. 88C-1175-J, U.S. District Court, Central District of Utah). On September 29, 1989, the court entered an order allowing Western to implement the post-1989 contracts, providing that the aggregate commitment level of firm capacity and energy would remain essentially the same as the 1978 levels until Western had completed an EIS. The court was concerned that an increase in commitment, which was a principal feature of the Post-1989 Criteria, might result in changed operation of the SLCA/IP power plants and changes in downstream environmental impacts. Thus, while the court's September 29, 1989, order permitted the post-1989 contracts to become effective, neither the post-1989 commitment level nor any alternative commitment level could be implemented until Western completed an EIS. Accordingly, current levels of commitment are based on 1978 levels with minor adjustments established by Western and the court. This EIS is intended to meet the requirement of the court order for an EIS that includes an assessment of downstream impacts of power generation at SLCA/IP facilities.

1.6 RELATIONSHIP OF THIS EIS TO OTHER ACTIONS

In determining the scope of this EIS, Western has taken into consideration other environmental assessments, environmental impact statements, and environmental surveys or studies related to the SLCA/IP prepared by Western and other Federal agencies. Western has integrated, to the fullest extent possible, these other assessments, EISs, analyses, and studies into this Electric Power Marketing EIS. These other instruments and programs include the Energy Planning and Management Program (EPAMP) EIS, the Glen Canyon Dam EIS (Reclamation 1993), the Recovery Implementation Program for Endangered Species in the Upper Colorado River Basin applicable to Flaming Gorge Dam and the Aspinall Unit, the NEPA compliance document for the Gunnison River contract, and the possible proposed formal integration of the Provo River Project with the SLCA/IP.

1.6.1 EPAMP EIS

Western is preparing the EPAMP EIS (56 Fed. Reg. 19,995, May 1, 1991 [Western 1991a]) on its proposal to replace its current conservation and renewable energy program with a two-part program that would determine the percentage of long-term allocations of Western's hydroelectric resources to be extended to its customers at the end of their existing contract terms (called the "power marketing initiative") and encourage long-term energy management planning (called the "energy management plan") by Western's firm power customers. Western proposes to apply the power marketing initiative to the SLCA/IP after this Electric Power Marketing EIS is completed. The draft EIS and final EIS for EPAMP is expected to be published during the time that this Electric Power Marketing EIS is being prepared.

Once the EPAMP final EIS and associated Record of Decision are issued, Western proposes that the energy management portion of EPAMP will apply to all of Western's

long-term firm power customers. If available before this EIS is issued, the general impact analyses included in the EPAMP EIS will be incorporated in this Electric Power Marketing EIS by reference (40 CFR 1502.21), adoption (40 CFR 1506.3), or tiering (40 CFR 1502.20 and 1508.28), as appropriate. Western proposes to apply the power marketing initiative portion of EPAMP to hydropower projects as marketable resources are defined. The power marketing initiative is not expected to apply to SLCA/IP customers until after this EIS is completed. Once both the Power Marketing EIS and the EPAMP EIS are completed, Western believes it will have sufficient NEPA documentation to apply the power marketing initiative to the SLCA/IP customers. If upon review of both EISs, Western determines that further NEPA documentation is required, such documentation will be prepared prior to the application of the power marketing initiative.

1.6.2 Glen Canyon Dam EIS

Reclamation is preparing the Operation of Glen Canyon Dam EIS (Glen Canyon EIS) (Reclamation 1993) to examine the impacts of current operations on downstream resources and the specific operational options for Glen Canyon Dam that could be implemented to minimize (consistent with law) adverse impacts on the downstream environment, cultural resources, and Native American interests in Glen and Grand canyons. Western, a cooperating agency in preparation of that document, has not repeated the analysis performed in the Glen Canyon EIS for this Electric Power Marketing EIS but has instead incorporated appropriate analyses and conclusions of that EIS into this document.

1.6.3 Biological Opinion on Operation of the Glen Canyon Dam

Concurrent with preparing the Glen Canyon EIS, Reclamation is consulting with the U.S. Fish and Wildlife Service (USFWS) on the effects of operation of Glen Canyon Dam on endangered species. This process, being conducted pursuant to the Endangered Species Act of 1973 (15 USC 1531 *et seq.*), will lead to the publication of a Biological Opinion on Glen Canyon Dam operations by the USFWS. A draft of this Biological Opinion has been prepared and was considered by Reclamation in preparing the Glen Canyon EIS (Reclamation 1993).

1.6.4 Biological Opinion on Operation of the Flaming Gorge Dam

On February 27, 1980, the USFWS requested consultation with Reclamation regarding projects under construction and regarding the continued operation of all existing Reclamation projects in the Upper Colorado River Basin (USFWS 1992b). Reclamation agreed with the request, and formal consultations on the operation of Flaming Gorge Dam were initiated on March 27, 1980. Western became a party to this consultation on August 9, 1991, with Reclamation remaining the lead agency. Coincident with its request to Reclamation, the USFWS issued a Biological Opinion on February 27, 1980, for the Strawberry Aqueduct and Collection System (Strawberry System). The Strawberry System Biological Opinion determined that depletions from the Duchesne and Green rivers would

likely jeopardize the continued existence of the Colorado squawfish and the humpback chub. The reasonable and prudent alternative for the Strawberry System was that the Flaming Gorge Dam and reservoir would compensate for those depletions and would be operated for the benefit of the endangered fish.

Jeopardy opinions were also issued in the late 1970s and early 1980s for the Upalco, Jensen, and Uinta projects of the Central Utah Project, and the reasonable and prudent alternative for each of these projects was the operation of Flaming Gorge Dam to provide flows for endangered fish (USFWS 1992b). Biological opinions for the Narrows Project (March 25, 1992) and the Price-San Rafael Salinity Control Project (February 4, 1992) are also linked to the Flaming Gorge Biological Opinion. Because of the absence of sufficient data, the Biological Opinion for the operation of Flaming Gorge Dam was delayed until studies were completed and sufficient scientific data were collected to recommend specific flows. Flows within the operational criteria of the dam were evaluated from 1979 to 1984, while a number of summer flow regimes were evaluated from 1985 to 1991.

The Final Biological Opinion for operation of Flaming Gorge Dam was issued by the USFWS on November 25, 1992 (USFWS 1992b), and dam operations have been constrained to comply with the reasonable and prudent alternative identified in that opinion. The Biological Opinion issued by the USFWS is consistent with the provisions of the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The purpose of the program is to recover the endangered fish while allowing water development to proceed in the Upper Colorado River Basin consistent with the Endangered Species Act (USFWS 1992b). The program identifies refining the operation of Flaming Gorge Dam as one of the principal habitat management strategies for recovering endangered fish in the Green River. The operations stipulated by the Biological Opinion are reflected in the range of dam operational scenarios for Flaming Gorge Dam that are being analyzed in this EIS.

1.6.5 Gunnison River NEPA Documentation

Reclamation, the National Park Service (NPS), the Bureau of Land Management (BLM), and the Colorado Water Conservation Board are initiating formal studies to provide a long-term water supply from the Aspinall Unit to the Black Canyon of the Gunnison National Monument through a water-delivery contract. Being considered is release of water stored in Blue Mesa Reservoir to the Monument in a manner that more closely resembles "natural hydrology." The proposed change would result in higher springtime water releases from the reservoir. Reclamation, NPS, and BLM have announced their intent to prepare an EIS on the proposed water-delivery contract (57 Fed. Reg. 19,437, May 6, 1992). Reclamation recently announced that it may not need to prepare an EIS, but may prepare another NEPA document. That document will examine the environmental impacts of executing this contract. The analyses and results of the Gunnison River NEPA evaluation will not be available for incorporation into this Electric Power Marketing EIS.

Before Gunnison River NEPA documentation is completed, the seasonal pattern recommended by the USFWS for study of endangered fish in the Gunnison River

(Harris 1992) and the draft contract to deliver water to the Black Canyon of the Gunnison National Monument would be used to determine releases from the Aspinall Unit. These research flows would be in place until 1997 and thus would be relevant to the interim period between issuance of the ROD for this Electric Power Marketing EIS and the Gunnison River NEPA documentation. These research flows form the basis of the seasonally adjusted release patterns of the hydropower operational scenarios for the Aspinall Unit evaluated in this EIS.

1.6.6 Biological Opinion on Operation of the Aspinall Unit

The Recovery Implementation Program for Endangered Species in the Upper Colorado River Basin includes a number of recovery activities in the Gunnison River, including a five-year research plan that was initiated in 1992 to evaluate the effects of the operation of the Aspinall Unit on endangered fish and their habitats. Following completion of that research, the USFWS will issue a Biological Opinion on operations at the Aspinall Unit. Upon receipt of the Biological Opinion, Reclamation will take necessary actions to incorporate the results into Aspinall Unit operations. The USFWS may also prepare a Biological Opinion on the proposed water contract for the Black Canyon of the Gunnison National Monument or may combine the two Biological Opinions on the Aspinall Unit.

Although certain constraints may be imposed on the operation of the Aspinall Unit once the proposed water contract is in place or the Biological Opinion is issued, Western cannot at this time anticipate the levels of capacity and energy that may result. Western will participate with Reclamation in the Gunnison River EIS concerning an analysis of power impacts and in any other NEPA process necessary in conjunction with the Biological Opinion. The operation of Crystal is constrained by operational limits set by Reclamation. Crystal Dam is a reregulation dam, which steadies the hourly fluctuations of the upstream power plants. Crystal's operation is not influenced by Western's power sales. Because of this situation and the environmental activities listed herein, environmental impacts below Crystal Dam (the farthest downstream facility in the Aspinall Unit) are not evaluated in this Electric Power Marketing EIS. However, a probable level of capacity and energy available from the Aspinall Unit is included in the evaluation.

1.6.7 Integration of Provo River Project with SLCA/IP

Western may, before completing this EIS, propose the formal integration of the Provo River Project (PRP) with the SLCA/IP. The projects have been functionally integrated for many years through the CRSP's purchases of surplus capacity and energy. Western anticipates formalizing this relationship and marketing PRP firm capacity and energy as SLCA/IP capacity and energy at SLCA/IP firm power rates. The necessary NEPA documentation will be prepared and incorporated into, adopted, or tiered from this EIS, as appropriate.

1.7 PUBLIC INVOLVEMENT

Public involvement for this EIS began with the publication of two Federal Register notices in April 1990. These notices announced Western's intent to prepare an EIS. Western held seven scoping meetings in Arizona, Utah, Colorado, and New Mexico and received more than 21,000 written comments during the formal scoping period. In response to this significant public response, Western developed a newsletter and mailing list to keep the public informed about the EIS process and the need for review and comment.

After receiving comments from the public, Western developed a scoping report to assist it in characterizing and understanding the scoping comments. From this report, Western developed a statement of scope. At this same time, Western developed the purpose and need statement for this EIS. Western described both the statement of scope and the purpose and need in a public newsletter requesting review and comment. Subsequent to this, Western developed draft commitment-level alternatives and hydropower operational scenarios for the three facilities under consideration. These alternatives and operational scenarios were submitted to the public for review and comment. On the basis of the comments received, Western published final alternatives and operational scenarios.

In addition to the above public involvement, Western visited directly with coordinating agencies, cooperating agencies, environmental groups, and customer groups before finalizing the statement of scope, the commitment-level alternatives, and the hydropower operational scenarios.

1.8 CONTENT OF THIS EIS

Chapter 1 of this EIS defines the proposed action and describes the purpose and need for the action. Chapter 2 describes the commitment-level alternatives and briefly explains how those alternatives were selected. Also included in Chapter 2 is a general description of the hydropower operational scenarios that provide marketable power from each of the SLCA/IP facilities. Since commitments also include power purchases and exchanges, such purchases and exchanges are also discussed in order to describe the relationship between power marketing and hydropower operational scenarios. Chapter 2 also compares the impacts of the various alternative commitment levels, including effects of hydropower operations.

Chapter 3 describes the affected environment of the SLCA/IP and the regional environment that may be affected by power marketing and hydropower generation. The descriptions include socioeconomic factors; air, water, ecological, and cultural resources; land use patterns; recreational features; and visual resources.

Environmental consequences of the commitment-level alternatives are analyzed in Chapter 4, Section 4.1. Section 4.2 evaluates the consequences of the various hydropower operational scenarios for the Glen Canyon and Flaming Gorge dams and the Aspinall Unit. Section 4.3 summarizes the projected impacts of the commitment-level alternatives and

hydropower operational scenarios, and Section 4.4 outlines possible mitigation and monitoring measures.

Chapter 5 describes the cumulative impacts of commitment-level alternatives and hydropower operational scenarios. Chapter 6 describes unavoidable adverse impacts, and Chapter 7 describes irreversible and irretrievable commitments of resources. Relationships between short-term uses and long-term productivity are identified in Chapter 8. Environmental statutes, regulations, executive orders, and permit requirements are listed in Chapter 9, and consultation and coordination activities are described in Chapter 10. This EIS also contains a list of references (Chapter 11), a list of preparers (Chapter 12), a list of acronyms (Chapter 13), a glossary (Chapter 14), an index (Chapter 15), and a list of recipients (Chapter 16). Supporting data for several resources are presented in appendixes at the end of the document.

2 ALTERNATIVES, INCLUDING NO ACTION

2.1 INTRODUCTION

Chapter 2 identifies and compares Western's power marketing commitment-level alternatives, including the no-action alternative, and describes the hydropower operational scenarios evaluated in this EIS. The bases for selecting the commitment-level alternatives are discussed in Section 2.2.1, and the alternatives selected are described in Section 2.2.2. The potential environmental impacts of these alternatives are summarized in a comparative format in Section 2.2.3.

The hydropower operational scenarios are addressed in Section 2.3. Section 2.3.1 describes the relationships between commitment-level alternatives and the operation of hydropower facilities. Section 2.3.2 discusses hydropower operations, purchases, and exchanges; Section 2.3.3 describes the hydropower operational scenarios selected for analysis for each facility. The impacts of these scenarios are compared in Section 2.3.4.

2.2 COMMITMENT-LEVEL ALTERNATIVES

Western proposes to establish the level of its commitment for sales of long-term firm electrical capacity and energy generated by the SLCA/IP. As indicated in Chapter 1, these commitments are included in the contracts establishing the terms for how capacity and energy are to be sold by Western.

Capacity is equivalent to the instantaneous output of a generator, usually stated in units of megawatts (MW)¹ or kilowatts (kW).² Generators are rated for their maximum capacity under specific conditions; this capacity is usually referred to as "nameplate generating capacity." Energy is the amount of power generated over a period of time and is stated in megawatt-hours (MWh)³ or gigawatt-hours (GWh).⁴ A level of commitment for sales specifies amounts of long-term firm capacity and energy.

The commitment-level alternatives, including the no-action alternative, evaluated in this EIS are defined on the basis of a specified level of both capacity and energy. This level of capacity and energy comes from two sources: hydroelectric power generated by SLCA/IP facilities and purchases from other sources. Western may purchase capacity and

¹ One megawatt equals 1,000,000 watts.

² One kilowatt equals 1,000 watts.

³ One megawatt-hour equals 1,000,000 watt-hours. A generator operating at a capacity of one megawatt for one hour would produce one megawatt-hour of energy. The same generator operating at a capacity of one megawatt for 10 hours would produce 10 megawatt-hours of energy.

⁴ One gigawatt-hour equals 1,000 megawatt-hours.

energy from any other utility offering them for sale. The commitment-level alternatives cover a broad range of capacity and energy levels that Western could make available to its customers. The following section describes how these possible commitment levels were selected for evaluation in this EIS.

2.2.1 Selection of Commitment-Level Alternatives

The selection of commitment-level alternatives was based on the combinations of capacity and energy that would feasibly and reasonably fulfill Western's firm power marketing responsibilities and statutory obligations. The generation capability of the SLCA/IP is only one part of the basis for determining the amount of power available for long-term firm contracts. The other part consists of energy purchases and interchanges. Interchanges are agreements that Western has with other utilities to trade generation resources from different locales to increase total system efficiency or avoid transmission limits that would occur without such agreements. Purchases and interchange are key elements in Western's power marketing activities. Without purchases and interchange, Western would have to reduce its long-term firm commitments to about one-third of historical levels. Western would have to market on the basis of highly variable hydrological conditions and could not commit to deliveries in excess of worst possible, highly improbable, drought conditions. In fact, it would be impractical for Western to make any long-term firm commitments that maximize the value of the hydropower resource without purchase flexibility.

The amount of SLCA/IP capacity and energy available for Western to market is determined after other needs are met, including the dam and power plant operators' station service requirements and dedicated uses for Bureau of Reclamation projects such as irrigation, maintenance requirements, and Western's reserves and system losses. The amount of marketable capacity and energy varies from year to year, depending on hydrological conditions (e.g., water flows), reservoir storage requirements, and downstream flow requirements.

Variations in hydrological conditions and other factors result in a risk that the SLCA/IP power plants would not be able to generate sufficient capacity and energy to meet Western's long-term firm commitments. For this reason, the amount of marketable long-term firm capacity and energy committed under each alternative is directly related to the level of risk Western assumes on behalf of its customers over the life of the contract. The risk Western assumes is essentially one of not having sufficient hydroelectric generation to meet contract commitments.

The amount of SLCA/IP capacity and energy that Western offers as long-term firm commitments is influenced by such factors as (1) the amount of installed hydroelectric capacity in the system; (2) restrictions on minimum and maximum water releases by each facility; (3) limitations on operations to protect or enhance natural, cultural, and recreational resources; (4) anticipated water conditions and water depletions; (5) resultant reservoir operations; (6) the amount of power needed by facility operators, such as Reclamation;

(7) dedicated project uses; and (8) the electrical energy market and the availability of regional electrical resources. Because many of these factors are uncertain and highly variable over time, Western, with assistance from Reclamation, forecasts probable future conditions for a given period and sets its level of long-term firm capacity and energy commitments according to these predictions and sound business principles. These forecasts include both upper and lower limits of capacity and energy.

Limits to Power Production: As a starting point to establish the boundaries of reasonable levels of projected power considered in this EIS, Western assumed that the maximum installed capacity for the SLCA/IP would be approximately 1,800 MW. Installed capacity might change over the life of hydropower facilities because unit modifications can be made as technology advances. Reclamation has programs proposed or under way to increase the capacity of several existing SLCA/IP facilities. Installed capacity is greater than marketable capacity because water is available to operate at the maximum limit (installed capacity) only for limited periods.

Prior to 1977, before Western was established as a power marketing agency, Reclamation had based its long-term firm power commitments on a conservative near-adverse risk assumption; that is, the minimum level of power that could be expected to be available in some future period, even in the poorest water years. Western continued this practice until the development of the Post-1989 Criteria, when Western modified this historical risk assumption by considering a "10% risk" assumption as reasonable. This means that in approximately 1 year out of 10, the water levels behind the system dams would not be sufficient to produce the capacity and energy needed to support the post-1989 commitment level. This 10% risk approach was applied to a projection of future available power for the SLCA/IP for the period 1989 through 1999. That projection was based on an assumption of maximum flexibility in daily releases. In other words, within the minimum and maximum flows set by Reclamation (the dam operator) before 1989, no restriction would be set on daily fluctuations at each hydropower facility. This assumption of 10% risk coupled with full operational flexibility resulted in the *upper boundary* of marketable firm capacity of 1,450 MW.

To determine a *lower limit* of power operations, Western considered restricted release rates currently affecting the Glen Canyon Dam, the principal hydropower resource of the SLCA/IP. Future additional constraints that may be placed on operations at the Flaming Gorge and Aspinall Unit facilities were also considered. Under assumptions of (1) future constant (nonfluctuating) releases at all SLCA/IP facilities and (2) continued worst-year water conditions for future years, the maximum level of marketable capacity after all adjustments would be approximately 550 MW. This value was identified as the assumed lower boundary of marketable firm capacity for the purpose of selecting commitment-level alternatives. This level provides minimum flexibility and essentially no risk.

Limits to Energy Production: Before 1977, Reclamation based long-term firm energy commitments on annual average energy generated by its facilities. To identify the *upper boundary* of long-term firm energy commitments for selection of alternatives for this

EIS, Western assumed a 54% risk (average energy plus 400 GWh). This level of risk would equate to about 6,200 GWh annually (adjusted for losses and project uses). For the *lower boundary*, assumptions of no risk and no purchases would result in a minimum energy commitment of approximately 3,300 GWh for the worst hydrologic year.

Figure 2.1 schematically illustrates the upper and lower boundaries of capacity and energy. The left side of the diagram indicates the lower, no risk, low flexibility boundary of marketable firm capacity (550 MW). The right side of the diagram is the upper, 10% risk, high flexibility boundary of marketable firm capacity (1,450 MW). The bottom of the diagram is the lower boundary of marketable firm energy (3,300 GWh), and the top is the upper boundary of marketable firm energy (6,200 GWh). Any point within the diagram represents a combination of marketable long-term firm capacity and long-term firm energy. Western could choose to market any combination of capacity and energy within the diagram.

Figure 2.1 also explains the desirability of the different commitment-level alternatives to Western's customers. The ratio of energy to capacity is called the load factor. The higher the amount of energy per unit of capacity, the higher is the load factor. Each of the diagonal lines in Figure 2.1 represents combinations of capacity and energy that yield the same load factor. Moving from the lower right corner to the upper left corner of the diagram, the load factor increases from 25% to 100%. When the load factor is low, the customer has

FIGURE 2.1 Commitment-Level Boundaries for Marketable Firm Energy and Capacity at the SLCA/IP

more flexibility regarding when it takes delivery of the amount of energy it has committed to purchase. Thus, with a low load factor, energy can be used just to serve the additional load that arises during peak demand periods. In addition, the customer has more flexibility over the decision of whether to substitute less expensive energy for energy that could be produced by more expensive technologies. As the load factor increases, the customer must take energy on a more regular basis to ensure it takes the total amount of energy that it has committed to purchase (and Western has committed to deliver). Because the customer has less control over when it takes delivery of this energy, the usefulness of the energy declines. In this case, a customer may find itself in the position of having to purchase energy from Western in periods (e.g., off-peak) when that energy really is not needed or desired.

The area within Figure 2.1 defines all reasonable amounts of marketable firm commitments for capacity and energy. Points within this diagram represent combinations of either high or low capacity with either high or low energy. (These points are labeled as "alternatives," which are described below.) The values at the four corners of this diagram were selected as commitment-level alternatives. These values represent the reasonable bounds of capacity and energy given current resources. Alternatives 1, 2, 4, and 5 represent high capacity and high energy, high capacity and low energy, low capacity and low energy, and low capacity and high energy. Two moderate capacity and moderate energy alternatives (3 and 6) are also shown in Figure 2.1. These six alternatives (commitment levels 1-6) and the no-action alternative (the 1978 commitment level) have been carried forward for analysis in this EIS.

A *minimum schedule requirement* is also a component of each alternative. The minimum schedule requirement is the minimum quantity of capacity that a contract customer must accept on an hourly basis. This is an important component of each alternative and changes with each combination of capacity and energy. A high minimum schedule requirement (e.g., 35%) would negate the flexibility of the low load factor alternatives by requiring that so much energy be used around the clock that very little energy is left to schedule when it is needed. Therefore, alternatives with low load factors also have low minimum schedule requirements.

2.2.2 Description of Commitment-Level Alternatives

This section describes the commitment-level alternatives assessed in this EIS, including the no-action alternative. The features of these alternatives are summarized in Table 2.1.

2.2.2.1 No-Action Commitment-Level Alternative: the 1978 Commitment Level

If Western were to take no action to change the level of its long-term firm capacity and energy sales, commitments would remain at the 1978 power marketing program levels for the CRSP, Collbran, and Rio Grande projects. The 1978 program contains commitments

TABLE 2.1 Electric Power Marketing EIS Commitment-Level Alternatives

Alternative	Capacity Commitment (MW)	Energy Commitment (GWh)	Load Factor (%)	Minimum Schedule Requirement (%)	Description
No action	1,291	5,700	50	35	Moderate capacity and high energy (the 1978 marketing program commitment level)
1	1,449	6,156	48.5 ^a	35	High capacity and high energy (the post-1989 commitment level)
2	1,450	3,300	26	10	High capacity and low energy
3	1,225	4,000	37	15	Moderate capacity and moderate energy
4	550	3,300	68	52	Low capacity and low energy
5	625	5,475	100	100	Low capacity and high energy
6	1,000	4,750	54	33	Moderate capacity and moderate energy

^a This load factor differs slightly from that published in the Post-1989 Marketing Criteria (50.2%) because of a difference between calculating this number annually versus seasonally.

for 1,291 MW of long-term firm capacity and 5,700 GWh of long-term firm energy (Figure 2.1). This alternative has a load factor of 50% and a minimum schedule requirement of 35%.⁵

2.2.2.2 Commitment-Level Alternative 1: the Post-1989 Commitment Level

Commitment-level alternative 1, or the post-1989 commitment level, is associated with the proposed 1989 marketing plan. This commitment level is for 1,449 MW of long-term

⁵ Minimum schedule requirements are associated with alternative combinations of capacity and energy to provide (1) sufficient load off-peak to match minimum release levels at all SLCA/IP facilities, (2) the ability for Western to purchase sufficient energy off-peak to satisfy energy commitments in an adverse water year, and (3) some remaining component of capacity and energy to be scheduled for the customer during on-peak periods. Unique minimum schedule requirements for each commitment-level alternative were determined through consistent application of this approach.

firm capacity and 6,156 GWh of long-term firm energy. The energy offered under this alternative represents the highest energy commitment among all alternatives (about 8% higher than the no-action alternative). This commitment level has a load factor of nearly 50%. In addition, it imposes a minimum schedule requirement of 35% on long-term firm customers.

2.2.2.3 Commitment-Level Alternative 2: High Capacity-Low Energy

Commitment-level alternative 2 is a commitment to a high level of long-term firm capacity (1,450 MW) but a low level of long-term firm energy (3,300 GWh). This commitment level has the lowest load factor (26%) and lowest minimum schedule requirement (10%) of all the alternatives. This type of commitment would enable customers to take the highest percentage of their commitment during the on-peak hours, when power is most valuable. Although customers would gain value by purchasing a low load-factor resource, the value of this alternative would be diminished by the low energy commitment.

2.2.2.4 Commitment-Level Alternatives 3 and 6: Moderate Capacity-Moderate Energy

Commitment-level alternative 3 is a commitment to a moderate level of long-term firm capacity (1,225 MW) and a moderate level of long-term firm energy (4,000 GWh), as shown in Figure 2.1. This commitment results in a load factor of 37% and a minimum schedule requirement of 15%, the second lowest load factor and minimum schedule requirement of all the alternatives.

Commitment-level alternative 6 also is a commitment to a moderate level of long-term firm capacity (1,000 MW) and a moderate level of long-term firm energy (4,750 GWh). This alternative represents the midpoint of the ranges of capacity and energy, as illustrated in Figure 2.1. This commitment level has a load factor of 54%, which is mid-range between a high-load and a low-load resource, and a minimum schedule requirement of 33%.

2.2.2.5 Commitment-Level Alternative 4: Low Capacity-Low Energy

Commitment-level alternative 4 is the lowest commitment for long-term firm capacity (550 MW) and long-term firm energy (3,300 MWh), as shown in Figure 2.1. It is based on an assumption of continued adverse water conditions. This commitment level has a load factor of 68%, the third highest of all alternatives. The minimum schedule requirement of 52% is the second highest of all alternatives. Commitment-level alternative 4 offers the lowest long-term firm commitment of capacity and energy at a high load factor.

2.2.2.6 Commitment-Level Alternative 5: Low Capacity-High Energy

Commitment-level alternative 5 is characterized by a low level for long-term firm capacity (625 MW) and a high level for long-term firm energy (5,475 MWh). The load factor and minimum schedule requirement for this alternative are both 100%, indicative of a base-loaded resource. Under this alternative, the customer would have to take energy at the stated capacity at all times in order to meet its purchase commitment. This situation would not allow the customer flexibility to vary the energy it takes to meet varying load requirements throughout the day or over the period of a week or a month.

2.2.3 Comparison of Impacts of Commitment-Level Alternatives

Exclusive of socioeconomics and air quality, the analyses conducted for this EIS indicate that each commitment-level alternative could result in a wide range of environmental impacts that are dependent on the operational scenario implemented at each of the hydropower facilities being considered in this EIS.⁶ Impacts of hydropower operational scenarios are presented in Section 2.3.4.

The results of the regional economic analysis suggest that the different commitment-level alternatives could have a slight impact on certain socioeconomic variables, including population, employment, disposable income, and economic output in each of the geographic subregions included in the analysis. This geographic area is depicted in Figure 2.2. However, the range of predicted impacts on regional economic variables across the various commitment-level alternatives is extremely small. As indicated in Table 2.2, the estimated impacts on each of these variables are not statistically different from zero for any of the alternatives considered. Impacts on agricultural production, as measured by changes in net income of the agricultural sector in each of the affected states, and on conservation and renewable energy programs, measured in terms of impacts on consumption efficiency and load management, would also be slight.

The alternatives were also analyzed with respect to possible impacts on the financial condition and retail rates of each of the utilities that receives an allocation of firm capacity and energy from Western's SLCA/IP. In this case, it was determined that certain utilities could experience adverse impacts as a result of a change in Western's commitment levels. Under each of the commitment-level alternatives, the number of utilities with a coverage ratio (which measures the ratio of cash flow to interest expense or debt) of less than 2.0 would remain unchanged, but the number of utilities with a ratio of less than 1.1 could increase slightly.⁷ With respect to retail rates, the different commitment-level alternatives

⁶ These analyses assume that Western adjusts its firm power rate for each commitment-level alternative so that required payments to the U.S. Treasury from the Federal projects are unaffected by choice of alternative.

⁷ It is an industry-wide standard that the coverage ratio for utilities should be greater than 2.0.

FIGURE 2.2 Affected Environment for Socioeconomics

would result in slight to moderate impacts. Impacts would be largest under commitment-level alternative 4.

The commitment-level alternatives would not result in any measurable impacts to regional or local air quality or measurable increase in noise levels.

2.3 HYDROPOWER OPERATIONAL SCENARIOS

2.3.1 Background

To meet the resource requirements for each commitment-level alternative, Western would use either the hydropower generated at each SLCA/IP facility or a combination of hydrogeneration and capacity and energy purchases and exchanges from outside sources. The statement of scope for this EIS (Western 1991b) indicated that Western ". . . would analyze the effects of alternatives on the operation of the applicable hydro facilities."

Under all conditions, Western obtains a finite amount of energy from the operation of SLCA/IP facilities. The amounts of energy produced by these facilities basically depend

TABLE 2.2 Relative Impacts of the Commitment-Level Alternatives

Commitment-Level Alternative	Financial Viability and Retail Rates	Regional Economic Activity	Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
No action (1978 Marketing Criteria)	Slight impacts on financial viability of Western's customers and the retail rates charged to end-users.	No impacts on the levels of population, employment, income or output.	No impacts on agricultural production.	No impacts on local or regional air quality or noise.	Impacts dependent on dam operations (see Tables 2.4, 2.5, and 2.6).
Commitment-level alternative 1	No impact on financial viability; slight impact on retail rates.	Estimated impacts on population, employment, income, and output are not statistically different from zero.	Slight impact on agricultural production.	Same as above.	Same as above.
Commitment-level alternative 2	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 3	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 4	No impact on financial viability; moderate or large impacts on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 5	Slight impact on financial viability; moderate to large impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 6	Slight impact on financial viability; moderate impact on retail rates.	Same as above.	Same as above.	Same as above.	Same as above.

on the amounts of water released from the dams, and the bounds of these releases are not set by Western. Monthly water volumes released through the CRSP facilities are established by Reclamation in consultation with the Colorado River Basin states according to legal requirements governing downstream water deliveries and the hydrological conditions of the river basin.⁸ Within these monthly constraints and limitations on the daily operations of the facilities, water releases can be made in different ways. Water can be released as fast as possible for a short period of time or slowly over a long period of time. Because the value of energy is greatest when it is needed most, more water is released during the day to meet peak loads, and less water is released at night.

Western, in conjunction with Reclamation, has studied the operations of each of the SLCA/IP dams that generate hydropower to determine the amount of influence that Western exercises on each facility for hydroelectric generation. Certain facilities are operated for specific project purposes (usually irrigation) with no consideration of hydropower generation, other than as a by-product of the release of irrigation water. Neither Western nor its marketing programs influence the operation of these particular facilities: Provo River, Collbran, Fontenelle, Rio Grande, and the power plant at Crystal Dam (Figure 1.1). These facilities, which are operated for water services (such as irrigation) or other nonpower purposes, are not included in the hydropower operational scenarios described in this section. However, the capacity and energy available from these facilities were included in the commitment-level alternatives because they contribute to the total amount of capacity and energy available to fulfill Western's power marketing responsibilities.

For the remaining facilities of the CRSP, Western has direct influence over their second-by-second, hourly, and daily operations within the minimum and maximum release rates and up- and down-ramp rates set by Reclamation. Hydropower operational scenarios were developed for these facilities and are analyzed in this EIS.

A study was recently completed examining the influence of Western's power marketing program on the operation of these facilities. That study indicated that hydropower operations are weakly linked to long-term firm commitments for capacity and energy (Veselka et al. 1994b). However, in this EIS, Western makes no presumption regarding what effects the commitment-level alternatives have on the operation of the SLCA/IP hydropower facilities. Instead, in order to assess the complete scope of potential impacts associated with hydropower generation, the full range of possible operations at each SLCA/IP facility is analyzed.

⁸ These legal requirements (sometimes collectively referred to as "the Law of the River") are stipulated in the following acts and compacts: the Colorado River Storage Project Act, the Colorado River Basin Project Act of 1968 (43 USC §§ 1501 *et seq.*), the Colorado River Compact (Dec. 21, 1928, Ch. 42, 45 Stat. 1057), Upper Colorado River Basin Compact (Apr. 6, 1949, Ch. 48, 63 Stat. 31), the Boulder Canyon Project Act (43 USC §§ 617 *et seq.*), the Boulder Canyon Project Adjustment Act (43 USC §§ 618 *et seq.*), as well as certain international boundary and water treaties.

2.3.2 Hydropower Operations, Purchases, and Exchanges

Simply stated, hydrogeneration plus purchases and exchanges must equal firm sales plus nonfirm sales. Western makes purchases and exchanges both in response to shortfalls in hydrogeneration and other operational constraints, such as transmission limitations, and in response to variations in the value of energy. This procedure is consistent with standard operating practices of electrical utilities.

Western's purchases and exchanges of capacity and energy vary with market conditions and changes in Reclamation's water release schedules and operational parameters of the dams. When Reclamation's monthly water releases are not sufficient to provide the capacity and energy needed for Western to meet its firm sales commitments, Western must purchase or exchange capacity and energy sufficient to meet its contractual obligations. Western may purchase or exchange capacity and energy to exactly meet its long-term and short-term firm commitments, or may purchase or exchange in excess of this amount for resale.

Purchases made by Western are usually short-term and may be made from any utility offering capacity and energy for sale. With Western's extensive transmission network across the Western states, purchases can be made from any number of utilities and generation units. As market conditions change and regional weather patterns create unusual load demands, Western can buy or sell power around the system to capture the benefit of purchasing from utilities with surplus generation and selling to customer utilities with deficit generation. Because these purchases are made on the open market, it is impossible to project from day-to-day or month-to-month which utilities or generation units would be dispatched to meet Western's firm loads and nonfirm sales commitments.

In addition to purchases, Western has entered into an agreement with the Salt River Project (SRP), referred to as the SRP Exchange Agreement, to (1) make efficient use of the existing transmission system of each participating utility, (2) provide a mutual benefit through generation exchange, and (3) match regional loads with proximate resources and thus conserve energy by reducing line losses. Most (72%) of Western's SLCA/IP generating resources are located at Glen Canyon Dam in northern Arizona, while many of Western's loads are located in Utah, Colorado, and New Mexico. The Glen Canyon-Kayenta-Shiprock transmission line, used to link Glen Canyon with these major areas of load, has a capacity of only 400 MW. During times of peak loads, limits on the Glen Canyon-Kayenta-Shiprock line may restrict operating levels at many or all SLCA/IP hydroelectric dams. Western and SRP have an "exchange" arrangement in which generating capacity owned by SRP in Craig and Hayden, Colorado, and the Four Corners unit in New Mexico is exchanged for surplus generating capacity at Glen Canyon Dam under certain conditions. The power exchanges with SRP enable Western to service its loads northeast of Glen Canyon without constructing additional transmission lines.

Purchases and exchanges allow Western to diversify its generation risk, capitalize on short-term market differentials in supply and demand, and maximize the value of SLCA/IP resources. The overall effect of these purchases and exchanges is to provide

Western flexibility over commitment levels given specific hydropower operational scenarios. This flexibility is illustrated by the effects of recent Reclamation interim flow restrictions at Glen Canyon Dam. This facility represents nearly 75% of SLCA/IP generation. Although operations have been severely restricted, Western has met its firm commitments with little interruption in supply by making purchases and exchanges.

Because of this flexibility, Western can meet load in excess of hydrogeneration. However, some commitment levels, when combined with certain hydropower operational scenarios, may not be desirable. For example, low commitment levels with hydropower operation scenarios that have high fluctuations may not be desirable because such a combination would have an economic cost without providing any environmental benefit. Western decisions regarding both commitment levels and hydropower scenarios will be based on all of the purposes stated for the EIS, in light of the environmental impacts. Ultimately, Western will determine both a commitment level and a means of supplying the commitment level, including operational scenarios at the hydropower facilities, within constraints and release volumes set by Reclamation.

2.3.3 Selection and Description of Hydropower Operational Scenarios

Only Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit require the development of operational scenarios for analysis in this EIS. For all facilities where operations are dictated by irrigation demands, municipal and industrial uses, flood control, or other nonpower purposes, operations are not described, and site-specific environmental analyses are not included because, although Western markets this power, Western does not affect hydrogeneration at those facilities.

2.3.3.1 Glen Canyon Dam

Nine modes of operation, which represent unique hydropower operational scenarios for Western's power marketing programs, have been identified in the Glen Canyon EIS (Reclamation 1993). These scenarios that are being evaluated as alternatives in the Glen Canyon Dam EIS are described in Table 2.3. When the Glen Canyon Dam EIS Record of Decision is issued, Western will have to maintain hydropower operations within the constraints specified by the alternative selected. These constraints will include such parameters as minimum flows, maximum flows, ramp rates, and allowable daily changes. The range of operations span no-action under new limits; 1,000 cubic feet per second (cfs) minimum flow to 33,200 cfs maximum flow (the highest level of operational flexibility); to year-round steady flows based on yearly prorated volumes with an allowable daily change of 2,000 cfs every 24 hours. A detailed explanation of the hydrology studies and release patterns derived from the EIS alternatives is provided in the Glen Canyon Dam EIS (Reclamation 1993). The release patterns and environmental impacts associated with those releases are based on results of the Glen Canyon Environmental Studies, the supporting literature, and related documentation found in the public record.

TABLE 2.3 Hydropower Operational Scenarios for Glen Canyon Dam

Parameter	Continuation of Historical Flows	Maximum Power Plant Capacity	Restricted Fluctuating Flows				Steady Flows		
			High	Moderate	Modified Low	Interim Low	Existing Monthly Volume	Seasonally Adjusted	Year-Round
Minimum releases ^a (cfs)	1,000 Labor Day-Easter 3,000 Easter-Labor Day ^b	1,000 Labor Day-Easter 3,000 Easter-Labor Day ^b	3,000, 5,000, 8,000, depending on monthly volume, firm load, and market conditions	5,000	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000	8,000 Oct-Nov ^c 8,500 Dec 11,000 Jan-Mar 12,500 Apr 18,000 May-Jun 12,500 Jul 9,000 Aug-Sep	Yearly volume prorated ^d
Maximum releases (cfs)	31,500	33,200	31,500	31,500 ^f	20,000 ^f	20,000	Monthly volumes prorated	18,000 ^f	Yearly volume prorated ^d
Allowable daily change in flow (cfs/24 hours)	30,500 Labor Day-Easter 28,500 Easter-Labor Day	32,200 Labor Day-Easter 30,200 Easter-Labor Day	15,000 to 22,000	±45% of mean flow for the month not to exceed ±6,000	5,000, ^g 6,000, or 8,000	5,000, ^g 6,000, or 8,000	±1,000 ^h	±1,000 ^h	±1,000 ^h
Allowable scheduled ramping (cfs/h)	Unrestricted	Unrestricted	Unrestricted up 5,000 or 4,000 down	4,000 up 2,500 down	2,500 up 1,500 down	2,500 up 1,500 down	2,000 cfs/d between months	2,000 cfs/d between months	2,000 cfs/d between months
Elements common to restricted fluctuating and steady flow alternatives	None	None	Adaptive management including long-term monitoring and research, monitoring and protection of cultural resources, flood frequency reduction measures, beach/habitat-building flows, new population of humpback chub, further study of selective withdrawal, emergency exception criteria						

^a In high volume release months, the allowable daily change would require higher minimum flows.

^b Releases each weekday during recreation season (Easter to Labor Day) would average not less than 8,000 cfs for the period from 8 a.m. to midnight.

^c Based on an 8.23 million acre-feet year; in higher release years, additional water would be added equally to each month, subject to an 18,000 cfs maximum.

^d For an 8.23-million acre-feet year, steady flow would be about 11,400 cfs.

^e Maximums represent normal or routine limits and may necessarily be exceeded during high water years.

^f May be exceeded during habitat-maintenance flows.

^g Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-feet; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet and 8,000-cfs for monthly volumes over 800,000 acre-feet.

^h Adjustments would allow for small power system load changes.

Source: Adapted from Reclamation (1993).

The Glen Canyon Dam EIS also proposes to impose adaptive management techniques, including research and monitoring, and may include beach/habitat building flows, reducing flood frequency, and making power system adjustments (Reclamation 1993).

2.3.3.2 Flaming Gorge Dam

Four operational scenarios for Flaming Gorge Dam were developed for this EIS (Table 2.4). As described below, three of these scenarios comply with the Biological Opinion issued by the USFWS (1992b). Compliance with the opinion is described as follows:

1. A target flow at Jensen, Utah, is set between 1,100 and 1,800 cfs for summer and autumn, except that up to 2,400 cfs would be allowed after September 15 for wet years. The time periods covered are July 20-October 31 for a wet year, July 10-October 31 for a moderate year, and June 20-October 21 for a dry year.
2. Variations of flow at Jensen are limited to a total of 25% around the target flow for any 24-hour period. Variations above or below the target should be as close as possible.
3. Except due to the effects of storm runoff, the flow at Jensen should stay within the range of 1,100 to 1,800 cfs, or up to 2,400 cfs after September 15 for wet years.

Release patterns were developed for representative wet, moderate, and dry years (1983, 1987, and 1989, respectively) (see Section 3.3). Release patterns for the four hydropower operational scenarios are presented in Appendix C. The principal difference in the hydropower operational scenarios is the hourly fluctuation characteristics of the release rate, as summarized below.

Scenario 1 — Year-Round High Fluctuating Flows: The ramping rates, maximum fluctuations, and maximum and minimum releases used to derive the representative release patterns are detailed in Appendix C. The minimum release is 800 cfs; the maximum release was assumed to be 4,700 cfs⁹ with no limit on maximum daily fluctuations. Ramp-rate restrictions are 3,900 cfs/h (minimum flow to maximum generator capacity). This operational scenario would not comply with the Biological Opinion. It is representative of maximum power plant operations and is considered here for comparative purposes. Consideration of this operational scenario enabled a determination of the environmental consequences of the seasonal and daily adjustment of releases required by the opinion.

⁹ The maximum possible release rate for Flaming Gorge Dam with uprated conditions could be in excess of 4,950 cfs for full reservoir conditions. However, such reservoir conditions would occur for limited periods.

TABLE 2.4 Hydropower Operational Scenarios for Flaming Gorge Dam^a

Parameter	Year-Round High Fluctuating Flows	Seasonally Adjusted Flows		
		High Fluctuating	Moderate Fluctuating	Steady
Minimum releases (cfs)	800	800 Oct-Jan 2,380 Feb-Mar 800 Apr-May 4,700 Jun 1-21 800 Jun 22-Jul 9 890 Jul 10-31 990 Aug 1,070 Sep	800 Oct 2,220 Nov-Jan 2,380 Feb-Mar 2,440 Apr 2,740 May 4,700 Jun 1-21 2,770 Jun 22-30 1,860 Jul 1-Jul 9 976 Jul 10-31 1,080 Aug 1,160 Sep	800 Oct 2,380 Nov-Mar 2,600 Apr 3,390 May 4,700 Jun 1-21 3,740 Jun 22-30 2,020 Jul 1-9 1,060 Jul 10-31 1,160 Aug 1,240 Sep
Maximum releases (cfs)	4,700	800 Oct 4,700 Nov-Jan 2,380 Feb-Mar 4,700 Apr-Jul 9 2,900 Jul 10-31 3,000 Aug 3,100 Sep	800 Oct 4,170 Nov-Jan 2,380 Feb-Mar 4,390 Apr 4,700 May-Jun 3,810 Jul 1-9 1,980 Jul 10-31 2,080 Aug 2,160 Sep	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,900	0 Oct 3,900 Nov-Jan 0 Feb-Mar 3,900 Apr-May 0 Jun 1-21 3,900 Jun 22-Jul 9 2,010 Jul 10-Aug 2,030 Sep	0 Oct 1,950 Nov-Jan 0 Feb-Mar 1,950 Apr-May 0 Jun 1-21 1,950 Jun 22-Jul 9 1,000 Jul 10-Sep	0
Allowable scheduled ramping (cfs/h)	3,900	3,900	1,950	0

^a For a moderate hydrological year.

Scenario 2 — Seasonally Adjusted High Fluctuating Flows: Hourly releases would reach the maximum fluctuation feasible as limited by the Biological Opinion, water available for release, minimum release requirement, and power plant capacity. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

Scenario 3 — Seasonally Adjusted Moderate Fluctuating Flows: Hourly releases would have fluctuations limited to 50% of the flow change identified under Scenario 2. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

Scenario 4 — Seasonally Adjusted Steady Flows: Hourly releases would be constant during the day. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

2.3.3.3 Aspinall Unit

The operations of the Aspinall Unit dams are being evaluated by Reclamation. Any NEPA documentation that is prepared will not be available for reference in this Electric Power Marketing EIS; however, Western has developed two operational scenarios for the Aspinall Unit (Table 2.5).

Scenario 1 — Seasonally Adjusted High Fluctuating Flows: This scenario would permit seasonally adjusted high fluctuating flows with daily fluctuations at Blue Mesa and Morrow Point dams, but only steady flows out of Crystal Dam.

Scenario 2 — Seasonally Adjusted Steady Flows: This scenario would provide for a steady water release through Blue Mesa, Morrow Point, and Crystal dams. The steady pattern would change monthly, depending on the monthly volume set by Reclamation.

2.3.4 Comparison of Impacts of Hydropower Operational Scenarios

This section summarizes impacts on natural and cultural resources from hydropower operational scenarios for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. The affected environments of these operational scenarios are depicted in Figure 2.3. These impacts are discussed in detail in Section 4.2. The natural and cultural resource impacts associated with Western's power marketing programs are direct results of hydroelectric operations rather than of the commitments of capacity and energy (i.e., commitment-level alternatives) specified in Western's contracts.

The operational scenarios examined for Glen Canyon and Flaming Gorge dams included scenarios that are similar to historical operations (e.g., continuation of historical operations and year-round high fluctuations, respectively). The current conditions of most resources downstream of the facilities result from such operations, and, therefore, these operational scenarios would have little additional impact to most resources. Other operational scenarios examined would result in reduced flow fluctuations below the dams, which could benefit many downstream resources. None of the operational scenarios considered would materially affect noise, land use, or visual resources. Therefore, these resources are not discussed further in this section. For reasons discussed in Chapter 4, impacts to air resources are considered as part of the commitment-level alternative analysis.

TABLE 2.5 Hydropower Operational Scenarios for the Aspinall Unit^a

Parameter	Seasonally Adjusted High Fluctuating Flows			Seasonally Adjusted Steady Flows		
	Blue Mesa	Morrow Point	Crystal	Blue Mesa	Morrow Point	Crystal
Minimum release (cfs)	1,750 Jun 0 Others	0 Oct-Mar 557 Apr 1,830 May 2,440 Jun 1,070 Jul 0 Aug-Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,200 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep	1,570 Oct 1,200 Nov 1,050 Dec 500 Jan-Mar 1,600 Apr 2,370 May 3,050 Jun 2,350 Jul 1,750 Aug-Sep	1,700 Oct 1,280 Nov 1,100 Dec 570 Jan-Mar 1,970 Apr 2,890 May 3,320 Jun 2,480 Jul 1,770 Aug 1,820 Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,250 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep
Maximum release (cfs)	3,700	5,300 Oct-Mar 2,680 Apr 3,420 May 3,770 Jun 3,190 Jul 5,300 Aug-Sep	Same as minimum releases	Same as minimum releases	Same as minimum releases	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,700 Oct-May 1,950 Jun 3,700 Jul-Sep	5,300 Oct-Mar 2,120 Apr 1,590 May 1,330 Jun 2,120 Jul 5,300 Aug-Sep	0	0	0	0
Allowable scheduled ramping (cfs/h)	3,700	5,300	0	0	0	0

^a For a moderate hydrological year

FIGURE 2.3 Affected Environment for Natural and Cultural Resources

2.3.4.1 Glen Canyon Dam

Table 2.6 summarizes impacts to water resources, ecological resources, cultural resources, and recreation in and along the Colorado River downstream of Glen Canyon Dam. Since hydropower operations have little effect on the surface level of Lake Powell upstream of the dam (because of the large reservoir capacity), resources in the reservoir are not considered.

The continuation of historical operations and maximum power plant capacity operational scenarios would have little additional impact on natural resources. These scenarios are similar to the operations that have occurred since the dam was completed in 1963, and existing water resources, ecological resources, and recreational activities have developed under these historical operations. Because these scenarios have relatively high erosion rates, the potential for adverse impacts to cultural resources would be greatest.

Because of their reduced fluctuations and maximum flows, all other operational scenarios would be beneficial for most resources. Restricted high fluctuations would result in moderate reductions in erosion rates and slight benefits to most ecological resources and recreation, but adverse impacts are expected to cultural resources. Moderate and low fluctuation operational scenarios would produce moderate or large benefits for water resources, terrestrial ecology, cultural resources, and white-water boating. Steady flow scenarios would produce moderate to large benefits for these resources, as well as for aquatic ecology and angling. The seasonally adjusted steady flow scenario could benefit the humpback chub, but any benefit might require the proposed occasional high flows to flush accumulated sediments from backwaters.

2.3.4.2 Flaming Gorge Dam

Table 2.7 summarizes impacts to water resources, ecological resources, cultural resources, and recreation in and along the Green River downstream of Flaming Gorge Dam. Because hydropower operations have little effect on the surface level of Flaming Gorge Reservoir (because of the large reservoir capacity), resources in the reservoir are not considered.

The year-round high fluctuating flow operational scenario features slightly higher daily maximum flows and fluctuations than historical operations. This scenario could result in adverse impacts to native and endangered fish, trout, woody riparian vegetation, and cultural resources.

The seasonally adjusted operational scenarios feature shifts in monthly volumes to meet requirements of the USFWS Biological Opinion (USFWS 1992b). All of these scenarios exhibit a high sustained flow in May or June, reduced fluctuations and lower flows in summer and autumn, and steady flows when an ice cover is present on the river (February and March). These flow patterns are intended to protect endangered fish in the system and

TABLE 2.6 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Continuation of historical flows	No change from current conditions.	Slight adverse impact to humpback chub; no change from current conditions for other resources.	Adverse impact because of high erosion rate.	No impact.
Maximum power plant capacity	Same as above.	Slight adverse impact to humpback chub and southwestern willow flycatcher; no impact to other resources.	Same as above.	Slight adverse impact to angling and white-water boating.
Restricted high fluctuating flows	Moderate benefit; decreased sediment load and erosion rate.	Slight adverse impact to humpback chub; slight benefit to aquatic resources; no impact to terrestrial resources.	Same as above.	Slight benefit to angling and white-water boating.
Moderate fluctuating flows	Large benefit; decreased sediment load and erosion rate.	Slight adverse impact to humpback chub; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; slight benefit to aquatic resources; moderate benefit to terrestrial resources.	Benefit because of reduced erosion rates.	Same as above.
Modified low fluctuating flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; slight to moderate benefit to aquatic resources; moderate benefit to terrestrial resources.	Same as above.	Moderate benefit to white-water boating; slight benefit to angling.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.	Same as above.
Existing monthly steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.

TABLE 2.6 (Cont.)

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Seasonally adjusted steady flows	Same as above.	Slight to moderate benefit to humpback chub; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to white-water boating; moderate benefit to angling.
Year-round steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, and peregrine falcon; moderate benefit to southwestern willow flycatcher; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 30 years of operations. No impacts to air resources, land use, or visual resources were identified.

TABLE 2.7 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Year-round high fluctuating flows	Slight impact; increase in erosion rate.	Slight to moderate adverse impacts to aquatic resources; slight adverse impacts to terrestrial resources.	Adverse impact because of high erosion rate.	Slight adverse impact to angling; no impact on white-water boating.
Seasonally adjusted high fluctuating flows	Same as above.	Slight to moderate benefits to native fish and endangered fish; slight to moderate adverse impacts to trout; slight adverse impact to terrestrial resources; moderate adverse impact to bald eagle.	Adverse impact because of high erosion rate.	Large adverse impact to angling in spring and early summer; large benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.
Seasonally adjusted moderate fluctuating flows	Slight benefit; decrease in erosion rate.	Slight to moderate benefit to native fish and endangered fish; moderate adverse impact to bald eagle; slight adverse impact to Ute ladies-tresses; slight adverse impact to terrestrial resources.	Moderate benefit because of reduced erosion rate.	Moderate to large adverse impact to angling in spring and early summer; moderate benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.
Seasonally adjusted steady flows	Same as above.	Moderate to large benefit to native fish and endangered fish; slight benefit to trout; slight benefit to terrestrial resources; moderate adverse impact to bald eagle and Ute ladies-tresses; slight benefit to peregrine falcon.	Same as above.	Same as above.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 30 years of operations. No impacts to air resources, land use, or visual resources were identified.

would benefit other resources as well. Some adverse impacts could result from seasonal adjustment, however. The spring peak flows would adversely affect anglers. In addition, the bald eagle and waterfowl could be adversely affected by steady flows in February and March. With steady flows, less open, ice-free water would be available for these species.

Seasonally adjusted high fluctuations would have slight to moderate benefits for native and endangered fish (e.g., humpback chub), but high fluctuations from November through January and in April and May could adversely affect trout. This scenario would produce large benefits for angling in mid-summer through autumn and moderate benefits for white-water boating during the spring peak. Slight adverse impacts to terrestrial ecology could occur because of the inundation of some woody riparian vegetation. Erosion rates would be similar to the year-round high fluctuation scenario, and thus cultural resources could be adversely affected.

Seasonally adjusted moderate fluctuations or steady flows could produce moderate to large benefits for native and endangered fish, cultural resources, angling, and white-water boating. Only the steady flow scenario would benefit terrestrial resources, however, by allowing a moderate increase in woody riparian vegetation. The threatened Ute ladies-tresses could be adversely affected if this scenario resulted in lower soil moisture levels in the alluvial meadows where this species occurs.

2.3.4.3 Aspinall Unit

Table 2.8 summarizes impacts to water resources, ecological resources, cultural resources, and recreation associated with the Aspinall Unit. Only slight impacts would result from the two operational scenarios under consideration because Crystal Dam reregulates flows from the unit. Thus, flows in the Gunnison River would not be affected by the hydropower operational scenarios, and little difference exists in the impacts of the scenarios for this facility.

TABLE 2.8 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources Associated with the Aspinall Unit^a

Operational Scenario	Water Resources	Ecological Resources	Cultural Resources	Recreation
Seasonally adjusted high fluctuating flows				
Blue Mesa Reservoir	Slight impact; daily fluctuations same as historical but monthly release volumes change.	No impact to any resources.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.	Same as above.
Crystal Dam Reservoir	Same as above.	No impacts to aquatic resources; slight benefit to terrestrial resources.	Same as above.	Same as above.
Seasonally adjusted steady flow				
Blue Mesa Reservoir	Large impact; daily fluctuations eliminated and monthly release volumes change.	No impact to aquatic or terrestrial resources; slight adverse impact to bald eagle.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Same as above.	No impact to aquatic resources; slight benefit to terrestrial resources; slight adverse impact to bald eagle.	Same as above.	Same as above.

^a The impacts presented are relative to a baseline of existing conditions that have formed over 28 years of operation. No impacts to air resources, land use, or visual resources were identified.

1

3 AFFECTED ENVIRONMENT

This chapter discusses the affected environment for each resource under consideration. For socioeconomics and air resources, the area served by the SLCA/IP is described because commitment-level alternatives would affect this broad geographical region. For other resources, including water resources, ecology, cultural resources, land use, recreation, and visual resources, the affected environment is the area associated with specific SLCA/IP hydroelectric facilities that provide most of the power marketed by Western — Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Crystal, Morrow Point, and Blue Mesa dams). Because commitment-level alternatives vary considerably in their impact on socioeconomics but differ little in their impact on the natural environment, socioeconomic topics are addressed first in this chapter.

3.1 SOCIOECONOMICS

This discussion of the socioeconomic environment in the affected region focuses on key regional economic variables, including population, income, employment, and gross regional product; selected regional activities, including recreation, nonuse values, and agriculture; and existing rates for electricity and the financial condition of potentially affected utilities. However, before describing baseline conditions, it is necessary to first describe the socioeconomic "regions of influence" that have been defined for analytical purposes in this EIS.

3.1.1 Regions of Influence

The total area served by Western's SLCAO includes portions of the states of Utah, Colorado, Wyoming, Nevada, Arizona, and New Mexico. As described in Chapter 2, the Western SLCAO sells electricity to utilities in each of these states; however, not all electric utilities within these state boundaries receive power from Western. In addition, some of these utilities sell power to customers in states other than the six listed above.¹ As a consequence of these distinctions, the regions of influence for which impacts are assessed in this EIS were defined differently depending on the impact being analyzed. In the following sections, the definition of impact regions are specified for the analysis of utility finance and rates, regional economics, recreational economics, nonuse values, and irrigated agriculture.²

¹ The additional areas served by some of Western's customers include 2 counties in California, 22 counties in Nebraska, 2 counties in Montana, 4 counties in Texas, 1 county in Oklahoma, and 1 county in South Dakota.

² In this EIS, analyses of impacts to utilities are reported for broad utility categories to protect the confidentiality of Western's customers.

3.1.1.1 Utility Finance and Retail Rates

The region of influence for the power system's utility finance and rate impacts covers the entire six-state SLCA service area. The SLCAO serves 183 customers that have the potential to be affected by changes in Western's marketing programs (i.e., changes in capacity and energy commitment levels). These customers include utilities of various sizes and types and end-use facilities given preference customer status. For presentation in this EIS, the utility categories are based on level of reliance on Western power and type of ownership. With respect to ownership, utilities were categorized as municipals or cooperatives. This categorization was done to capture potential differences between urban and rural environments. Detail on these categorizations is provided in Section 3.1.3.

3.1.1.2 Regional Population, Employment, Income, and Output

The geographic region included in the analysis of regional population, employment, income, and output in this EIS consists of 195 counties in 12 states. The counties selected were identified as those most likely to experience effects as a result of a change in Western's commitment levels. This determination was based on the proportion of locally consumed power supplied by Western.

The 195 counties were divided into nine subregions by grouping counties with a common economic base. As shown in Figure 3.1, the groupings consist of six metropolitan subregions and three rural subregions. Each of the metropolitan subregions has a rather diversified economy, while each of the rural subregions is organized around a relatively homogenous economic base. The nine subregions include the Arizona Metropolitan, Colorado Metropolitan, Nevada Metropolitan, New Mexico Metropolitan, Utah Metropolitan, Wyoming Metropolitan, High Plains, Rocky Mountains, and Great Basin subregions. The individual counties included in each of the nine subregions are listed in Appendix A, Table A.2. For a discussion of how the nine subregions were selected, see Allison and Griffes (1994).

3.1.1.3 Recreation

Each of the affected facilities — Glen Canyon, Flaming Gorge, and Aspinall Unit — attracts many recreationists each year. Although these recreational activities have little effect on the regional economics defined above, they form a component of the local economy contiguous (adjacent) to the site.

The local economy associated with the Green River below Flaming Gorge Dam was defined to include the following counties: Uintah and Daggett in Utah, Sweetwater and Uinta in Wyoming, and Moffat and Rio Blanco in Colorado. This selection was based on the fact that together these counties include all of the cities and towns located reasonably close

Counties in the Six Metropolitan Subregions

Counties in the Three Rural Subregions

FIGURE 3.1 Metropolitan and Rural Subregions in the Regional Economic Analysis

to the major recreation centers on the affected portion of the Green River. The local economy associated with recreation on the Colorado River below Glen Canyon Dam was defined to include Coconino and Mohave counties in Arizona (Reclamation 1993).

No economic analysis was conducted of recreation-related impacts for the affected environment associated with the Aspinall Unit. This decision was based on the determination that commitment-level alternatives and operational scenarios would not affect recreation use rates at the Aspinall Unit (Section 4.2.7).

3.1.1.4 Agriculture

About 49% of the irrigated acreage in agriculture in the study region is pump-irrigated and could be affected by Western's commitment levels through changes in electricity costs. Because the modeling approach used to estimate the regional economic impacts does not provide sufficient detail to estimate these types of impacts, current conditions regarding irrigated agriculture are described at the state level.

3.1.2 Socioeconomic Baseline

The socioeconomic baseline is defined as the conditions predicted to prevail under the post-1989 marketing criteria for the years 1993 through 2008.³ To adequately assess the possible effects of the different commitment-level alternatives, an array of variables was selected to describe the baseline socioeconomic conditions in the affected region and subregions. These variables include population and three key economic indicators: employment, real disposable income (i.e., total real income adjusted for taxes and transfer payments), and real gross regional product⁴ (GRP). Estimated baseline values for these variables are provided in Table 3.1.

As shown in Table 3.1, an estimated 11.8 million individuals resided in the affected region in 1993, about half of them in the Arizona and Colorado Metropolitan subregions. This relationship is predicted to remain relatively stable over the forecast period. Total population in the affected region is predicted to grow at an annual rate of approximately 1.4% — from 11.8 million to 14.6 million — between 1993 and 2008. Population growth is expected

³ The forecasts of the variables that are discussed here were generated with the REMI modeling system for each of the subregional economies. A discussion of the REMI modeling system and corresponding assumptions is provided in Appendix A, Section A.5. Further discussion of the REMI and IMPLAN modeling systems can be found in Allison and Griffes (1994). Although the contract period runs from 1989 to 2004, the study period included the years 2004 through 2008 in order to adequately address the potential socioeconomic impacts attributable to the commitment-level alternatives over a 15-year period.

⁴ Gross regional product is a measure of the value of total output produced in a year and adjusted for the effects of price changes.

TABLE 3.1 Estimated Baseline Statistics: Population, Employment, Disposable Income, and Gross Regional Product

Subregion ^a	Population (1,000)		Average Annual Change (%)	Employment (1,000)		Average Annual Change (%)
	1993	2008		1993	2008	
1	3,264.3	4,597.1	+2.3	1,737.0	2,366.8	+2.1
2	2,398.7	2,890.4	+1.3	1,265.6	1,566.9	+1.4
3	778.2	1,072.8	+2.2	431.2	590.0	+2.1
4	683.7	936.1	+2.1	410.9	546.5	+1.9
5	1,440.6	1,698.2	+1.1	743.2	915.6	+1.4
6	58.5	64.6	+0.7	37.6	43.7	+1.0
7	835.1	817.5	-0.1	435.5	459.1	+0.4
8	1,026.2	1,114.6	+0.6	456.6	521.9	+0.9
9	1,325.3	1,380.0	+0.3	610.3	684.9	+0.8
Total	11,810.8	14,571.3	+1.4	6,127.8	7,695.5	+1.5

Subregion ^a	Disposable Income (billions of 1994 \$)		Average Annual Change (%)	Gross Regional Product (billions of 1994 \$)		Average Annual Change (%)
	1993	2008		1993	2008	
1	54.4	88.2	+3.3	71.0	108.9	+2.9
2	44.7	66.2	+2.6	51.2	74.4	+2.4
3	12.7	21.0	+3.4	17.2	24.9	+2.5
4	11.7	18.8	+3.2	17.3	25.3	+2.6
5	20.7	29.9	+2.4	31.4	44.7	+2.4
6	1.2	1.6	+2.2	2.8	3.6	+1.6
7	15.4	19.1	+1.5	21.3	25.8	+1.2
8	15.1	20.4	+2.1	20.7	26.4	+1.6
9	18.1	23.9	+1.8	27.1	33.5	+1.4
Total	194.0	289.1	+2.7	260.0	367.5	+2.3

^a 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains Subregion, and 9 = Great Basin Subregion.

Source: The data were estimated using the REMI modeling system, which is described in Appendix A (Section A.5).

to be most rapid in the Arizona Metropolitan Subregion (with an average annual growth rate of about 2.3%), while the population in the High Plains Subregion is predicted to decline in both relative and absolute terms.

The number of individuals employed in the affected region is predicted to increase by an average of 1.5% per year, to just under 7.7 million workers in 2008 (Table 3.1). The Nevada Metropolitan Subregion is predicted to experience the highest average annual growth rate of 2.1%. In contrast, employment in the High Plains Subregion is predicted to grow at an annual rate of 0.4% over the same period.

Employment is most heavily concentrated in the wholesale and retail sectors and the business and public services sectors in each of the metropolitan subregions. In contrast, employment is more evenly distributed across sectors in each of the rural subregions; no sector accounts for more than 25% of total employment. By 2008, the share of total employment in the retail and wholesale sectors and the business and public services sectors in the six metropolitan subregions will range from 52% to 70%; no sector in the three rural subregions will account for more than 23% of total employment.

Real disposable income in the affected region is predicted to increase by an average of 2.7% per year, rising from \$194 billion⁵ in 1993 to just over \$289 billion in 2008 (Table 3.1). The Arizona Metropolitan Subregion is predicted to experience the highest average annual growth rate, 3.3%. In contrast, real disposable income in the High Plains Subregion is predicted to grow at an annual rate of 1.5% over the same period. Once again, relative growth rates across subregions are consistent with the relative growth rates in population reported in Section 3.1.2.1.

For 1993, real GRP is estimated to be approximately \$260 billion (Table 3.1). This figure is expected to rise to nearly \$368 billion by 2008, which translates to an average annual growth rate of 2.3%. All of the nine subregions are expected to experience an increase in real GRP over the forecast period. The Arizona Metropolitan and New Mexico Metropolitan subregions are predicted to experience the highest growth rates, while the High Plains Subregion is predicted to experience the lowest.

Recreation-related expenditures contribute to the levels of income and employment in many local economies. In the case of Flaming Gorge Dam, approximately \$24.8 million (in 1994 dollars), or 0.22% of the 1991 economic activity in the local economy identified in Section 3.1.1.3, was directly or indirectly attributable to expenditures associated with recreational activities (fishing, boating, hunting, etc.) on the Green River below Flaming Gorge Dam (Rose and Frias 1993). Similarly, recreation-related expenditures were responsible for an estimated \$24 million (1994 dollars) in the local economic activity around Glen Canyon Dam (Reclamation 1993).

⁵ All dollar amounts are expressed in 1994 dollars.

In addition to producing economic benefits to the local economy, recreation at each site brings in economic benefits to the recreationists who engage in activities there. These benefits, referred to as use values, are measured as the difference between participants' willingness to pay for the recreational experience and the actual costs incurred. On the basis of results of a study by Bishop et al. (1987) and estimated use rates (Section 3.7.2.1), the annual use value of trout fishing on the Green River below Flaming Gorge Dam was estimated at \$4.0 million in 1991. Similarly, the annual use value of white-water rafting on the Green River between Flaming Gorge Dam and Jensen, Utah, was estimated at \$0.1 million. (See Appendix A, Section A.6, for a more detailed discussion of the derivation of these estimates.) The annual use values of trout fishing and white-water rafting below Glen Canyon Dam were estimated at \$1.3 million and \$8.1 million, respectively.

Evidence is growing that many individuals also attach "nonuse" values to many resources. As the term suggests, a nonuse value measures the amount individuals would be willing to pay to maintain the condition of a particular resource, independent of any use values they attach to that resource (see Appendix A, Section A.6 for a discussion of this concept). A growing number of studies, including recent efforts by Loomis (1987) and Sanders et al. (1990), have attempted to estimate the nonuse value of specific resources. According to these studies and a review of a number of earlier studies (Fisher and Raucher 1984), nonuse values might be one-half to 73 times as large as the estimated recreational use value of the resource.⁶ On the basis of the available research on this topic, it is estimated that a reasonable lower bound on the nonuse value associated with the environment below Flaming Gorge Dam would be \$2.1 million. The estimated lower bound on the nonuse value associated with the environment below Glen Canyon Dam would be approximately \$4.7 million. However, because of the unique characteristics of the natural environment at these two locations, the nonuse values could be considerably higher than the lower bounds noted above.

The agriculture, forestry, and fisheries sector in the affected region produced about \$1.4 billion dollars of output and employed more than 65,000 persons in 1990 (Allison and Griffes 1994). By the year 2000, employment in this sector is expected to grow to over 83,000 persons. Only two other economic sectors in the six-state region (services and medical/educational) will see their share of total employment increase over this period.

Because of the arid climate of much of the affected region, agriculture is heavily dependent on irrigation. About 49% of total irrigated acreage in this six-state region is pump irrigated (compared with irrigation of 11% of total farm acreage in the United States as a whole). The data in Table 3.2 show that over 80% of the pumped irrigated acreage in the region is electrically irrigated.

⁶ The relationship between use values and nonuse values is strongly influenced by such factors as the design of the study, the uniqueness of the resource in question, and the size of the relevant population used to calculate each value (see Appendix A, Section A.6).

TABLE 3.2 Irrigated Acreage in Six-State Region in 1987

State	Total Farm Acreage	Irrigated Acreage	Irrigated Acreage Pumped	Irrigated Acreage Electrically Powered
Arizona	865,817	859,654	465,613	388,748
Colorado	5,522,216	2,442,358	1,445,164	1,239,603
Nevada	526,067	524,067	229,064	206,565
New Mexico	989,214	606,344	481,100	271,231
Utah	1,076,886	829,732	294,992	231,816
Wyoming	1,717,027	1,132,266	228,039	186,829
Total	10,697,227	6,394,421	3,143,972	2,525,507

Source: Bajwa et al. (1992).

Table 3.3 illustrates the variation in crop production activity by state and irrigation method. For most states, irrigated crop production exceeds dryland production. The notable exception is wheat production in Colorado, which is predominantly dryland.

3.1.3 Electric Power Marketing Baseline

Utilities that could be affected the most by changes in Western's commitment-level alternatives and dam operations include Western's preference customers and the systems that are directly interconnected with those customers. These utilities range in size from small municipalities to large investor-owned utilities that have service territories spanning several states. In general, the larger utilities tend to own their electricity-generating resources and transmission capabilities. Smaller systems have very limited or no generating resources and rely principally on purchases to meet load. Many of these systems have formed associations.⁷

For purposes of this analysis, utilities were grouped by level of reliance on Western power and by ownership type. The level of reliance on Western power consists of high and low categories. A utility was defined as having "high" reliance on Western power if more than 25% of its total system load is met by Western sources. If 25% or less of a utility's load

⁷ For a detailed explanation of Western's electric power systems operation, see the hydropower section of Chapter 3 of the Glen Canyon Dam EIS (Reclamation 1993).

TABLE 3.3 Agriculture Output for Selected Crops in 1984

Crop	Farming Method	Output (1,000 tons)						Total
		Arizona	Colorado	Nevada	New Mexico	Utah	Wyoming	
Alfalfa	Dryland	0.0	254.3	0.0	150.2	153.1	213.0	770.6
	Irrigated	1,008.0	2,132.7	940.0	1,175.8	1,726.9	1,037.0	8,020.4
Barley	Dryland	0.0	8,604.9	0.0	0.0	339.2	2,388.6	11,332.7
	Irrigated	5,353.0	11,545.1	3,330.0	1,500.0	11,267.9	8,011.4	41,007.3
Corn	Dryland	222.1	0.0	0.0	446.8	0.0	776.7	1,445.5
	Irrigated	3,027.9	91,115.2	0.0	8,403.2	1,888.0	5,223.3	109,657.7
Cotton	Dryland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Irrigated	1,185.1	0.0	0.0	99.4	0.0	0.0	1,284.5
Sorghum	Dryland	0.0	9,718.7	0.0	11,201.5	0.0	0.0	20,920.2
	Irrigated	1,360.0	6,191.3	0.0	4,198.5	0.0	0.0	11,749.8
Oats	Dryland	0.0	635.4	0.0	0.0	0.0	789.4	1,424.7
	Irrigated	0.0	2,096.7	0.0	0.0	871.0	2,430.6	5,398.3
Wheat	Dryland	0.0	100,910.6	0.0	7,032.1	5,482.5	7,293.7	120,718.9
	Irrigated	12,780.0	14,109.4	1,840.0	4,927.9	2,572.5	778.3	37,008.1
Total	Dryland	222.1	120,123.9	0.0	18,830.5	5,974.8	11,461.4	156,612.6
	Irrigated	24,714.0	127,190.3	6,110.0	20,304.9	18,326.2	17,480.6	214,126.1

Sources: Schaible et al. (1989a,b).

is served by Western sources, it was categorized as having a "low" reliance level. Within each of the reliance categories, utilities were further disaggregated according to whether they are municipal or cooperatively owned.

Table 3.4 provides some detail on the categorization of the utility systems. The total load served by the low-reliance utility systems is slightly more than 2,650 MW. Municipals account for 680 MW of this total. Approximately 6% of their average energy is served by Western. Cooperatives serve the remaining 1,970 MW of load, with 12% of their energy served by Western. The high-reliance utilities serve approximately 750 MW of load. Municipals account for 541 MW, with 32% of their energy being provided by Western. Cooperatives account for the remaining 215 MW. Approximately 47% of their load is served by Western.

Average retail rates for each of the utility categories are presented by state in Table 3.5. The values presented represent estimates of the rates that are forecasted to exist under baseline conditions for the years 1993, 2000, and 2008. To facilitate comparison over time, all values have been indexed to 1994 prices. As the data indicate, rates charged by the low-reliance utilities are predicted to remain fairly stable over the forecast period. The major exceptions include Nevada, where rates are predicted to increase by approximately 53%, and Colorado, where rates are predicted to fall by approximately 23% over the forecast period. In the case of the high-reliance utilities, rates charged by municipals are predicted to increase somewhat, while the rates charged by the cooperatives are generally predicted to decrease.

TABLE 3.4 Power Marketing Utility Categories

Utility Category	Number of Utilities	Total Load (MW)	Average % Load Served by Western
Low reliance			
Municipals	22	680	6
Cooperatives	56	1,968	12
High reliance			
Municipals	54	541	47
Cooperatives	11	215	32
Total	143 ^a		

^a This total of 143 utilities is less than the 183 customers served by the SLCA/IP resource. The additional 39 customers are nonutilities such as Federal installations, state universities, irrigation districts, and others.

Source: Bodmer et al. (1994).

TABLE 3.5 Average Retail Rates by State and Utility Size — 1993, 2000, 2008 (1994 dollars)

Utility Category	Average Retail Rate (\$/MWh)			
	Low Reliance		High Reliance	
	Municipals	Cooperatives	Municipals	Cooperatives
Arizona				
1993	106	69	43	90
2000	107	63	53	81
2008	105	73	60	73
Colorado				
1993	56	86	54	NA ^a
2000	63	76	64	NA
2008	57	66	71	NA
New Mexico				
1993	75	73	91	90
2000	68	74	97	81
2008	65	74	99	73
Nevada				
1993	NA	72	NA	NA
2000	NA	94	NA	NA
2008	NA	110	NA	NA
Utah				
1993	75	72	73	64
2000	72	94	76	87
2008	67	110	73	102
Wyoming				
1993	65	69	NA	NA
2000	72	67	NA	NA
2008	66	63	NA	NA

^a Not applicable.

Source: Bodmer et al. (1994).

TABLE 3.6 Baseline Coverage Ratio (CR) by Reliance Level

Utility Category/ Coverage Ratio	Number of Utilities
Low Reliance	
CR < 1.1	5
$1.1 \leq \text{CR} < 2.0$	7
$\text{CR} \geq 2.0$	10
High Reliance	
CR < 1.1	3
$1.1 \leq \text{CR} < 2.0$	5
$\text{CR} \geq 2.0$	13
Total^a	43

^a The number of systems in this table differs from the number of systems shown on the rate impact table. For financial impact purposes, only independent financial entities were modeled. For example, Tri-State was modeled rather than its members because the principal financial impacts accrue to Tri-State as a generation and transmission cooperative.

Source: Bodmer et al. (1994).

As was discussed in Chapter 2, the coverage ratio is a commonly used indicator of the financial viability of a utility. Table 3.6 provides data on the number of firms with coverage ratios of varying magnitudes. In this case, the disaggregation has been limited to whether a utility has a low or high degree of reliance on Western. According to the data in Table 3.6, the majority of Western's customers currently have coverage ratios of less than 2.0. About a quarter of the utilities in each category have coverage ratios of less than 1.2.

3.2 AIR RESOURCES

3.2.1 Climate and Meteorology

The six-state study region includes Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. The climate of this region is characterized by low precipitation, low humidity light winds, and highly variable (but generally warm) temperatures. All of these parameters vary greatly with topography and latitude. Summer thunderstorms with heavy downpours and strong winds contribute most of the total annual precipitation in the northern part of the region. Winter storms are important contributors to annual precipitation in the southern

part of the region. A discussion of climate in the region is provided in Appendix B, Section B.1.1.

3.2.2 Air Quality

The six-state study region encompasses many major population centers, including Phoenix and Tucson, Arizona; Denver and Colorado Springs, Colorado; Albuquerque, New Mexico; Las Vegas, Nevada; and Salt Lake City, Utah. These population centers and some of their suburbs are designated as nonattainment areas with respect to one or more of the National Ambient Air Quality Standards (NAAQS) (40 CFR 50). A list of the NAAQS and State Ambient Air Quality Standards (SAAQS) for each of the six states in the study region is given in Appendix B, Table B.1; nonattainment areas within the six-state study region are listed in Table B.2, and their locations are shown in Figure B.2.

Nonattainment areas that are not associated with large population centers include (1) those for total suspended particulates (TSP) (Trona Industrial Park in Wyoming and the Grand Junction area in Colorado), where high levels of dusts are emitted from sources such as unpaved roads and road sanding in winter, and (2) those for sulfur dioxide (SO₂) and/or TSP, which involve a number of small cities in Arizona with large power-generating facilities or mining operations. (These cities are all located in the southernmost part of the state except for Joseph City, which is located in the northeastern quadrant of the state.)

The electric utility sector is a major contributor to the overall human-produced air pollutant emissions within the six-state study region. The location, name, capacity, and type of major electric power plants within the study region are shown in Figure B.1. Annual emissions from the region's utilities of SO₂ and nitrogen oxides (NO_x), the precursor pollutants for acid deposition and visibility impairment, represented approximately 49 and 56%, respectively, of the region's total human-produced emissions of these pollutants in 1990. However, the utility sector contributed only small amounts of TSP and volatile organic compounds (VOCs) (Appendix B, Table B.3). Annual emissions of carbon dioxide (CO₂), a greenhouse gas, from the electric utility sector accounted for a significant portion (36%) of the region's total human-produced emissions in 1990, but represented only a small fraction (2%) of the emissions of the United States as a whole (Appendix B, Table B.4).

Ambient air quality data from the monitoring stations located within the study region for 1987-1990 show that, except for scattered industrial sites and the major cities of the region, the air quality in the basin is quite good (Arizona Office of Air Quality 1988-1991; Colorado Air Pollution Control Division 1988-1991; Clark County Air Pollution Control Division 1991; Nevada Bureau of Air Quality 1989; State of New Mexico Air Quality Board 1990, 1991; Utah Bureau of Air Quality 1991; Wyoming Air Quality Division 1988-1991). During this period, nitrogen dioxide (NO₂) and lead (Pb) levels were substantially below the NAAQS throughout the region. Carbon monoxide (CO) levels remained fairly constant in the major cities of the region over the same period. Regionwide, ozone (O₃) concentrations slightly decreased, but SO₂ and PM concentrations slightly increased. Figures B.3 through B.9 in Appendix B show the location of all ambient air quality monitoring stations reporting

to the six states in 1989 and indicate which stations reported ambient concentrations in exceedance of the applicable standards for that year.

Visibility impairment is caused by light scattering and absorption by particles (primarily fine particles), and, to a lesser extent, NO₂ present in the lower atmosphere. The largest single factor controlling the seasonal and long-term variations in visibility in the Colorado River Basin is the concentration of fine, airborne sulfate aerosols (Malm 1989). The region's four largest sources of fine sulfates identified by the NPS for 1983-1985 were, in descending order, Southern California, Monterrey (Mexico), the coal-burning generating stations in the Four Corners⁸ region, and the copper smelters in southeastern Arizona and in New Mexico (Malm et al. 1990).

Regional visibility in the six-state study region is currently the best in the contiguous United States. The Four Corners region has a summer visibility of over 120 mi (Appendix B, Figure B.10). Except for Arizona, the remainder of the study region has summer visibility above 110 mi. In Arizona, the summer visibility decreases from 120 mi in the northeast corner to 60 mi in the southwest corner bordering California. Throughout the region, visibility varies greatly with the seasons. In winter, visibility is approximately 1.5 times better than in the summer. Long-term trends for the region indicate that, overall, visibility has decreased since the mid-1950s, with some recovery made during the 1970s and essentially no change in the 1980s (Malm 1989). The study region has a large number of Federal Class I areas for which the U.S. Environmental Protection Agency (EPA) has determined that visibility is an important value (Appendix B, Figure B.11).

3.2.3 Acoustic Environment

The principal noise sources at Western's major hydroelectric generating plants (Glen Canyon, Flaming Gorge, and Blue Mesa, Morrow Point, and Crystal of the Aspinall Unit) include turbine generators, step-up transformers, and substation transformers. Because turbine generators and step-up transformers are located near canyon bottoms and because the turbine generators are also enclosed inside concrete plant buildings,⁹ they contribute minimally to the environmental noise levels in areas beyond the canyon rims. Section B.1.3 contains a description of the acoustic environment in facility areas.

3.3 WATER RESOURCES

Important water resource parameters for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit include flow, stage (water elevation), sediment, temperature, and flood-plains. For each facility in this EIS, an affected environment was defined consistent with the

⁸ The point where the four states of Arizona, Colorado, New Mexico, and Utah meet.

⁹ In the case of Morrow Point, the turbine generator and step-up transformer are located inside the rock cavity near the bottom of the canyon.

anticipated impacts of the hydropower operational scenarios. The hydrological parameters of interest for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are discussed in Sections 3.3.1, 3.3.2, and 3.3.3, respectively. A brief description of the geology near each facility is provided for context.

3.3.1 Glen Canyon Dam

Glen Canyon Dam is part of the Colorado River Storage Project (CRSP) and serves the CRSP through storage and release of water from Lake Powell. Glen Canyon Dam is located on the Colorado River about 15.5 mi upstream of Lees Ferry, Arizona (Figure 3.2). The drainage area for the river is shown in Figure 3.3. An EIS being prepared for Glen Canyon Dam (Reclamation 1993) includes a description of an affected environment that extends from Lake Powell to Lake Mead. Lake Powell, however, was not included in the affected environment for this Power Marketing EIS because hydropower operational scenarios would not affect it.

The Colorado River in northern Arizona is located on the Colorado Plateau in an area of nearly horizontal sedimentary rocks that generally are more than 5,000 ft above mean sea level (MSL). The Colorado River and its tributaries have eroded large quantities of material from the plateau. This erosion, in conjunction with other natural weathering processes and geologic uplift, have carved the Grand Canyon, which is more than 1 mi deep and ranges in width from about 600 ft at river level to 18 mi on the rim. In cutting the Grand Canyon, the Colorado River has exposed rocks of all known eras of geologic time, recording a span of nearly two billion years.

The rocks in the Grand Canyon can be classified in three distinctive groups or sequences. The upper, youngest rock sequence is of Mesozoic age and is exposed around the northern and eastern margins of the canyon. These rocks were deposited between 60 and 230 million years ago during the Age of the Dinosaurs. The Mesozoic Era ended when disturbances began to raise both the Rocky Mountains and the Colorado Plateau. The second sequence of rocks in the Grand Canyon is of Paleozoic age and is exposed as horizontal sedimentary beds upstream of the mouth of the Little Colorado River and in canyon walls. These rocks were deposited between 230 and 600 million years ago. In this sequence, the harder sandstone and limestone layers form vertical cliffs, and the slopes between the cliffs are composed of softer shale beds. The oldest sequence of rocks in the Grand Canyon is of Precambrian age. It occurs as granite and schist that make up large portions of the Inner Gorge, middle Granite Gorge, and lower Granite Gorge. This sequence was deposited more than 600 million years ago, presumably as silt and fine sand.

3.3.1.1 Flow and Stage

Before Glen Canyon Dam was constructed, flow in the Colorado River below the dam was unregulated and variable (Figure 3.4); annual peak flows averaged 93,400 cubic feet per

FIGURE 3.2 Colorado River between Glen Canyon Dam and Lake Mead (Source: Reclamation 1993)

FIGURE 3.3 Drainage Basin for the Colorado River (Source: Carothers and Brown 1991; reprinted with permission of The University of Arizona Press)

FIGURE 3.4 Historical Daily Flows at Lees Ferry (Source: Reclamation 1990a)

second (cfs) between 1921 and 1962. The lowest recorded flow of 700 cfs occurred in December 1924 (Carothers and Brown 1991). The average annual minimum flow was about 4,000 cfs. The average yearly flow in the Colorado River at Lees Ferry for the period 1922 through 1990 was about 11.3 million acre-feet (maf). Although the range in river flows varied widely on an annual and seasonal basis, daily fluctuations (difference between maximum and minimum daily flow) and hourly changes in flow were small before dam operations, except during flood events.

Upon completion of the dam in 1963, flow in the Colorado River below the dam became regulated and ranged from about 1,000 to 60,200 cfs between 1963 and 1980 (Figure 3.4) when Lake Powell filled (Reclamation 1990a). After Lake Powell filled in 1980, excess water storage capacity was eliminated, and spring releases of greater than 31,500 cfs became more frequent. From June 1983 to July 1986, higher than normal peak flows occurred because of wet weather. A peak flow of 92,600 cfs occurred on June 29, 1983.

Water from the dam can be released in three ways: normal power plant releases (up to 31,500 cfs); bypass water releases through the river outlet works (15,000 cfs capacity); and spillway releases (208,000 cfs capacity) (Reclamation 1993). The combined release capacity is 256,000 cfs but is never expected to exceed 180,000 cfs. Although the maximum combined release capacity of the eight turbines at Glen Canyon Dam is about 33,200 cfs, past releases have been limited to 31,500 cfs (Reclamation 1993). Release schedules for dam operations vary greatly on an annual basis, but a minimum yearly release of 8.23 maf is targeted, and when releases are to be greater, a storage equalization must be maintained between Lake Powell and Lake Mead to satisfy long-range operating criteria.

Power demand and associated water releases are highest during the summer and winter months. For low-, moderate-, and high-release years, the monthly release for August corresponds to about 0.9, 1.3, and 1.7 maf, respectively (Reclamation 1993). Lowest monthly releases occur in the fall (October) and are about 0.6, 1.2, and 1.6 maf, respectively (Reclamation 1993). Maximum and minimum daily flows for selected low-, moderate-, and high-release years are plotted in Figure 3.5.

Hourly releases are set to achieve monthly release volumes, to maintain established release restrictions, and to complement the pattern of energy demand (Reclamation 1993). Historically, minimum releases were generally 1,000 cfs during the winter (Labor Day through Easter) and 3,000 cfs in summer. Dam releases for power have ranged from the minimum release to a maximum value of 31,500 cfs. In general, releases were maximized during peak energy demand periods — Monday through Saturday between 7 a.m. and 11 p.m. The ranges of daily fluctuations for Glen Canyon Dam releases during 1966-1989 for months having the greatest range in daily flow (July, December, October, and April) are shown in Figure 3.6 (Reclamation 1993). Hourly release patterns for a typical day with high, moderate, and low fluctuations are shown in Figure 3.7.

Between Glen Canyon Dam and Lake Mead, the Colorado River drops about 1,900 ft in a series of pools and rapids, from an elevation of 3,100 to 1,200 ft (Reclamation 1993).

FIGURE 3.5 Maximum and Minimum Daily Flows for Moderate-, Low-, and High-Release Years for the Glen Canyon Dam (Source: Reclamation 1993).

2 of 5

|

FIGURE 3.6 Maximum Daily Fluctuations for Glen Canyon Dam (Source: Adapted from Reclamation 1993)

FIGURE 3.7 Hourly Releases from Glen Canyon Dam for a Typical Day Having High, Moderate, and Low Fluctuations (Source: Adapted from Reclamation 1993)

More than 100 rapids account for most of this change in elevation. The average slope of the river (change in elevation per distance) is about 8 ft/mi (Reclamation 1993); in rapids, the slope may be 10 times steeper. In contrast, low-slope (0.5 ft/mi), low-velocity areas exist between rapids where water moves slowly across deep pools (Reclamation 1993). In both narrow and wide reaches, channel characteristics change in the vicinity of rapids that are formed at the mouths of steep tributaries. The channel is shallower, narrower, and steeper near the rapids than it is upstream or downstream. The channel bed in the vicinity of rapids is composed primarily of boulders.

The time for a 15,000-cfs discharge to travel from Lees Ferry to Lake Mead has been estimated at 104 hours (2.3 mph) (Reclamation 1993). Peak releases travel downstream as an identifiable wave. For fluctuating flows, wave peaks travel faster than wave troughs, eventually overrun them, and catch up with preceding wave peaks. This process causes a dampening of the amplitude of the release and an increase in the minimum flow (Reclamation 1993). Thus, farther downstream, fluctuations in flow and stage are less than at the dam.

3.3.1.2 Sediment

Sediment below Glen Canyon Dam includes suspended solids (sand and silt) in the Colorado River and its tributaries, as well as deposits on the river bottom and banks that include silt, sand, gravel, cobble, and boulders. For this EIS, the most important sediment is sand because the smaller silts move through the system to Lake Mead and are largely unaffected by dam operations whereas the larger sediments are only moved by large flood events. The most important section of the Colorado River in terms of hydropower impacts on sediment is found between the confluence of the Paria River and the Little Colorado River. Upstream of the Paria River, most fine riverbed and bank sediments have been removed by high-velocity water, although some large terraces of fine sediments still exist in this reach. Below the Little Colorado River, sediment and river flow are nearly in equilibrium, so there is no net erosion or aggradation of the riverbed and banks (Reclamation 1993).

Sediment deposits of concern and related physical processes are illustrated in Figures 3.8 and 3.9, respectively. Debris flows (moving rocks, sand, and clay containing less than 40% water by volume) move downstream in tributaries until the main channel of the Colorado River is reached. When the debris flows reach the main channel, they form a debris fan — a sloping mass of boulders, sand, silt, and clay formed at the mouth of a stream valley.

At the upstream edge of the debris fan (Figure 3.9), a sand deposit (separation bar) can be formed by current in the main channel. The projection of the debris fan into the main channel results in a zone of recirculating water, with well-defined eddy currents (currents of water moving against the main current in the river channel with a circular motion) just beyond the point of separation. Downstream of the recirculation zone, the current reattaches to the river bank at the reattachment point (Figure 3.9) and forms another sand deposit (reattachment bar). The region between the separation and reattachment points can be an

FIGURE 3.8 Separation, Reattachment, and Channel Margin Deposits (Bars) in the Colorado River below Glen Canyon Dam (Source: Adapted from Reclamation 1993)

FIGURE 3.9 Recirculation Zone below a Debris Fan in the Colorado River below Glen Canyon Dam (Source: Adapted from Reclamation 1993)

important backwater area for Colorado River fish. If the sand deposits associated with the debris fan are large enough for camping, they are referred to as beaches. The height of the sand above the river level is an important consideration for recreation and ecology. In addition to deposits associated with debris fans, deposits of sand (channel margin bars) (Figure 3.8) often continuously line the edge of the river in wide regions. These bars are deposited by currents in the main channel of the river and are associated with small, local eddies.

Since completion of Glen Canyon Dam in 1963, the average quantity of sand (load) passing the Bright Angel Creek confluence (Phantom Ranch) has decreased from 85.9 to 11 million tons per year (Reclamation 1993). This decrease in load occurred because the dam removes sediment from the water (Williams and Wolman 1984), thereby decreasing the amount of sediment available for transport.

Tributaries now supply most of the sediment to the Colorado River below Glen Canyon Dam. About 70% of the sediment load is delivered by the Paria and Little Colorado rivers, although this sediment contribution varies from year to year. For example, the total sand load in the Paria River at Lees Ferry was estimated to be 4.0 million tons in 1980 and 0.13 million tons in 1985 (Reclamation 1993). Debris flows in other, ungaged tributaries also contribute sand to the Colorado River downstream of Glen Canyon Dam (approximately 0.7 million tons per year). However, the quantity of sediment delivered by debris flows is highly variable in terms of magnitude and frequency.

Sediment may go through numerous cycles of temporary deposition, erosion, and transport while moving downstream. The bed of the river is composed of bedrock, boulders, cobbles, gravel, and sand. The location of these materials depends on the local river velocity, geology, and supply of incoming sediment. During periods of low flow, sediment is stored in pools and eddies. During high flows, some sand is transported downstream, whereas other sand is deposited on beaches and channel margin bars. In general, net erosion decreases downstream because of attenuation of the daily extremes in water levels and the addition of sand from tributaries.

The amount of sediment that water can transport is proportional to the flow in the river raised to the third or fourth power. Fluctuating flows transport more sediment than steady flows of the same volume because fluctuating flows are higher than steady flows during a portion of each day. Sand loads for historical steady and fluctuating releases having the same daily volume were calculated with a model developed for the Glen Canyon Dam EIS (Reclamation 1993). The results of the computations are listed in Table 3.7 for three U.S. Geological Survey (USGS) gaging stations on the Colorado River. For all three gages, fluctuating flows increased the sediment load by about 70% relative to steady flow conditions.

Following construction of the dam, beaches underwent a process of net erosion beginning in 1965 — especially between the dam and Lees Ferry, a reach with no major tributaries. These deposits later stabilized by the late 1970s. Between 1974 and 1982, some beaches lost up to three vertical feet, while others gained one to two vertical feet. Overall,

TABLE 3.7 Computed Colorado River Sand Loads for Steady and Fluctuating Flows

Release Pattern	Sand Load (tons/day)		
	Lees Ferry	Little Colorado River Confluence	Phantom Ranch
Steady flow (15,700 cfs)	200	1,500	3,100
Fluctuating flow (3,600 to 23,700 cfs)	340	2,500	5,100
Percent increase over steady flow	70	67	65

Source: Reclamation (1993).

slightly more sand was lost than gained, suggesting a slow and gradual depletion of sand from the beaches studied (Reclamation 1993). After the high flows of 1983 and 1984, beach deposits changed appreciably. Major deposition occurred on upper terraces, whereas lateral erosion cut the lower faces of the beaches. Between October 1985 and January 1986, high rates of bank erosion were observed during 3.5 months of fluctuating releases, especially during the return to lower fluctuations (Reclamation 1993). Since 1986, erosion rates have decreased and sandbars have stabilized at levels similar to those of the 1970s.

Dam operations also affect debris fans at tributary confluences. Flows within power plant capacity remove some of the smaller sediments deposited in the main stem of the river. However, very large flood flows are needed to remove large boulders from debris fans, to increase the width of the channel, and to decrease the elevation drop (Reclamation 1993). For example, the Bright Angel Creek debris flow of 1966 deposited a large quantity of material in Bright Angel Rapid (confluence of Bright Angel Creek and the Colorado River) that was not removed by flows in the range of normal operations. However, the flood releases of 1983 returned the rapid to pre-1966 conditions.

Like the sand deposits downstream of Glen Canyon Dam, the delta in Lake Mead is affected by dam operations, particularly the frequency, duration, and magnitude of fluctuating flows (Reclamation 1993). Higher levels and durations of fluctuations increase the sediment load delivered to Lake Mead and increase the height and extent of the delta, as well as its rate of growth.

3.3.1.3 Temperature

Seasonal water temperatures in the Colorado River varied from about 32° to 82°F for the period 1949-1962 prior to completion of the Glen Canyon Dam (Reclamation 1993).

Since the dam was completed, maximum water temperatures have decreased and minimum temperatures have increased (ranging from 43° to 54°F). For the months of May through October 1977-1983, river water temperatures at the USGS gaging station at Lees Ferry averaged about 46°F.

Water temperature in the river increases in a downstream direction, but the temperature profile has little variation (Reclamation 1993). Temperature variations over short distances are related to the location of the site and fluctuations in water levels. Shallow near-shore areas tend to be a few degrees warmer than deeper mid-channel sites. Lower temperatures are associated with high flows; higher temperatures are associated with low flows.

3.3.1.4 Floodplains

No floodplain maps exist for the area below Glen Canyon Dam. Such maps are generally produced for flood insurance purposes, which are unimportant for unpopulated regions. A 100-year flow was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded at the Lees Ferry USGS gaging station between 1963 and 1990. The 100-year flow predicted by this model for post-dam conditions is 91,400 cfs. The highest recorded flow for the post-dam period occurred on June 29, 1983 (92,600 cfs). Because the 100-year flow is very similar to the maximum recorded post-dam flow, for this EIS the 100-year floodplain was assumed to correspond to the high water level of the 1983 maximum flow.

3.3.2 Flaming Gorge Dam

Flaming Gorge Dam is part of the CRSP and is used for hydropower production. It is located on the Green River about 30 mi north of Vernal, Utah (Figure 3.10). The affected environment for this EIS extends from the dam to the USGS gaging station near Jensen, Utah (about 93 mi downstream of the dam). This reach was chosen to be consistent with the Flaming Gorge Biological Opinion (USFWS 1992b), which specifies that flows must achieve target values at the Jensen gage. Although Andrews (1986) reports a net aggradation in sediment downstream of the confluence of the Duchesne River (river mile 166), the affected environment has not been extended this far downstream because aggradation in this reach results from the presence of the dam, which reduces peak flows relative to pre-dam conditions, rather than hydropower operations.

The affected environment for Flaming Gorge Dam lies within the Uinta Basin. The Green River cuts into Jurassic and Triassic rocks. The uppermost rocks are Glen Canyon Sandstone; lower lying units consist of shales. Below the dam, the river flows through Red Canyon (see Figure 3.16 in Section 3.3.2.1), which is entirely cut into Precambrian rocks — except at Little Hole where a parklike opening is underlain by the Tertiary Browns Park Formation, a thick fill of gravel, sand, clay, and volcanic ash (Hansen 1975).

FIGURE 3.10 Green River Basin (Source: Adapted from USGS 1985)

In Browns Park, the Green River crosses the Uinta anticline above Swallow Canyon. Lodore Canyon, just downstream of Browns Park, is on the south limb of the anticlinal fold. Lodore Canyon is composed of Precambrian quartzite of the Uinta Mountain Group. Because of the dip in the surrounding strata, the river crosses successively younger rocks en route. At the mouth of the canyon, the river flows on Weber Sandstone, having crossed rocks of Precambrian, Cambrian, Mississippian, and Pennsylvanian age. Below Echo Park, the Mitten Park fault has raised the Precambrian rocks back again above the level of the river.

After meandering through Island Park and Rainbow Park below Lodore Canyon, the Green River flows through Split Mountain Canyon, an eroded anticline. Flowing swiftly over upturned beds, the river passes Jurassic rocks at Rainbow Park onto rocks of Mississippian age in the core of the Split Mountain anticline. On the south flank of this anticline, the Weber sandstone is eroded into an array of buttress-like forms. The river emerges at the mouth of the canyon, 118 mi below its point of entry at Flaming Gorge.

3.3.2.1 Flow and Stage

Before completion of Flaming Gorge Dam in 1963, flow in the Green River was unregulated and fluctuated seasonally on the basis of natural flow cycles; after the dam was completed, flows were restricted within a more narrow range, but a number of releases in excess of 7,000 cfs have occurred (Figure 3.11). The presence of the dam has changed the seasonal pattern of flow at Greendale. Historical spring flows that averaged about 7,000 cfs between 1951 and 1962 have been replaced with flows of about 3,000 cfs (Smith and Green 1991).

Water releases from the dam for power generation have ranged from 800 to 4,200 cfs, although a rewind of the system's generators allows water releases for power generation up to 4,950 cfs. The maximum power release is constrained by the size of the turbines, whereas the lower bound (800 cfs) is set by an agreement with the state of Utah to maintain a high-quality, coldwater fishery (Smith and Green 1991). An additional 4,000 cfs of water can be released through steel-lined jet tubes, and 28,800 cfs can be discharged over the spillway. Flows greater than 4,950 cfs are referred to as spills and produce no power in excess of the operating capacity.

Daily releases from the dam can vary from 800 to 4,950 cfs to meet power commitments. Figure 3.12 illustrates maximum and minimum daily water releases for moderate (1987), dry (1989), and wet (1983) water years. Maximum daily fluctuation exceedance curves for these years are shown in Figure 3.13. These three water years (October through the following September) were selected for this EIS because they are representative of different hydrological conditions. Less than ten years of hourly flow and release data were available for analysis. Water years 1983 and 1989 represented the wettest and driest years for which data were available and were deemed appropriate for the analysis because of the desire to represent extreme conditions.

FIGURE 3.11 Historical Flows at Greendale, Utah, 1951-1989 (Source: Based on data from Smith and Green 1991)

Flow-exceedance curves for historical water releases from Flaming Gorge Dam are shown in Figure 3.14 for water years 1983, 1987, and 1989. The lowest flow recorded is 800 cfs (Smith and Green 1991). For the selected dry year (1989), flow was maintained near 800 cfs for approximately 75% of the time and only exceeded 2,000 cfs approximately 10% of the time. For the selected wet year (1983), flow exceeded 4,000 cfs approximately 80% of the time and was in excess of 8,000 cfs approximately 30% of the time.

Daily fluctuations are greatest during a moderate water year (Figure 3.12). For a dry year, releases are nearly constant at a minimum value (approximately 900 cfs); whereas for a wet year, releases remain near the maximum value of the turbines to lower the level of water in the reservoir (approximately 4,500 cfs). For a moderate year, the largest fluctuations occur in the winter and spring (Figure 3.12) and range from about 900 to 4,400 cfs.

Hourly releases within one month are illustrated in Figure 3.15. Dam releases range from about 1,300 to 4,200 cfs, and the water-release pattern is spiked. Below the confluence with the Yampa River, the variations in flow are dampened, and the flow appears to be nearly sinusoidal. During high runoff years, high monthly release volumes correspond with maximum dam release capacity; little daily variation occurs. During low water years, releases are held to a minimum and fluctuations are reduced (Smith and Green 1991).

FIGURE 3.12 Maximum and Minimum Daily Water Releases for Power Generation at Flaming Gorge Dam for Moderate, Dry, and Wet Years

FIGURE 3.13 Maximum Daily Fluctuations at Flaming Gorge Dam for Moderate, Dry, and Wet Years

FIGURE 3.14 Flow-Exceedance Curves for Moderate, Dry, and Wet Years at Flaming Gorge Dam

FIGURE 3.15 Releases from Flaming Gorge Dam, February 1987

For 1987, flow in the Green River, as recorded at the Jensen gage, ranged from about 1,000 cfs in August to 11,000 cfs in early May. Flaming Gorge usually stores some spring runoff for release in other seasons. Thus, during the spring, most of the flow at the Jensen gage comes from the Yampa River (e.g., during April 1987, about 75% of the flow at Jensen was from the Yampa River). During the fall and winter, on the other hand, the majority of water at Jensen comes from releases at Flaming Gorge Dam (e.g., during February 1987, about 80% of the flow at Jensen was from the dam). In general, yearly flows near Jensen can be characterized as low during the summer, fall, and winter, with a large spring flow associated with high flows on the Yampa River.

For the first 7 mi below Flaming Gorge Dam, the Green River flows through Red Canyon (Figure 3.16), a hard-rock canyon with fast current and moderate rapids. Waters are clear because the dam removes suspended sediment (Williams and Wolman 1984). Bed material in this reach is composed mostly of coarse gravel, cobbles, and boulders (Andrews 1986). The river has a pool-and-riffle form and ranges in depth from about 3 ft in the riffles to 25 ft in the pools; the average slope of the river (change in elevation per distance) is about 8.5 ft/mi (Wheat 1989).

The river changes character abruptly about 2 mi below Red Creek as the canyon opens into Browns Park, about 11 mi downstream of the dam (Figure 3.16). The river meanders through Browns Park (about 36.5 mi), attaining widths of up to 500 ft. Under

FIGURE 3.16 Green River from Flaming Gorge Dam to Jensen, Utah

normal flow conditions, the current is slow and the river is fairly shallow, with depths of about 3 ft; the average slope is about 2.3 ft/mi. Numerous sandbars occur in the reach. The banks of the river are composed of Holocene alluvium (Stephens and Shoemaker 1987), and cutbanks line the channel in the vicinity of channel meanders and valley plain terraces. In Browns Park, the river increases in turbidity as sediment is transported downstream from the bed and banks.

At the Gates of Lodore, 48 mi downstream of the dam (Figure 3.16), the river enters Lodore Canyon in the Uinta Mountains and flows through 19 mi of hard-rock canyon in Dinosaur National Monument. The current is swift and numerous rapids are present; the average slope of the river is 12.7 ft/mi (Wheat 1989). Lodore Canyon ends in Echo Park where the Green River is joined by the Yampa River (about 65 mi downstream of the dam), its main tributary in the study area. At Echo Park, the combined flows of the Green and Yampa rivers enter into Whirlpool Canyon (Figure 3.16). As for Lodore Canyon, the average slope of the river through Whirlpool Canyon is about 12.7 ft/mi (Wheat 1989).

Below Whirlpool Canyon, the river meanders through open country in Island Park and Rainbow Park (Evans and Belknap 1973). Many wooded islands are present in this reach as the river flows through the Browns Park Formation of gravels, sand, and clay. Water turbidity is much greater than in Browns Park because of sediment eroded along the flow path and sediment introduced by the Yampa River. At Split Mountain Canyon, the current again quickens as the river flows back into a hard-rock region. The average slope is about 12.7 ft/mi (Wheat 1989). Below Split Mountain Campground, the river enters a cultivated valley and flows slowly for the next 100 mi.

The time for a water wave to travel from Flaming Gorge Dam to Jensen, Utah, is a function of the volume of water released. High flows (4,000 cfs) have a travel time of about 30 hours (3 mph), whereas low flows (1,000 cfs) have a travel time of about 36 hours (2.6 mph). Thus, high flows travel about 20% faster than low flows. Fluctuating flows would travel at an intermediate velocity between the high and low flows because of interference effects (high flows catch up with low flows and pass them). No measurements have been performed to determine the travel time of the released water; however, the travel time would be longer (in the case of the Colorado River, the travel time for released water is about 2.5 times longer than the travel time for the wave).

3.3.2.2 Sediment

Little fine sediment remains in the bed of the Green River between Flaming Gorge Dam and Red Creek near the beginning of Browns Park, and there are few upstream tributaries to contribute suspended sediment loads or debris flows to the main stem of the river. Beginning at Browns Park, the river erodes large quantities of sand from the extensive alluvial banks and bed. In Lodore Canyon, additional erosion occurs; however, because of the influx of sediment from Browns Park, the rate of erosion is lower. At the confluence of the Yampa River, an additional large quantity of sand (approximately 2 million tons annually) is delivered to the system (Elliott et al. 1984), further reducing downstream erosion. By the

time the river reaches Jensen, a near equilibrium condition has been established, with no net erosion or aggradation taking place; however, the annual sediment load has decreased by about 54% since construction of the dam (Andrews 1986).

To predict whether the river is likely to develop an equilibrium condition between average discharge and sediment load, two values can be calculated from hourly dam releases: the coefficient of variation and the index of variability (Gordon et al. 1992). Large values of these coefficients indicate that the river is likely to be out of equilibrium and will either erode or aggrade its bed and banks. The values of these coefficients calculated for historical hourly releases are small, indicating that the sediment load in the Green River should be close to equilibrium (Appendix C, Section C.1.3).

Because no gage data are available for flow and sediment at Browns Park, the Engelund-Hansen technique (Appendix C, Section C.1.4) was used to calculate total sediment loads for water years 1987, 1989, and 1983. The results of these calculations are shown in Figure 3.17. Sediment in Flaming Gorge Reservoir is not considered here because such sediment would not be affected by hydropower operations due to the large size of the reservoir — about 3.8 maf (USFWS 1992b). Downstream of Flaming Gorge Dam, the Green River combines with the Colorado River and eventually flows into Lake Powell. Hydropower operations at Flaming Gorge Dam would not measurably affect sediment deposits in Lake Powell because Lake Powell is more than 300 mi downstream of the dam and there are a large number of tributaries that supply sediment to the Green, Colorado, and San Juan rivers.

3.3.2.3 Temperature

Before construction of Flaming Gorge Dam, the mean water temperature at the town of Green River, Utah, ranged from about 32° to 72°C (January and July, respectively) during the period 1951 through 1962 (Smith and Green 1991). After completion of the dam, water temperature variations decreased in the vicinity of the dam.

In 1978, Reclamation modified the dam's penstocks (10-ft-diameter tubes that carry water from the reservoir to the turbines at the base of the dam) to permit selective withdrawal of warmer water from the reservoir. Steel intake extensions were fastened to the face of the dam, extending down to each of the three fixed-elevation penstock inlets. Shutter gates along the face of each extension could then be opened to withdraw water from selected elevations in the reservoir. For example, in the spring and fall, warmer water is released by withdrawing water from nearer the surface.

The water temperature measured in 1989 at the Greendale, Utah, USGS gaging station varied from about 39°F in winter to about 60°F in summer (Figure 3.18). At the USGS gaging station near Jensen (93 mi downstream from the dam), the winter water temperatures are about the same as at Greendale; however, the summer temperatures are about 14°F higher (Figure 3.18). This increase in temperature results primarily from warm

FIGURE 3.17 Cumulative Sediment Load as a Function of Flow at Browns Park for Moderate, Dry, and Wet Years

FIGURE 3.18 Green River Water Temperature at Greendale and Jensen, Utah, and in the Yampa River, 1989

water input from the Yampa River. No measurements are available to determine the rise in temperature between the dam and the confluence of the Yampa River (65 mi). However, because the slowest travel time for releases is about one day, effects of solar insolation are expected to be small and the change in temperature would be minor.

3.3.2.4 Floodplains

No floodplain maps exist for the area below Flaming Gorge Dam because of the low population density. A 100-year floodplain was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded at the Greendale USGS gaging station between 1963 and 1992. The 100-year water release predicted by this model for post-dam conditions is 12,200 cfs. Floodplains associated with the 100-year flood event therefore correspond very well with the high water levels of the maximum daily release for 1983 (Figure 3.14).

3.3.3 Aspinall Unit

The Aspinall Unit was developed as part of the CRSP to store water for multiple purposes and to generate hydroelectric power. Three dams and hydroelectric power plants along a 40-mi section of the Gunnison River in Colorado are included in the unit: Blue Mesa, Morrow Point, and Crystal. The dams and drainage basin for the Aspinall Unit are shown in Figures 3.19 and 3.20, respectively. For this EIS, the affected environment extends from the headwaters of Blue Mesa Reservoir to Crystal Dam and does not include areas below Crystal Dam because releases from the dam would not be controlled to produce hydropower.

Blue Mesa Dam, constructed in 1965, is located on the Gunnison River about 30 mi below Gunnison, Colorado. Blue Mesa Reservoir has a total capacity of 941,000 acre-feet and an active capacity of 748,000 acre-feet (Reclamation 1983). At maximum water surface elevation, (7,519 ft) the reservoir occupies 9,040 acres and has a depth of 342 ft (Van Buren and Burkhard 1981).

Morrow Point Dam is located 12 mi downstream of Blue Mesa Dam on the Gunnison River and was constructed in 1970. The capacity of Morrow Point Reservoir is 117,910 acre-feet at maximum water elevation (7,160 ft), and the active capacity is 42,120 acre-feet (Reclamation 1983). The surface area for Morrow Point Reservoir is 817 acres at an elevation of 7,160 ft and a depth of over 400 ft (Van Buren and Burkhard 1981).

Crystal Dam, constructed in 1976, is located 6 mi downstream of Morrow Point Dam on the Gunnison River. Crystal Dam Reservoir has a total capacity of 25,236 acre-feet with an active capacity of 12,891 acre-feet at an elevation of 6,755 ft (Reclamation 1983). At that elevation, the reservoir has a surface area of 301 acres. The capacity of Crystal Reservoir is small, and the dam is operated by Reclamation for flow reregulation (smoothing downstream

FIGURE 3.19 Location of Dams in the Aspinall Unit

FIGURE 3.20 Drainage Area for the Aspinall Unit

fluctuations) rather than storage. Crystal Reservoir release is generally dictated by the release from Morrow Point Reservoir. Conversely, Crystal Reservoir releases could require corresponding releases from Morrow Point Reservoir. The Gunnison Tunnel is located just downstream of Crystal Dam; it diverts part of the river water for irrigation, usually from March through October. The flow diverted was about 300,000 acre-feet in 1983, 390,000 acre-feet in 1987, and 430,000 acre-feet in 1989 (Lehman 1992). These diverted flows represent about 23% of the river flow during the diversion months for 1983, about 40% for 1987, and 70% for 1989. The remaining water enters the Black Canyon of the Gunnison (Figure 3.20).

The affected environment lies in the transition zone between two physiographic provinces: the Southern Rocky Mountains on the east and the Colorado Plateau on the west. Because no well-defined boundary exists between the two provinces, the affected environment has properties of both (Hansen 1987).

In the area of Blue Mesa and Morrow Point reservoirs, remnants of a broad volcanic cover overlie a crystalline basement. Proterozoic rocks on the shore of Blue Mesa Reservoir at Lake Fork and Cebolla Creek were formed between 570 and 1,600 million years ago. The major physiographic feature of the area is a nearly continuous palisade of resistant volcanic rock 2,000 ft or more above the canyon floor, which gradually climbs higher to the west. Of the many kinds of igneous rocks outcropping from the canyon walls, the most common can be classified as proterozoic granite — i.e., granodiorite, quartz monzonite, and pegmatite (Hansen 1987).

In the area of Crystal Dam, the rims and walls of the canyon are hard crystalline rock. The overlying sedimentary rocks are stripped back because they are less resistant to erosion. They form a subdued outer rim on the north side of the canyon, but this rim is largely removed to the south (Hansen 1987).

During the early and middle Paleozoic (290 to 570 million years ago), a moderately thick blanket of strata (Uncompahgre Highland) accumulated in the area. Beginning in the Pennsylvanian age (300 million years ago), a sharp mountainous uplift halted the deposition and started a long period of erosion that removed the strata. Because of extensive erosion, almost none of this original cover remains (Hansen 1987).

3.3.3.1 Flow and Stage

Before construction of the Aspinall Unit in 1965, flow in the Gunnison River varied greatly, with peak annual discharges of about 12,000 cfs. At times, flow exceeded 19,000 cfs (Hansen 1987). Damming and regulation of the river since the early 1960s have leveled out the flow of water through the area by eliminating former peak flows and adding supplemental flows during low water.

Flows out of Blue Mesa and Morrow Point dams vary seasonally and hourly. Highest flows normally occur in the spring and lowest flows in the summer. In addition to seasonal

variations, dam releases are varied on an hourly basis to produce peaking power. Daily release fluctuations are illustrated in Figures 3.21 and 3.22 for Blue Mesa Dam and Morrow Point Dam, respectively, for moderate (1987), dry (1989), and wet (1983) water years. Flows below Crystal Dam vary much less than releases from either Blue Mesa or Morrow Point dams because the Crystal facility is used to reregulate flows (Figure 3.23). For Crystal Dam, the lowest flows (500 cfs) occur in fall and the highest flows (2,500 cfs) in spring. Water releases from Crystal Dam are nearly constant on a daily basis. Maximum daily fluctuation exceedance curves for the three dams are shown in Figure 3.24. Daily fluctuations for both Blue Mesa and Morrow Point dams are pronounced, regardless of the wetness of the year.

3.3.3.2 Sediment

No beaches are present in the Aspinall Unit, and there are no associated debris flows in the affected area. Water released from one reservoir flows into the headwater of the next over well-armored reaches. Thus, sediment is not an important resource for the Aspinall Unit.

3.3.3.3 Temperature

No temperature data are available for the Gunnison River prior to construction of the Aspinall Unit. However, it was assumed that temperatures were similar to those in the Green River (about 32° to 72°F) because of the similarities in climate and local topography. With completion of the dams, variations in water temperature would have been reduced because of the action of the upstream reservoirs. Temperature profiles were obtained for Blue Mesa Reservoir from July through October 1980 for six locations and various depths (Van Buren and Burkhard 1981). Surface temperatures averaged about 66°F in July. At 100 ft below the surface, the water temperature averaged 52°F. The highest temperatures occurred in summer and then decreased in fall. At Morrow Point Reservoir, three temperature profiles were developed (Van Buren and Burkhard 1981). The highest surface temperatures occurred in July (63°F), whereas the temperature at 100 ft below the surface was lowest (45°F). Temperatures at Morrow Point Reservoir are less than those at Blue Mesa Reservoir because releases from Blue Mesa Dam occur at a depth of 171 ft below the surface where the water temperature is about 18°F cooler than at the surface. Although no temperature measurements are available for water in the Crystal Dam Reservoir or for the water released from the dam, the temperatures should be nearly the same as those for Morrow Point Reservoir.

3.3.3.4 Floodplains

No floodplain maps are available for the Aspinall Unit. A 100-year flow was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded in the Gunnison River just below the diversion tunnel

FIGURE 3.21 Maximum and Minimum Daily Releases at Blue Mesa Dam for Moderate, Dry, and Wet Years

FIGURE 3.22 Maximum and Minimum Daily Releases at Morrow Point Dam for Moderate, Dry, and Wet Years

FIGURE 3.23 Maximum and Minimum Daily Releases at Crystal Dam for Moderate, Dry, and Wet Years

FIGURE 3.24 Maximum Daily Release Fluctuations at Blue Mesa, Morrow Point, and Crystal Dams for Moderate, Dry, and Wet Years

between 1963 and 1990. The 100-year water release predicted for post-dam conditions is 14,400 cfs. This value was exceeded before dam completion (19,000 cfs) but has not been equaled for the period of record used in the calculation; a maximum flow of 10,600 cfs occurred on June 26, 1983.

3.4 ECOLOGICAL RESOURCES

This section describes the aquatic and terrestrial biotic resources in the vicinity of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Crystal, Morrow Point, and Blue Mesa dams). Topics include fish, aquatic habitats, aquatic food base, vegetation, wildlife, and threatened and endangered species. The scientific names and habitats of species mentioned in the text are listed in Appendix D, Section D.1.

3.4.1 Glen Canyon Dam

This section describes the ecological resources in and along the Colorado River between Glen Canyon Dam and Lake Mead. Resources in Lake Powell above Glen Canyon Dam are not discussed because they would not be affected by hydropower operations.

3.4.1.1 Aquatic Ecology

The construction of Glen Canyon Dam caused dramatic changes in the aquatic ecosystem of the Colorado River below the dam. Before the dam was constructed, productivity of the aquatic food base was very low, primarily because of high turbidity, low levels of light penetration, and large amounts of sand and silt constantly shifting along the river bottom. The filamentous green alga called cladophora (*Cladophora glomerata*) (Section 3.4.1.1.3), which is now present in large beds throughout the river between the dam and Lees Ferry, had a limited distribution in the river before the dam was constructed. Similarly, the small crustacean called gammarus (*Gammarus lacustris*) (Section 3.4.1.1.3) was uncommon and limited in its distribution.

Before construction of the dam, the fish fauna of the river consisted of native and introduced warmwater species, such as the Colorado squawfish, razorback sucker, humpback chub, bonytail chub, carp, and channel catfish. Water temperatures in the main channel varied seasonally from just above freezing up to 85°F (Carothers and Brown 1991), and coldwater species such as trout were confined primarily to a few tributaries. By the time the dam was completed, two introduced species, the carp and channel catfish, were the most common fish in the river. These species may have been important contributors to the decline of several native species (Minckley 1991).

After the dam was finished, the nature of the river changed. Water clarity and light penetration greatly increased, and under daily fluctuations in dam releases, cladophora abundance and distribution increased so dramatically that this species is now considered the foundation for the aquatic food base below the dam. Gammarus underwent a similar increase

in abundance and distribution, and is now considered a major food item for a variety of fish, including trout. Water temperatures also changed as a consequence of the dam, becoming very stable and cold. Water releases from the dam average about 46°F, while the average river temperature below the dam is about 55°F (Reclamation 1993). River temperatures increase slowly downstream of the dam to no more than about 60°F (Minckley 1991). As a consequence, reproduction by the native and introduced warmwater species virtually ceased in the main channel, and a world-class coldwater trout fishery was established between the dam and Lees Ferry.

3.4.1.1.1 Fish

Thirty-two species of fish (Appendix D, Table D.1) have been reported from the lower Colorado River between Glen Canyon Dam and Lake Mead (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991). These fish include introduced trout, other introduced species, and native species.

Trout

Trout have been stocked in the Grand Canyon since the early 1920s (Carothers and Brown 1991). Currently, rainbow trout, brook trout, and brown trout occur in the Colorado River below Glen Canyon Dam. The rainbow trout is now the most valued recreational fish in the system and since the late 1970s has replaced the carp as the most abundant fish between Glen Canyon Dam and Lake Mead. Brown and brook trout are also present but are much less abundant than the rainbow trout. Brook trout are most common between Glen Canyon Dam and Lees Ferry and decline in abundance downstream. Brown trout are most abundant in the middle reaches of the river from the Little Colorado River to National Canyon (about 182 mi below the dam), and in some locations (such as near the mouth of Bright Angel Creek) the brown trout may be the dominant fish species (Maddux et al. 1987).

Stocking below Glen Canyon Dam was estimated to account for about 73% of the rainbow trout population in 1985 (Maddux et al. 1987). Preliminary information from more recent trout surveys (1989-1993) indicates that about 78% of the current trout population now results from natural reproduction (Arizona Game and Fish Department 1993). Rainbow trout spawn in the main channel of the Colorado River and its tributaries from November through April, primarily on gravel and cobble bars in shallow water, and most commonly above Lees Ferry (Section 3.4.1.1.2). Rainbow trout also successfully reproduce in many of the major tributaries below Lees Ferry, particularly Nankoweap, Clear, Bright Angel, Tapeats, and Deer creeks (Carothers and Brown 1991). The brown trout, which is typically a fall-spawning species throughout its range, reproduces in winter and spring, primarily in tributaries, while little or no natural reproduction by the brook trout occurs (Maddux et al. 1987). The diets of adult rainbow trout in the Colorado River below Glen Canyon Dam consist primarily of cladophora, aquatic insect larvae, and gammarus (Section 3.4.1.1.3). Early life stages of trout

feed primarily on chironomid (midge fly) larvae, zooplankton (microscopic crustaceans that live in the water column), and freshwater worms called oligochaetes (Maddux et al. 1987).

Other Introduced and Native Fish

Introduced fish other than trout have been present in the Lower Colorado River Basin since the late 1800s (Minckley 1991). The present community of introduced fish below Glen Canyon Dam consists of 23 species (Appendix D, Table D.1), and the most common species other than trout are channel catfish, carp, and fathead minnow (Reclamation 1993). These species are most abundant in the middle and lower reaches of the river downstream from the dam, and spawning occurs primarily in the warmer waters of tributaries. Carp comprised 70-80% of all fish collected from 1970 to 1978 (Carothers and Brown 1991). Since then, the abundance of this species has declined dramatically for unknown reasons.

Only five native fish species now occur in the Colorado River between Glen Canyon Dam and Lake Mead — humpback chub, razorback sucker, flannelmouth sucker, bluehead sucker, and speckled dace. Healthy reproducing populations of flannelmouth sucker, bluehead sucker, and speckled dace are present in the Colorado River and its tributaries below Glen Canyon Dam (Maddux et al. 1987; Minckley 1991). The latter two species are most common in the lower reaches of the river and generally are absent from the tailwaters. Highest densities of the speckled dace occur in clear, high-gradient tributaries such as Shinumo and Bright Angel creeks (Carothers and Brown 1991). The flannelmouth sucker is rare or absent in the Colorado River above Nankoweap Creek but is common in the lower reaches of the river (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991), and large numbers of this species enter the Paria River in spring during spawning.

Reproduction by bluehead and flannelmouth suckers and the speckled dace occurs primarily in the warm tributaries; cold water temperatures preclude successful reproduction in the Colorado River. Reproduction in the river by the bluehead sucker may be limited to the lowest reaches (from 180 to 240 mi below the dam) (Maddux et al. 1987), where water temperatures are warmer (55-64°F). Backwater areas between the Little Colorado River and Diamond Creek (about 240 mi below the dam) are thought to provide important nursery habitats for these species (Maddux et al. 1987).

The razorback sucker is very rare in the Grand Canyon portion of the Colorado River (Section 3.4.1.3.1). Only 14 specimens have been collected since 1978 (Minckley et al. 1991), and this species was placed on the Federal list of endangered species in 1991. A large population of humpback chub, which is also Federally listed as endangered, occurs in the Colorado River below the dam, centered on the Little Colorado River. The status of the razorback sucker and humpback chub in the river below the dam is discussed in more detail in Section 3.4.1.3.1.

3.4.1.1.2 Aquatic Habitats

Several habitats that are important to fish and that can be affected by hydropower operations have been identified in the Colorado River below the Glen Canyon Dam. These habitats include (1) trout spawning areas in the dam tailwaters, (2) tributaries used by trout and native fish for spawning, (3) backwaters and other quiet water areas along the Colorado River that serve as nursery habitats for native and endangered fish, and (4) the mouth of the Little Colorado River, which serves as a staging and nursery area for the Federally endangered humpback chub and other native fish.

Spawning trout construct nests (called redds) on bars of sediment that occur throughout the Glen Canyon Dam tailwaters. In the past, fluctuating releases, as well as low flows, from the dam have been reported to strand adult trout on these bars and to dewater trout redds, causing complete or near-complete spawning failure in affected areas (Maddux et al. 1987).

Tributaries provide spawning areas for a variety of fish, including rainbow trout, speckled dace, carp, fathead minnow, and bluehead and flannelmouth suckers (Maddux et al. 1987). Species such as brown trout, speckled dace, and the suckers use tributary mouths as staging areas during spawning migrations from the main channel into tributaries. Fluctuating flows or low flows may hinder access of spawning fish into some tributaries by decreasing water depths at the tributary mouths (Maddux et al. 1987).

Backwaters and other quiet water areas are important to many warmwater species (Maddux et al. 1987; Carothers and Brown 1991). In summer and autumn, backwater and tributary mouth habitats are typically warmer and have lower current velocities than the main channel. These warmer and calmer areas provide shelter for larval and young-of-the-year fish from cold temperatures and fast currents and thus provide better conditions for growth and survival than does the main river channel. Backwaters (including eddies) also provide important refuges for adult fish from high currents in the main channel. The amount of backwater habitat is affected by fluctuating flows and stage.

The mouth of the Little Colorado River is a major staging area for the Federally listed endangered humpback chub (Section 3.4.1.3.1) and other fish preparing to enter the Little Colorado River to spawn. This area may also serve as a nursery for larval fish leaving the Little Colorado River (Maddux et al. 1987). The mixing zone at the mouth of the Little Colorado River appears to be an important transition zone for larval humpback chub leaving the warm waters of the Little Colorado River and entering the colder Colorado River.

3.4.1.1.3 Aquatic Food Base

The base of the aquatic food chain in the Colorado River between Glen Canyon Dam and Lake Mead is dominated by the filamentous green alga cladophora, which attaches to hard substrates such as cobble and boulders; yellow-green algae called diatoms, which live on the cladophora; the small crustacean gammarus; and the larvae of midge flies, which are

called chironomids (Maddux et al. 1987; Carothers and Brown 1991). Cladophora serves as important substrate for a variety of aquatic invertebrates and diatoms, which in turn are important food items for aquatic invertebrates and fish.

Cladophora is the dominant alga in the upper reaches of the river below the dam. It is particularly abundant above the Paria River and at the mouths of tributaries, where it exists in dense beds in areas with hard substrates. The abundance of cladophora decreases downstream of the Paria River, and a blue-green alga called oscillatoria (*Oscillatoria* sp.) becomes dominant in the lower reaches of the river (Blinn and Cole 1991). Cladophora is also present in the system as part of the sestonic drift (organic material that occurs unattached in the river and is transported downstream by the current), particularly during high flows. Although trout consume drifting cladophora fragments (Reclamation 1988), it is not clear if the fragments are ingested directly as nourishment or if the intake of algae is incidental as the trout feed on other items that inhabit the algae, such as aquatic insects and gammarus.

Most of the algae attached to or living on cladophora, rocks, and other hard surfaces in the river are diatoms, which are used as food by gammarus, fish, and a variety of macroinvertebrates. The diversity of diatoms decreases downstream from the dam (Usher et al. 1987).

Common macroinvertebrates in the river are chironomids, gammarus, snails, freshwater worms called oligochaetes, and blackfly larvae. Gammarus is one of the most important food items for fish below the dam. The abundance of gammarus and other macroinvertebrates in the river decreases downstream from the dam (Leibfried and Blinn 1987). In general, macroinvertebrates are most abundant in the river above the confluence of the Little Colorado River (Leibfried and Blinn 1987).

The zooplankton community below Glen Canyon Dam is not diverse and is derived primarily from the zooplankton community present in Lake Powell (Haury 1986; Maddux et al. 1987; Blinn and Cole 1991). The density of zooplankton in the main channel is relatively constant from the dam to Lake Mead. However, in backwater areas and tributary mouths, the density is greater (Blinn and Cole 1991) and may be influenced by daily changes in flow and stage that result from hydropower operations. In backwaters and tributary mouths, the zooplankton serve as an important food for the larvae of a variety of native and introduced fish (Maddux et al. 1987).

3.4.1.2 Terrestrial Ecology

This section describes the vegetation and wildlife in riparian areas along the Colorado River below Glen Canyon Dam. Species and habitats in adjacent upland areas are not discussed in detail because they are neither dependent on nor directly affected by river flow.

3.4.1.2.1 Vegetation

Between Glen Canyon Dam and Lake Mead, the Colorado River crosses three ecoregions — the Colorado Plateaus, Arizona/New Mexico Plateau, and Southern Basin and Range ecoregions (Omernik and Gallant 1987a). The Colorado Plateaus and the Arizona/New Mexico Plateau ecoregions are tablelands with high relief and are vegetated with desert shrubs and grasses. The physiography of the Southern Basin and Range ecoregion is plains with low mountains and supports desert shrubs and cactus.

The riparian habitat between the dam and Lake Mead is the largest protected riparian corridor in the western United States (Anderson and Ruffner 1987). Figure 3.25 depicts the riparian habitat found along the river. Although riparian habitat is considered wetland under the USFWS wetlands classification system (Cowardin et al. 1979), only isolated patches would qualify as jurisdictional wetlands under the U.S. Army Corps of Engineers definition (COE 1987).

Before Glen Canyon Dam was completed in 1963, two zones of riparian vegetation occurred along the Colorado River (Anderson and Ruffner 1987; Reclamation 1988). Closest to the river, in the area exposed to annual scouring floods, ephemeral herbaceous and short-lived woody species became established between floods. Above this elevation (about the 90,000-cfs level), the plant community consisted of long-lived shrubs and trees that depended on occasional elevated flows for growth and reproduction (Anderson and Ruffner 1987;

FIGURE 3.25 Generalized Representation of Riparian Vegetation Zones and Their Relationship to Flow Levels (Widths of vegetation zones are represented by lines shown below name of vegetation type; actual locations and widths of vegetation zones vary and depend on site-specific soil and moisture conditions.)

Reclamation 1988). This *old high-water-zone* community was dominated by western honey mesquite, catclaw acacia, apache plume, redbud, and netleaf hackberry (Anderson and Ruffner 1987).

Riparian vegetation in the old high-water zone has remained relatively stable since the completion of Glen Canyon Dam (Pucherelli 1986), although the growth of mature trees in this zone has slowed (Anderson and Ruffner 1987). An estimated 1,870 acres of old high-water-zone vegetation exists between the dam and Lake Mead (Reclamation 1993). Reproduction of old-high-water zone species occurs in both the old high-water zone and below, but the greater survivorship of seedlings closer to the river suggests an eventual shift of the community closer to the river's edge (Anderson and Ruffner 1987).

Following construction of Glen Canyon Dam, riparian vegetation became established closer to the river. This new community, termed the *new high-water zone*, consists of long-lived plant species that grow in the old ephemeral zone at and above the elevation of maximum operating releases (31,500-cfs; Carothers and Brown 1991). Long-lived species became established at these lower elevations because of the elimination of large annual floods. The new high-water zone is dominated by a mix of native and nonnative species, including tamarisk, desert broom, willows, and arrowweed (Pucherelli 1986). Vegetation in this zone occupies about 1,320 acres between the dam and Lake Mead (Reclamation 1993).

In 1983, flows in excess of 90,000 cfs occurred below the dam (Reclamation 1990a; Stanford and Ward 1991). This flood and others in the subsequent wet years of 1984 to 1986 significantly reduced (by about 49%) plant cover in the new high-water zone that was inundated by floodwaters (Pucherelli 1986; Stevens and Waring 1986; Brian 1987). The absence of floods since 1986 has allowed vegetation to begin recovery in the new high-water zone.

Below the new high-water zone is the area affected by fluctuating flows from the dam. This zone is comparable to the old flood zone in that periodic inundations prevent colonization by many long-lived plant species. However, within the fluctuation zone, marsh vegetation has colonized some protected beaches, backwater areas, and tributary mouths where fine sediments have accumulated (Carothers and Brown 1991). Common marsh species include sedges, bulrush, rushes, cattail, scouring rush, and common reed.

After Glen Canyon Dam was completed in 1963, the number of marshes along the river increased — from about 10 in 1965 to 65 in 1976 (Stevens and Ayers 1993). Although 95% of these marshes were eliminated during the floods of 1983-1986 (Carothers and Brown 1991), a rapid reestablishment of marsh vegetation has occurred since then, and currently about 1,100 patches (totaling 62 acres) of marsh vegetation occur along the river (Reclamation 1993).

Since institution of interim flows that feature reduced fluctuations (8,000 to 20,000 cfs) in August 1991, the number of small marshes present has increased, especially in backwater areas at the 20,000-cfs level (Wegner 1992). Above that level, marshes appear to be in a drying trend because of the reduction in maximum releases under interim flows.

3.4.1.2.2 Wildlife

Numerous species of nongame wildlife use the riparian habitats below Glen Canyon Dam. In general, these species have responded favorably to changes to the river that have occurred since construction of the dam, and both population size and species diversity is greater now than before the dam was built (Brown 1988; Carothers and Brown 1991). Populations of most species have increased in response to increases in riparian vegetation. These species include many of the birds and small mammals present within the river corridor, including black-chinned hummingbird, common yellowthroat, Bell's vireo, yellow-breasted chat, pinyon mouse, and brush mouse. Other species appear to have responded to increases in insect populations rather than directly to changes in vegetation. Such species include most of the amphibians and reptiles (e.g., red-spotted toad, side-blotched lizard) and some birds (e.g., white-throated swift, violet-green swallow).

Few ducks and geese use the Colorado River below the dam. Most species occur only during migration in the spring and fall (Brown et al. 1984) and concentrate on the river in Marble Canyon (about 20 mi below dam) (Brown et al. 1987). Species occurring during migration include common merganser, green-winged teal, common goldeneye, and bufflehead. Canada goose, ruddy duck, and bufflehead are uncommon winter residents. A few species of ducks and geese breed along the river, but do so rarely; species known to breed there include mallard, green-winged teal, and American coot (Brown et al. 1987).

Shorebirds and herons using shoreline habitats (especially the fluctuation zone) along the river include spotted sandpiper, great blue heron, black-crowned night heron, and snowy egret. Most of these species (except the spotted sandpiper) are present year-round. The spotted sandpiper and killdeer breed along the river and nest on the ground above the high-water line.

Mule deer and bighorn sheep are the only game mammals that occur in riparian habitats below the dam (Carothers and Brown 1991). Both species are relatively common in the area, and no information indicates their populations have been affected by the dam. Mule deer are more prevalent along the forested canyon rim but do move down into the canyon during winter. Bighorn sheep frequent the steep side canyons above the riparian zone and occasionally come to the river to drink and forage, especially during the hotter summer months.

3.4.1.3 Threatened and Endangered Species

This section presents the current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species in and along the Colorado River below Glen Canyon Dam. Definitions of listing categories maintained by the Federal Government and the state of Arizona are presented in Appendix D, Section D.4. correspondence with the USFWS regarding threatened and endangered species in the area is reproduced in Section D.4.5 of Appendix D.

3.4.1.3.1 Aquatic Species

Four Federally listed endangered aquatic species and one candidate for Federal listing occur or have occurred in the Colorado River below Glen Canyon Dam: humpback chub, bonytail chub, razorback sucker, Colorado squawfish, and flannelmouth sucker (Table 3.8). The occurrence and status of the Federally listed endangered species below the Glen Canyon Dam are discussed in the remainder of this section.

Humpback Chub (Endangered)

The total population of the endangered humpback chub in the Grand Canyon below Glen Canyon Dam has been estimated at 7,000 to 10,000 adult fish (Minckley 1991). This population, which includes fish in the Colorado and Little Colorado rivers, is the largest self-sustaining population of humpback chubs remaining anywhere in the Colorado River Basin and is the only known reproducing population in the Lower Colorado River Basin. The humpback chub does not occur between the dam and the Paria River, is most abundant around the confluence of the Little Colorado River between 72 and 80 mi downstream of the dam, and has been collected as far as 220 mi downstream of the dam (Maddux et al. 1987; Reclamation 1993). Recently, young humpback chub have been collected in the Colorado River about 180 mi below the dam (Arizona Game and Fish Department 1993). These chub may be the offspring of a second, previously undocumented, population of adult chub or may be individuals originating from the Little Colorado River that have been carried downstream by floods.

The USFWS has proposed designating approximately 379 mi of river in the Upper and Lower Colorado River basins as critical habitat for the humpback chub (USFWS 1993a). The proposed designation includes the lower 8 mi of the Little Colorado River and about 174 mi of the Colorado River between 34 and 208 mi below Glen Canyon Dam.

Within the Colorado River, adult and juvenile humpback chubs are most often associated with eddies and boulder-sand substrates (Maddux et al. 1987; USFWS 1990c; Reclamation 1993), while young-of-the-year fish are most abundant in backwaters and other nearshore areas (such as talus shorelines) with a variety of substrates (Maddux et al. 1987; Reclamation 1993). The number and survival of young humpback chub in backwaters in the Colorado River may be affected by fluctuating flows associated with dam operations (Maddux et al. 1987; Reclamation 1993). Fluctuating flows drain and fill backwaters on a daily basis, and thereby reduce the quality of these habitats for young humpback chub. Fluctuating flows may also flush young fish from the relatively sheltered environment of backwaters into the main channel of the river, where the young are exposed to colder water temperatures and higher currents. It is not known if young-of-the-year humpback chub in the Colorado River are important in maintaining an adult population in the river, or if the main channel population is maintained primarily by recruitment from the Little Colorado River.

In the Little Colorado River, spawning occurs from spring (March) through mid-summer (July) (Kaeding and Zimmerman 1983; Maddux et al. 1987; USFWS 1990c), following the peak of spring runoff and at water temperatures between 61° and 68°F (USFWS 1990c).

TABLE 3.8 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Glen Canyon Dam^a

Common Name	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Humpback chub	<i>Gila cypha</i>	E	AZ-E	Large population in the Little Colorado River and the immediate upstream and downstream portions of the Colorado River (Maddux et al. 1987; USFWS 1990c; Minckley 1991). This is the only known population of humpback chub left in the Lower Colorado River Basin and the largest known population in existence.
Bonytail chub	<i>Gila elegans</i>	E	AZ-E	Historically occurred in the Grand Canyon, now extirpated from riverine habitats in the Lower Colorado River Basin (USFWS 1990d).
Colorado squawfish	<i>Ptychocheilus lucius</i>	E	AZ-E	Historically occurred in the Grand Canyon, now extirpated from the Lower Colorado River Basin (Minckley 1991; USFWS 1991c).
Razorback sucker	<i>Xyrauchen texanus</i>	E	AZ-E	Very rare between Glen Canyon Dam and Lake Mead; fewer than 20 specimens collected since 1978 (Bestgen 1990; Carothers and Brown 1991; Minckley 1991). No recruitment to the adult population in this reach is known to occur (Minckley 1991).
Flannelmouth sucker	<i>Catostomus latipinnis</i>	C2	AZ-NL	Rare or absent in the Colorado River above Nankoweap Creek, common in lower reaches (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991).

^a List of species derived from USFWS (1991a,c,d); Harris (1991); Spiller (1991); Carothers and Brown (1991); Riley (1992).

^b Federal listing codes: E = endangered, C2 = category 2 candidate (definitions provided in Appendix D, Section D.4.1).

^c State listing codes: AZ-E = Arizona endangered, AZ-NL = not listed by Arizona (definitions provided in Appendix D, Section D.4.2).

All known successful reproduction occurs in the Little Colorado River (Kaeding and Zimmerman 1983; Maddux et al. 1987; USFWS 1990c). Spawning does not occur in the Colorado River, apparently because of cold water temperatures. Water is released from the dam at about 48°F and rarely exceeds 60°F by the time it reaches Lake Mead (Minckley 1991). Water temperatures of at least 60°F are needed for successful reproduction (USFWS 1990c).

Some young humpback chubs descend the Little Colorado River after hatching and use the mouth of this river as a nursery area (Maddux et al. 1987). When flows in the Colorado River are stable and relatively high, the confluence of the Little Colorado is a quiet, lakelike environment that serves as nursery habitat for young humpback chubs (Kaeding and Zimmerman 1983; Maddux et al. 1987). By autumn, these fish are large enough to ensure overwinter survival in the cold Colorado River (Maddux et al. 1987). Some young-of-the-year humpback chubs enter the Colorado River directly and occupy backwater and other nearshore habitats (Maddux et al. 1987; Reclamation 1993). The survival of these fish and their contribution to the Colorado River population of humpback chub is unknown.

The humpback chub eats a variety of aquatic and terrestrial insects. Below Glen Canyon Dam, the diet of the humpback chub consists principally of chironomids and blackfly larvae (Kaeding and Zimmerman 1983; Reclamation 1993).

Bonytail Chub (Endangered)

Historically, the bonytail chub was present throughout much of the Colorado River Basin, including the Glen Canyon and Lees Ferry reaches in the Lower Colorado River Basin (USFWS 1990d; Minckley 1991). Bonytail chub populations began to decline in the Lower Colorado River Basin early in the 20th century. This species had disappeared from the Salt and upper Gila rivers by the mid-1920s and was all but gone from the Colorado River by 1950, 12 years before completion of Glen Canyon Dam (USFWS 1990d). Today, the bonytail chub is considered extirpated (no longer present) between Glen Canyon Dam and Lake Mead; old individuals are occasionally collected from Lakes Havasu and Mohave (USFWS 1990d; Spiller 1991).

Major factors suggested for the decline of the bonytail chub throughout its historical range have included interactions with introduced fish species, habitat alterations (particularly lower summer water temperatures) caused by dams, water depletions for irrigation, and hybridization with humpback and roundtail chubs (USFWS 1990d).

Colorado Squawfish (Endangered)

The Colorado squawfish was common in the Lower Colorado River Basin until the 1930s, and then the population began to decline. It is considered extirpated in the Colorado River system below Glen Canyon Dam, (Spiller 1991; Tyus 1991a; USFWS 1991b).

The decline of the Colorado squawfish has been attributed to several factors, including habitat fragmentation resulting from dam construction, water withdrawals, altered water temperatures and flow regimes, channelization, and competition with and predation by introduced fish species (USFWS 1991b).

Razorback Sucker (Endangered)

Although once abundant and relatively widespread throughout the Colorado River and the Gila River basins, the razorback sucker is now very rare or absent from most of its former range (Bestgen 1990). The largest known existing population occurs in Lake Mohave below Hoover Dam in Arizona and Nevada; this population is estimated at about 60,000 adults (USFWS 1991c). The USFWS has proposed designating approximately 1,824 mi of river in the Upper and Lower Colorado River basins as critical habitat for the razorback sucker (USFWS 1993a). The proposed designation includes the Colorado River and its 100-year floodplain from the confluence of the Paria River to Hoover Dam, including Lake Mead to the full pool level (USFWS 1993a,b).

The decline of the razorback sucker throughout its historical range has been attributed to such factors as habitat loss due to dam construction, altered water temperatures, loss of nursery habitats as a result of diking and dam operations, altered flow regimes, changes in water chemistry and turbidity, and competition with or predation by introduced species (Bestgen 1990; Minckley et al. 1991; Tyus and Karp 1991).

The razorback sucker is very rare within the Colorado River between Glen Canyon Dam and Lake Mead and may never have been common in this reach (Minckley et al. 1991). This species persists in the river below Glen Canyon Dam in very low numbers, with fewer than 20 specimens collected since 1979. All individuals that have been collected are adults (Minckley 1991), and apparently no recruitment (addition of new, reproductively capable adults) into this or any other wild population has occurred for more than 20 years. Cold water may prevent successful reproduction and recruitment below Glen Canyon Dam (Minckley 1991).

3.4.1.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the Colorado River below Glen Canyon Dam are listed in Table 3.9. The table also lists the habitats or locations where those species occur. Federally listed and proposed species are discussed below.

Kanab Ambersnail (Endangered)

The Kanab ambersnail currently is known from only two small populations — one in south-central Utah and one in the Grand Canyon (USFWS 1992a). This small snail occurs

TABLE 3.9 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Glen Canyon Dam^a

Common Name	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Plants				
Grand Canyon flaveria	<i>Flaveria macdougalii</i>	C1	AZ-HS	Found in springs and seeps in area; not in danger from dam operations (Stevens and Ayers 1993).
Invertebrates				
Kanab ambersnail	<i>Oxyloma haydeni kanabensis</i>	E	AZ-NL	Found in spring-fed wetland in Grand Canyon above fluctuation zone (USFWS 1992a).
Reptiles				
Chuckwalla	<i>Sauromalus obesus</i>	C2	AZ-NL	Common in cliff, desert, and riparian areas (Carothers and Brown 1991).
Birds				
White-faced ibis	<i>Plegadis chihi</i>	C2	AZ-NL	Potential occurrence in riparian marshes during migration (Brown et al. 1981).
Osprey	<i>Pandion haliaetus</i>	NL	AZ-T	Potential occurrence along Colorado River during migration (Brown et al. 1981).
Bald eagle	<i>Haliaeetus leucocephalus</i>	E	AZ-E	Winters along Colorado River between dam and Lake Mead (Carothers and Brown 1991).
Northern goshawk	<i>Accipiter gentilis</i>	C2	AZ-C	Uncommon in coniferous forests of area (Brown et al. 1981); potential occurrence year-round in riparian woodlands along river.
Peregrine falcon	<i>Falco peregrinus</i>	E	AZ-C	Nests on cliffs along Colorado River between dam and Lake Mead (Carothers and Brown 1991); some individuals may spend winter in the area (Brown et al. 1984).

TABLE 3.9 (Cont.)

Common Name	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Birds (Cont.)				
Mexican spotted owl	<i>Strix occidentalis lucida</i>	T	AZ-T	Potential occurrence year-round in riparian woodlands along river (Riley 1992).
Belted kingfisher	<i>Ceryle alcyon</i>	NL	AZ-C	Known to occur along Colorado River between dam and Lake Mead during migration (Brown et al. 1981).
Southwestern willow flycatcher	<i>Empidonax traillii extimus</i>	PE	AZ-E	Nests in woody riparian vegetation along Colorado River between dam and Lake Mead (Carothers and Brown 1991); riparian areas of Colorado River below dam are proposed critical habitat.
Loggerhead shrike	<i>Lanius ludovicianus</i>	C2	AZ-NL	Transient in woody riparian vegetation along river between dam and Lake Mead (Brown et al. 1981).
Mammals				
Spotted bat	<i>Euderma maculatum</i>	C2	AZ-C	Recorded in Grand Canyon (Hoffmeister 1986); may forage above Colorado River and in riparian habitat.
Southwestern river otter	<i>Lutra canadensis sonora</i>	C2	AZ-E	Historically occurred in area; no recent evidence of occupation (Carothers and Brown 1991; Riley 1992).

^a List of species derived from USFWS (1991a,d); Harris (1991); Spiller (1991); Riley (1992); Arizona Game and Fish Department (1988).

^b Federal listing codes: C1 = category 1 candidate, C2 = category 2 candidate, E = endangered, NL = not listed, PE = proposed endangered, T = threatened, (definitions provided in Appendix D, Section D.4.1).

^c State listing codes: AZ-C = Arizona candidate for listing, AZ-E = Arizona endangered, AZ-HS = Arizona highly safeguarded, AZ-NL = not listed by Arizona, AZ-T = Arizona threatened, (definitions provided in Appendix D, Section D.4.2).

in marshes fed by springs and seeps in the vicinity of sandstone or limestone cliffs. It requires a permanently wet soil surface, or shallow standing water, and vegetative cover. Cattails appear to be preferred by this species, but wetland grasses and sedges can also provide suitable habitat. The Grand Canyon population is located within the canyon in a small marsh above the 32,000-cfs level that is fed by springs flowing down the cliff walls.

Bald Eagle (Endangered)

The bald eagle is regularly observed in the winter along the Colorado River below Glen Canyon Dam. Bald eagles occur throughout the river corridor below the dam, but immature eagles concentrate at the confluence of Nankoweap Creek, where spawning trout provide an abundant food supply (Carothers and Brown 1991; Reclamation 1993). Up to 26 eagles have been observed at any one time at the confluence of Nankoweap Creek (Reclamation 1993). Use of the river corridor by bald eagles is relatively recent and has occurred as eagle populations have increased throughout the western United States over the past decade.

Nesting by bald eagles has not been observed along the river between the dam and Lake Mead but is possible as evidenced by nesting activity within the region in 1990. Published results of annual bald eagle breeding surveys included 2 nests in Utah along the Colorado River (USFWS 1990a) and 26 nests in Arizona (Kjos 1992).

Peregrine Falcon (Endangered)

The peregrine falcon occurs along the Colorado River between Glen Canyon Dam and Lake Mead. Peregrines prefer high rocky cliffs for nest and perch sites, especially at locations adjacent to large rivers (USFWS 1977). Peregrines are linked to the productivity of the river and riparian ecosystem through their food requirements (Carothers and Brown 1991); they feed predominantly on birds, including ducks, shorebirds, and a variety of songbirds, that they overtake and capture in the air (USFWS 1977). Peregrines may travel up to 17 mi from nesting sites in search of prey (USFWS 1977).

The area below Glen Canyon Dam may support the largest breeding population of peregrine falcons within the contiguous United States (Carothers and Brown 1991); 37 pairs were counted in the river corridor in 1989, and this number apparently represents only a portion of the breeding population. Although peregrines usually occur in the area during the breeding season (March-October), some birds may be present during the winter (Brown et al. 1984).

Mexican Spotted Owl (Threatened)

Mexican spotted owls are rare residents in Arizona. They inhabit old-growth coniferous forest and wooded canyons. They roost during the day in shaded canyon areas or dense canyon trees; at night they hunt wood rats, mice, bats, and occasionally small birds

and insects. These owls nest in caves and other cavities in cliffs, tree cavities, and abandoned raven, hawk, and eagle nests. The Mexican spotted owl is a potential year-round resident in the area below Glen Canyon Dam, but the species has not been observed within the area (Riley 1992).

Southwestern Willow Flycatcher (Proposed Endangered)

The southwestern willow flycatcher occurs in riparian habitats along rivers, streams, or other wetlands where dense growths of woody species such as coyote willow, desert broom, arrowweed, or tamarisk are present. The southwestern willow flycatcher nests in this habitat along the Colorado River below Glen Canyon Dam; the reach of the river between 55 and 87 mi below the dam has been proposed as critical habitat for this species (USFWS 1993c). The number of willow flycatchers nesting in the Grand Canyon increased after construction of the dam because reduced flooding allowed an increase in riparian vegetation along the river (Reclamation 1993). In the 1980s, the population peaked in the canyon at a few dozen pairs; however, the population then began to decline, and in 1991 a survey found only two nesting pairs (Reclamation 1993). Reduction of the population has been attributed to parasitism by brown-headed cowbirds and to habitat fragmentation.

3.4.2 Flaming Gorge Dam

This section describes ecological resources in and along the Green River between Flaming Gorge Dam and Jensen, Utah. Resources in Flaming Gorge Reservoir are not discussed because they would not be affected by hydropower operations.

3.4.2.1 Aquatic Ecology

Before completion of Flaming Gorge Dam in 1962, the Green River exhibited seasonal fluctuations in flow and temperature. Water temperatures in the river ranged from near freezing in winter to greater than 70°F in summer (Holden and Crist 1981). The fish community consisted of both native and introduced species, including several fish that are currently classified as endangered or threatened. Many of these species were successfully reproducing in the river above its confluence with the Yampa River. Trout were absent from this portion of the river (Holden and Crist 1981). The natural flow pattern of the river before construction of the dam (Figure 3.26) featured a large spring peak discharge, which is considered to be important in the reproductive cycles of many of the endangered and threatened species and other native fish.

To prepare the future Flaming Gorge Reservoir for the establishment of a trout fishery, the Wyoming and Utah fish and game departments, with assistance from the USFWS, in 1962 undertook a massive poisoning of approximately 440 mi of the Green River and its tributaries (Holden 1991) to remove "trash" fish, such as carp, channel catfish, and redbreast shiner, as well as native minnows and suckers. The fish poison rotenone was

FIGURE 3.26 Pre- and Post-Dam Flows in the Green River at Greendale (0.5 mi downstream of Flaming Gorge Dam) and Jensen, Utah (94 mi down river of the dam) (Source: USGS gage data as presented by Smith and Green 1991)

released in the Green River from the headwaters in Wyoming to the present location of Flaming Gorge Dam. Rotenone killed fish as far downriver as the lower end of Split Mountain Canyon. Currently endangered fish were eliminated from the Green River above the location of the dam but not below (Holden 1991).

Following completion of Flaming Gorge Dam, release of cold, clear water from the dam permitted an outstanding trout fishery to become established and eliminated most, if not all, successful reproduction by native fish species. An outstanding trout fishery existed below the dam between 1963 and 1967. However, in the late 1960s and early 1970s, the fishery experienced a dramatic decline, apparently because water temperature dropped below the optimal levels for trout (Holden and Crist 1981). To warm the tailwaters and improve conditions for the trout fishery, the penstock inlets of Flaming Gorge Dam were modified in 1978 (Section 3.3.2.3) to permit the release of warmer water from the reservoir. With the release of warmer water, trout production increased, and the downstream river reach became one of the best trout fisheries in the western United States. Many native fish are absent from the river above the Gates of Lodore because of the cold waters. Natural warming of the water occurs through the Browns Park region; native fish are present in the river below the Gates of Lodore, and some species successfully reproduce in this reach. The controlled releases from the dam also eliminated spring peak flow in the river above the Yampa River confluence (Figure 3.26). Below the confluence, the Green River is more similar in temperature and flow to pre-dam conditions because of the inflow of the Yampa River.

3.4.2.1.1 Fish

A total of 33 species of fish have been reported from the Green River between Flaming Gorge Dam and Jensen, Utah, and from the lowermost reach of the Yampa River (Appendix D, Table D.2). The fish community below the dam, consisting of trout, warmwater introduced fish, and native species, is strongly affected by water releases from the dam and the inflow of the Yampa River. The Yampa River enters the Green River at Echo Park in Dinosaur National Monument, about 65 mi below Flaming Gorge Dam (Figure 3.16). Above the confluence, the character of the river is strongly affected by the clear, cold water released from the dam, and the fish community in this reach is dominated by trout. Below its confluence with the Yampa River, the Green River becomes warmer and more turbid and exhibits a more natural flow pattern (Figure 3.26). As a result, trout are less common, and native and warmwater introduced species are the major components of the fish community. The lower reach of the Yampa River is also important to the fish community of the Green River because it includes known spawning sites for razorback sucker, Colorado squawfish, and humpback chub, many of which inhabit the Green River below Echo Park as adults and move into the lower Yampa River to reproduce.

Trout

The Green River below Flaming Gorge Dam is considered one of the finest trout fisheries in the West; trout densities between the dam and Taylor Flat (16 mi below the dam)

have been estimated to range from 185 to 900 fish per acre (Modde et al. 1991). Trout species in this area include rainbow, brook, and brown trout, as well as several strains of cutthroat trout (Appendix D, Table D.2). The Utah Division of Wildlife Resources currently manages the tailwaters below Flaming Gorge Dam as a "put and take fishery," with 90,000-125,000 fingerling trout (6-in. length) stocked annually since 1985 (Modde et al. 1991). Rainbow, cutthroat, and brook trout are annually stocked in the river between the dam and Little Hole, and some natural reproduction of these species also occurs in this reach (Modde et al. 1991). Brown trout have not been stocked into the Green River for several years, and current populations are sustained through natural reproduction.

The rainbow trout is the dominant species from the dam to Little Hole, constituting about 50% of the trout population. Brook and cutthroat trout are the next most abundant trout in this section of the river, constituting about 30% and 12% of the estimated trout population, respectively (Modde et al. 1991). At Little Hole, rainbow trout constitute about 70% of the total trout population. Brown trout (20% of the trout population) are the second most abundant trout species, while brook and cutthroat trout each constitute no more than 5% of the trout population.

Rainbow and brook trout densities generally decrease below Little Hole, while brown trout become more abundant. Densities of all trout species decrease in the Green River downstream of its confluence with the Yampa River because of increases in water temperature and turbidity. Rainbow and brown trout are locally abundant at the confluence of the Green River and Jones Hole Creek, which supports naturally reproducing populations of these trout species.

Brown trout and brook trout spawn in the fall and cutthroat trout in spring; rainbow trout spawn in both seasons (Modde et al. 1991). Trout redds occur in the 16-mi stretch of the river between the dam and the Taylor Flat Bridge. The greatest density of redds occurs immediately below the dam and between Little Hole and Red Creek (Modde et al. 1991). Brown trout redds have been identified only downstream of Little Hole. Young-of-the-year trout typically inhabit shallow (less than 16 in. deep) nearshore areas with low water velocity (less than 1 cfs).

Other Introduced and Native Fish

Other than trout, introduced fish (17 species) constitute about 53% and native fish (10 species) about 31% of the fish community of the Green River between the dam and Jensen (Appendix D, Table D.2). Many of the introduced species entered the system after construction of the dam, some intentionally and some accidentally. Introduced fish are of particular concern because of their potential adverse impacts on native fish populations (Tyus et al. 1982; Minckley and Meffe 1987; Minckley 1991). Many of the introduced species present in the Green River system share habitats with the native species (Haines and Tyus 1990; Karp and Tyus 1990b; Tyus and Beard 1990; Tyus 1991a), and predation by and competition from introduced species have been suggested to be critical factors in the decline

of native fish throughout the Colorado River system (Kaeding and Osmundson 1988; Marsh and Langhorst 1988; Karp and Tyus 1990a; Tyus and Nikirk 1990; Minckley et al. 1991).

The most common introduced species in the river are the channel catfish, carp, fathead minnow, and red shiner (Holden and Crist 1981; Tyus et al. 1982; Karp and Tyus 1990b; Haines and Tyus 1990; Tyus and Nikirk 1990). In general, these species are rare from the dam to Browns Park. However, they increase in abundance after that point, and most are common between the Yampa River confluence and Jensen. The fathead minnow and red shiner are very abundant in shoreline habitats around Jensen in summer and autumn and constitute more than 80% of the fish present in backwater habitats in that area (Haines and Tyus 1990). The introduced sand shiner, redbreasted shiner, and creek chub are locally abundant around the Yampa River confluence but are rare or absent from other areas of the river.

Other introduced species are present in low numbers and have relatively limited distributions in the river. These species include the northern pike, green sunfish, black bullhead, walleye, bluegill, and largemouth and smallmouth basses (Appendix D, Table D.2). The northern pike may be a predator of the endangered fish in the system. This species was introduced into the Yampa drainage in 1977 and was first reported in the Green River in 1981 (Tyus and Beard 1990). Although uncommon in the main channel, the northern pike has been increasing in abundance and may be numerous in some quiet backwater habitats below the Yampa River confluence (Modde 1993). The relative absence of most of the introduced species above the Gates of Lodore (about 47 river miles below the dam) is most likely a result of colder water.

Reproduction by introduced warmwater fish is limited in the Green River above the Yampa River, especially above the Gates of Lodore (Holden and Crist 1981), presumably because of cold water. Many of the introduced species do, however, reproduce below the Yampa River (Holden and Crist 1981; Grabowski and Hiebert 1989; Haines and Tyus 1990; Tyus and Nikirk 1990). Larvae of introduced species dominate the larval fish community in backwaters below Split Mountain (Haines and Tyus 1990). Little or no successful reproduction by the northern pike and walleye occurs between the dam and Jensen. Juveniles and adults apparently enter the system from established reproducing populations in the upper Yampa River Basin (Tyus and Beard 1990).

The native fish community consists of 10 species (Appendix D, Table D.2) and is dominated by the flannelmouth and bluehead suckers and the speckled dace. These species are rare above the Gates of Lodore but are common or abundant below the Yampa River (Holden and Crist 1981; Karp and Tyus 1990b). The razorback sucker, humpback chub, bonytail chub, and Colorado squawfish are Federally endangered. These species are discussed in detail in Section 3.4.2.3.1.

Little or no successful reproduction by native fish occurs in the Green River above the Gates of Lodore (Holden and Crist 1981), presumably because of the cold water. Some reproduction occurs between the Gates of Lodore and the Yampa River, but most occurs downstream of the Yampa River (Holden and Crist 1981). Although native fish continue to

produce large numbers of larvae each year, by summer and autumn most of these larvae have died. Predation and competition from introduced fish and human activities, including fluctuating flows from hydropower operations, have been suggested as causes for the loss of native fish larvae (USFWS 1992b).

3.4.2.1.2 Aquatic Habitats

Between Flaming Gorge Dam and Jensen, the Green River can be delineated into reaches of two general types: relatively high-gradient, narrow canyon reaches with cobble, boulder, and gravel substrates or low-gradient, alluvial reaches with sand substrates and flowing through meandering canyons or flat open terrain.

The reach between the dam and Taylor Flat provides the best habitat for trout in the Green River, and redds of rainbow, brook, brown, and cutthroat trout occur throughout (Modde et al. 1991). Eddies are preferred by adult rainbow and cutthroat trout. However, a variety of other habitats are used, and use changes seasonally and with changing flows. The amount of habitat available for trout is strongly influenced by flow and is maximized in the tailwaters at flows between 800 and 1,200 cfs (Modde et al. 1991).

Below the confluence with the Yampa River, backwaters, eddies, side channels, and other nearshore areas in the Green River serve as nursery habitats for larval and juvenile fish, staging areas for some endangered species such as the razorback sucker, and habitat for adult native and endangered fish (Haines and Tyus 1990; Tyus and Karp 1991). High spring flows, such as those identified in the Biological Opinion for Flaming Gorge Dam, are thought to create new backwater areas while removing debris and replenishing nutrients in old backwaters (USFWS 1992b). The abundance of backwater in summer and autumn in the Green River is affected by flow. The size and number of backwater areas in Island Park and near Jensen decrease with increasing flows and are greatest in these areas at flows between 1,100 and 1,600 cfs (Pucherelli et al. 1990). However, backwater size may have little or no relationship to the quality of the backwater as a nursery habitat; other factors, such as temperature, substrate type, and depth, may be important in determining nursery habitat quality. The importance of backwaters to endangered fish species is discussed in Section 3.4.2.3.1.

3.4.2.1.3 Aquatic Food Base

The food base for fish in the Green River is dominated by macroinvertebrates and is strongly influenced by flow, available substrates, and the inflow of the Yampa River. Macroinvertebrates are most abundant above the Yampa River confluence (Holden and Crist 1981). In the tailwaters and canyons between the dam and Browns Park, large, stable substrates (e.g., boulders) and clear, cold water support abundant growths of cladophora and other attached algae. These algae are food for macroinvertebrates, including gammarus and chironomid, mayfly, blackfly, and caddisfly larvae (Holden and Crist 1981; Gosse 1982; Modde et al. 1991).

Low-gradient reaches at Browns Park, Island Park, Rainbow Park, and below Split Mountain lack cladophora except where occasional rapids and riffles provide suitable hard substrates. Macroinvertebrates in these low-gradient reaches include chironomids, oligochaetes, mayfly larvae, and biting midges and sandflies (Annear 1980; Holden and Crist 1981; Grabowski and Hiebert 1989).

Zooplankton density is low in the main channel, but it is greater in backwaters below the Yampa River (Grabowski and Hiebert 1989). Larger backwaters with narrow connections to the river, and thus with a lower water exchange rate and a greater retention time, have higher densities of zooplankton. The zooplankton in these backwater areas are important food for young native and introduced fish species (Grabowski and Hiebert 1989).

3.4.2.2 Terrestrial Ecology

This section describes the vegetation and wildlife in riparian areas along the Green River below Flaming Gorge Dam. Species and habitats in adjacent upland areas are not described in detail because they are not dependent on nor directly affected by river flow.

3.4.2.2.1 Vegetation

The Green River flows through three ecoregions — Wasatch and Uinta Mountains, Wyoming Basin, and Colorado Plateaus (Omernik and Gallant 1987a,b). Each ecoregion has characteristic physiography and vegetation — in the Wasatch and Uinta Mountains, conifers (especially Douglas fir) are the dominant vegetation; the Wyoming Basin is a relatively flat plain with hills or low mountains and shrub-steppe vegetation; and the Colorado Plateaus ecoregion is a highly dissected tableland dominated by desert shrubs.

Riparian vegetation occurs along most of the 93 mi of Green River between Flaming Gorge Dam and Jensen. Riparian vegetation is absent only in the few areas where sheer rock walls abut the river. Figure 3.25 depicts the riparian habitat found along the river. Although riparian areas are considered wetland by the U.S. Fish and Wildlife Service (Cowardin et al. 1979), only isolated patches of this habitat along the Green River would qualify as jurisdictional wetlands under the U.S. Army Corps of Engineers definition (COE 1987).

The riparian vegetation of the Green River corridor has changed since completion of Flaming Gorge Dam in 1963. The dam eliminated the characteristic high spring flood flows (9,000-19,000 cfs) and low summer and autumn flows (600-700 cfs). This characteristic seasonal pattern has been replaced by a shift in monthly releases to meet irrigation demands and daily fluctuations to produce hydropower (Section 3.3.2.1). Below the confluence with the Yampa River, flows in the Green River are strongly influenced by flows from the unregulated Yampa and, as a result, exhibit a more natural flow regime that includes high spring flows.

Before construction of Flaming Gorge Dam, the vegetation along the river occupied two distinct zones (Fischer et al. 1983). Nearest the river, flooding occurred each year during the spring. Plants in this flood zone were predominantly annuals or scour-tolerant perennials such as wild licorice, dogbane, and sedges. Dominant species above the flood zone included box elder, squawbush, Fremont cottonwood, and coyote willow (Holmgren 1962). After construction of the dam, woody riparian vegetation colonized much of the old flood zone from adjacent riparian and upland areas. Species that spread by underground stems (such as wild licorice, common reed, and scouring rush) formed dense stands along the shoreline in some areas and, by stabilizing sediment deposits, appear to be gradually making the channel narrower and deeper with steep banks. The riparian area above the high water line, including pre-dam woody riparian vegetation, currently occupies about 13.3 acres per mile.

Between Flaming Gorge Dam and Jensen, the Green River alternately flows through narrow canyons (Red Canyon, Canyon of Lodore, Whirlpool Canyon, and Split Mountain Canyon) and broad valleys (Browns Park, Island Park, and Rainbow Park) (Figure 3.16) that are quite different in terms of riparian vegetation. The moderate to steep slopes of the canyon areas are vegetated with pinyon pine, Utah juniper, Douglas-fir, or ponderosa pine. The riparian zone occurs on a predominantly rocky substrate (mostly cobble and boulder, with sand and gravel becoming more common farther downstream) and extends 25 to 35 ft above the low-water level (800 cfs). Above the normal high-water line (4,200 cfs), grasses; scouring rush; giant whitetop; wild licorice; and a variety of woody species, including box elder, coyote willow, tamarisk, and Fremont cottonwood, are common. The latter two species are more common farther downstream.

Through the wide valley areas, the river meanders within a broad, open floodplain of mostly sand and silt (and gravel in upstream areas). The surrounding uplands support sagebrush, desert shrubs, and, in some areas, pinyon pine and Utah juniper. Islands and backwaters are frequent throughout these sections of river. The riparian zone is relatively broad (up to 200 ft wide) and extends to 15-20 ft above the low-water level. Above the high-water line, grasses, coyote willow, wild licorice, giant whitetop, and scouring rush are common. Large stands of Fremont cottonwood, box elder, or tamarisk occur on high terraces; these stands depend on large spring floods (well above maximum power plant capacity) for regeneration. Steep cutbanks are common, and in some areas almost all banks are cut and severely eroded.

Marshes occur along the Green River between the dam and Jensen, although no estimate is available of acreage. The fluctuation zone (between the elevations of 800- and 4,200-cfs flows), where most of marshes occur, occupies about 5.8 acres per mile along the river. No estimate is available of the amount of pre-dam marsh vegetation.

Marshes occur within the fluctuation zone in backwater areas; side channels; on vegetated islands; and in low, flat, sandy or silty areas on the inside curves of the river where the current slows and sediments are deposited. The greatest abundance of marsh vegetation is between the 2,000- and 3,000-cfs levels. Marshes also occur occasionally along the channel margin in protected areas, such as downstream of protruding rocks or cliffs. Marshes are

most abundant in lower Browns Park and Island Park, where the river meanders extensively and many backwaters and side channels occur. Common species in these marshes are cattail, bulrush, rush, common reed, and scouring rush.

3.4.2.2.2 Wildlife

Numerous species of nongame vertebrate wildlife use riparian habitats along the Green River below Flaming Gorge Dam (Bogan et al. 1983). The greatest species diversity occurs in the riparian habitats of broad valleys, such as Browns, Echo, Island, and Rainbow parks. Wildlife is relatively sparse in canyon areas (e.g., Lodore, Split Mountain) because of the lack of habitat diversity. Representative species inhabiting riparian habitats include Woodhouse's toad, fence lizard, gopher snake, lazuli bunting, red-tailed hawk, deer mouse, and coyote.

The Green River provides excellent habitat for the river otter. Reintroduction of river otter to the Green River drainage began in 1989 and 1990 with the release of 23 otters along the river in Browns Park (Utah Division of Wildlife Resources 1992). Since then, otters have been seen between Flaming Gorge Dam and Island Park. Fish (especially carp) make up most of this species' diet. Abandoned beaver dens, clusters of boulders, or rock crevices near the water's edge are used as shelters.

The Green River and wetlands of the valley provide important breeding, migration, and wintering habitat for numerous waterfowl species (Aldrich 1992). Before the dam was constructed, annual spring floods inundated bottomland areas in Browns Park and other broad floodplain areas along the river. These flooded bottomlands provided important foraging areas for migrating waterfowl and were also used as major breeding grounds for several species. Browns Park National Wildlife Refuge and Browns Park Wildlife Management Area, situated along the river corridor in Browns Park, are managed to mitigate the effects of dam-induced reductions in spring flooding on these important waterfowl habitats. Within these management areas, bottomlands are artificially flooded each year by pumping river water into diked marshlands to create suitable waterfowl habitat.

Waterfowl species that commonly breed along the Green River corridor include Canada geese, mallard, common merganser, gadwall, green-winged teal, and redhead. In addition to these species, American widgeon, common goldeneye, and American coot are common during migration or winter. Waterfowl use unfrozen areas of the river during the winter.

Canada geese are particularly susceptible to changes in flow on the Green River (Holden 1992; Aldrich 1992). Islands and sandbars with low vegetation (e.g., grasses and forbs) are important nesting habitat for this species, and Browns Park is the most important nesting area for Canada geese in the area (Schnurr 1992). Most nesting occurs from March 15 to May 15.

Great blue heron, spotted sandpiper, and killdeer forage along shoreline and riparian habitats during the breeding season (Bogan et al. 1983). The great blue heron uses large trees (e.g., cottonwood) as nesting and roosting sites along the river. Killdeer and spotted sandpiper nest on the ground above the high-water line.

Several species of game mammals, including mule deer, elk, moose, pronghorn, and bighorn sheep, occur along the Green River corridor below Flaming Gorge Dam (BLM 1990; Schnurr 1992). All of these species use riparian habitats as foraging areas but are not restricted to riparian areas at any time of the year. Mule deer, elk, and pronghorn range widely throughout this portion of Utah and Colorado but move toward the river in the fall and use the river valley, especially Browns Park, as wintering range. Mule deer occur along the river throughout the year and are the most abundant game mammal in the area. They may currently exceed carrying capacity (BLM 1990). Moose numbers are low in the region but appear to be increasing (BLM 1990). Within the area, moose habitat occurs in Browns Park (Schnurr 1992). Bighorn sheep are common in riparian areas along the Green River in Canyon of Lodore (Schnurr 1992). The presence of these animals has resulted from reintroductions begun in 1952 after a die-off of the natural population.

3.4.2.3 Threatened and Endangered Species

This section discusses the current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species below Flaming Gorge Dam. Definitions of listing categories maintained by the Federal Government and the states of Utah and Colorado are presented in Appendix D, Section D.4; correspondence with the USFWS regarding threatened and endangered species in the area is provided in Section D.4.5 of Appendix D.

3.4.2.3.1 Aquatic Species

Seven Federally or state-listed, sensitive, or candidate fish species have been reported in the Green River between Flaming Gorge Dam and Jensen (Table 3.10). The occurrence and status of the Federally listed species are discussed below.

Humpback Chub (Endangered)

Below Flaming Gorge Dam, the humpback chub occurs primarily within Dinosaur National Monument in upper Whirlpool Canyon of the Green River and the lower Yampa River (Karp and Tyus 1990b; USFWS 1990c). The USFWS has proposed designating the Yampa River within Dinosaur National Monument and the Green River from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument as critical habitat for the humpback chub (USFWS 1993a). The size of the humpback chub population within this part of the Green River Basin is not known, although this chub is most abundant

TABLE 3.10 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Flaming Gorge Dam in the Green River

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Colorado squawfish	<i>Ptychocheilus lucius</i>	E	UT-E CO-E	Absent from the Green River above the Canyon of Lodore; rare from the Gates of Lodore to Jensen and in lower Yampa River (Tyus and Karp 1991).
Razorback sucker	<i>Xyrauchen texanus</i>	E	UT-E CO-E	Absent from the Green River above the Gates of Lodore; rare from the Gates of Lodore to Jensen and in the lower Yampa River (Tyus and Karp 1991).
Humpback chub	<i>Gila cypha</i>	E	UT-E CO-E	Absent from Green River above the Gates of Lodore; rare from Gates of Lodore to Jensen and in lower Yampa River; most abundant in eddies of high-gradient reaches of Yampa River and in Whirlpool Canyon (Tyus and Karp 1991).
Bonytail chub	<i>Gila elegans</i>	E	UT-E CO-E	Historically present at the confluence of the Green and Yampa rivers; last verified specimen collected in 1979 from the lower Yampa River (Tyus and Karp 1991).
Roundtail chub	<i>Gila robusta</i>	C2	UT-T CO-NL	Common in the Green River from Browns Park through Island Park and in the lower Yampa River (Karp and Tyus 1990b).
Flannelmouth sucker	<i>Catostomus latipinnis</i>	C2	UT-NL CO-NL	Rare in the Green River above the Gates of Lodore; common from the Gates of Lodore to Jensen (Tyus et al. 1982; Karp and Tyus 1990b).

^a Lists of species derived from USFWS (1991a,c,d); Harris (1991); Holden (1992); Schnurr (1992); Williams (1992); Pague (1992).

^b Federal listing codes: C2 = category 2 candidate, E = endangered (definitions provided in Appendix D, Section D.4.1).

^c State listing codes: CO-E = Colorado endangered, CO-NL = not listed by Colorado, UT-E = Utah endangered, UT-NL = not listed by Utah, UT-T = Utah threatened (definitions provided in Appendix D, Section D.4.3 and D.4.4).

in the lower Yampa River (Karp and Tyus 1990b). Within Dinosaur National Monument, adult humpback chub occur most often in shallow eddies within high-gradient, white-water reaches with cobble and sand substrates (USFWS 1990c; Tyus and Karp 1991). Aquatic insects constitute the bulk of the humpback chub diet (Karp and Tyus 1990b).

The humpback chub spawns in the Yampa and Green rivers within Dinosaur National Monument (Karp and Tyus 1990b). Humpback chubs in Dinosaur National Monument spawn in spring and early summer at water temperatures of about 68°F (Tyus and Karp 1991). Reproductive adults occur in shoreline eddies and may return to specific eddies to spawn in different years (Karp and Tyus 1990b).

The decline of the humpback chub in the Green River, as well as throughout its historical range, has been attributed to such factors as stream alterations from dams, water withdrawals, channelization, competition with and predation by introduced fish species, and hybridization with related species (USFWS 1990c).

Bonytail Chub (Endangered)

Before construction of Flaming Gorge Dam, the bonytail chub was present in the Green River above and below the Yampa River confluence (Schnurr 1992). Since then, the number of bonytail chub in the Green and Yampa rivers within Dinosaur National Monument has declined. Although the last verified bonytail chub collected from the Upper Green River Basin (above Jensen) was captured in the lower Yampa River in 1979 (Tyus and Karp 1991), this species is not yet considered extirpated from the region. A fish suspected of being a bonytail chub was collected from the upper Green River in 1987 (Tyus and Karp 1991). Major factors suggested for the decline of the bonytail chub throughout its historical range have included interactions with introduced fish species, habitat alterations (particularly lower summer water temperatures) caused by dams, water depletions for irrigation, and hybridization with humpback and roundtail chubs (USFWS 1990d).

The USFWS has proposed designating about 344 mi of river in the Upper and Lower Colorado River basins as critical habitat for the bonytail chub (USFWS 1993a). In the upper basin, the proposed critical habitat includes the Yampa River within Dinosaur National Monument and the Green River from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

Little is known about the life history of this species. The bonytail chub is generally considered a big-river species. In the Green River, adults were most common in pools and eddies rather than swifter, main-channel areas, and spawning is believed to have occurred in late spring and early summer at water temperatures of about 64°F (USFWS 1990d). Bonytail chubs in the Green River in Dinosaur National Monument fed on a variety of aquatic and terrestrial insects.

Colorado Squawfish (Endangered)

Historically, the Colorado squawfish was abundant throughout the big-river portions of the Colorado River Basin but is now absent from the lower basin (USFWS 1991b). Within the upper basin, the Colorado squawfish is most abundant in the Green River below the Yampa River and in the Yampa River itself (Tyus and Karp 1991; USFWS 1991b). The decline of the Colorado squawfish has been attributed to alteration and fragmentation of habitats by dams, loss of nursery habitats because of dam- and hydropower-induced hydrological changes, water depletions for irrigation, channelization, and interactions with introduced fish species (USFWS 1991b).

The USFWS has proposed designating 1,148 mi of river in the Upper Colorado River Basin as critical habitat for the Colorado squawfish (USFWS 1993a). The proposed critical habitat includes a portion of the Green River evaluated in this EIS, namely that portion of the river from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

The Colorado squawfish population in the Green River has been estimated to range from about 4,000 to 17,000 adult fish (Tyus 1991a). The Colorado squawfish does not occur in the Green River between Flaming Gorge Dam and the Gates of Lodore, primarily because of cold water, altered flow patterns, sediment loads, and water chemistry (USFWS 1991b; Schnurr 1992). This species is most common below the Yampa river confluence. Adult Colorado squawfish occur in eddies, pools, runs, and shoreline backwaters over silt, sand, gravel, and boulder substrates (Tyus and Karp 1991; USFWS 1991b). Young-of-the-year fish usually occur in shoreline backwaters (Tyus 1991b), especially in Island and Rainbow parks and near Jensen (C. Johnson 1992).

Colorado squawfish in the upper Green River spawn over a four- to five-week period between late June and mid-August, soon after the peak in spring flows, at water temperatures between 64° and 77°F (USFWS 1991b). One of the two major spawning sites of the Colorado squawfish is in the lower Yampa River 15-31 mi upstream from the Green River (USFWS 1991b; C. Johnson 1992). Every spawning season, adult Colorado squawfish in the upper Green and Yampa rivers migrate to the Yampa River spawning ground (Tyus 1990; 1991a).

In the lower Yampa River, spawning occurs over gravel, cobble, and boulder bars (Tyus 1990) that are cleared of accumulated sediments during spring floods (Tyus and Karp 1991). Breeding adults concentrate in pools and eddies adjacent to the spawning bars, move onto bars to spawn, and then return to pools and eddies. Upon hatching, the larval fish are carried by the current downstream to nursery areas at Island and Rainbow parks and in the Jensen area, where they concentrate in backwaters and other nearshore habitats (Tyus and Haines 1991).

The diet of very young Colorado squawfish consists primarily of zooplankton and small insect larvae (Grabowski and Hiebert 1989; USFWS 1991b). However, the young fish

begin to eat other fish very early — 86% of the diet of juvenile Colorado squawfish is fish. Adult squawfish eat other fish almost exclusively.

Razorback Sucker (Endangered)

The Yampa River and the Green River from the Yampa to upper Desolation Canyon now contain the largest remaining riverine population of razorback suckers, estimated in 1989 to be between 800 and 1,100 adult fish (Lanigan and Tyus 1989). More recent estimates suggest the population may be much smaller, about 250-600 adult fish (Modde 1993). The razorback sucker does not occur in the Green River from Flaming Gorge Dam to the Gates of Lodore (Minckley et al. 1991) but does occur from the Gates of Lodore to Jensen and in the lower 13 mi of the Yampa River above its confluence with the Green River (Tyus and Karp 1991). Razorback suckers overwinter in Echo, Island, and Rainbow parks and near Jensen (Valdez and Masslich 1989).

The USFWS has proposed designating 1,824 mi of river in the Upper and Lower Colorado River basins as critical habitat for the razorback sucker (USFWS 1993a). In the upper basin, the proposed critical habitat includes a portion of the Green River that is evaluated in this EIS — that portion of the river from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

The decline of the razorback sucker in the Green River has been attributed primarily to loss of habitat from dam construction, loss of spawning and nursery habitats from diking and dam operations, and the alteration of seasonal streamflow patterns (Tyus and Karp 1991; USFWS 1992b). Competition with and predation by introduced fish species may also be important factors in the decline of this species (Bestgen 1990; Minckley et al. 1991; USFWS 1992b).

Reproduction by the suckers in the Upper Green River Basin occurs from late April through mid-June during peak spring flows at water temperatures between 48° and 63°F (Tyus and Karp 1990). Spawning areas have been identified in (1) the lower Yampa River above Echo Park, (2) the Green River in Echo Park, and (3) between Split Mountain Canyon and Ashley Creek near Jensen (Tyus and Karp 1990; Schnurr 1992; C. Johnson 1992). Potential spawning areas have also been identified in Split Mountain Canyon and Island Park (Schnurr 1992). Razorback suckers spawn on riffles with cobble, gravel, and sand substrates (Tyus and Karp 1990).

Although larvae are produced in the Green River above Jensen, there is little or no recruitment to the adult population (Tyus 1987; Minckley et al. 1991; Tyus and Karp 1991; Modde 1993). Predation and loss of flooded bottomland nursery habitat have been suggested as major factors affecting recruitment in the Green River and throughout the range of the razorback sucker (Minckley et al. 1991; Modde 1993).

Little is known about the diet of razorback suckers from the Green River. In other rivers and reservoirs, the razorback sucker consumes aquatic insects, zooplankton, and algae. Larvae prey on chironomid larvae, algae, and small zooplankton (Bestgen 1990).

3.4.2.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the Green River below Flaming Gorge Dam are listed in Table 3.11. Habitats or location where these species occur are also included in the table. Federally listed species are discussed below.

Ute Ladies-tresses (Threatened)

The threatened Ute ladies-tresses, a small species of orchid, is known from seven populations in open riparian areas of Colorado and Utah. These populations occur in locations where soil moisture is high but that are at elevations above rivers and streams where flooding is infrequent, of short duration, and flood scouring less likely (Coyner 1990; USFWS 1990b). Threats to the species include collection of live plants, alteration of habitat, and alteration of the water regime. One population of Ute ladies-tresses occurs along the Green River within Browns Park. About 500 plants within this population are located in an open meadow; the nearest plants to the river are about 10 ft from the water's edge and 6 ft above the river's surface. Seven other plants are located just downstream in a marshy area along an old river channel more than 300 ft from the water's edge.

Whooping Crane (Endangered)

Whooping cranes migrate through the region of Flaming Gorge Dam and the Green River Basin in the spring and fall. These cranes belong to a population established at Gray's Lake National Wildlife Refuge in southeastern Idaho as part of the recovery program for this species (Armbruster 1990). Efforts to establish the Gray's Lake population began in 1975. The current population consists of 13 cranes that have not yet nested but migrate annually with sandhill cranes to wintering grounds in and around the Bosque del Apache National Wildlife Refuge, New Mexico. Two areas are heavily used by migrating cranes and have been designated as critical habitat — Monte Vista National Wildlife Refuge and Alamosa National Wildlife Refuge. Both areas are in southern Colorado, away from the area of Flaming Gorge Dam (Armbruster 1990). Habitats used by whooping cranes during migration include agricultural fields, wetlands, and small reservoirs (Rose 1992). Although whooping cranes have not been observed along the Green River below Flaming Gorge Dam, wetlands along the river could be used occasionally by migrating individuals.

TABLE 3.11 Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Flaming Gorge Dam on the Green River

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Plants				
Ute ladies-tresses	<i>Spiranthes diluvialis</i>	T	UT-NL, CO-1	Population in alluvial soils along Green River within Browns Park (Coyner 1990).
Ownbey thistle	<i>Cirsium ownbeyi</i>	C2	UT-S, CO-1	Population in alluvial soil at confluence of Yampa and Green rivers; endemic to Dinosaur National Monument area (Naumann 1990).
Smooth cliff-brake	<i>Pellaea glabella</i>	NL	UT-NL, CO-3	Several individuals along Green River in rock crevices of Lodore Canyon above river level (Naumann 1990).
Giant helleborine	<i>Epipactis gigantea</i>	NL	UT-NL, CO-2	Potential occurrence in riparian areas of Green River; known populations in Split Mountain above river level (Naumann 1990).
Alcove bog-orchid	<i>Habenaria zothecina</i>	NL	UT-S, CO-2	Potential occurrence in riparian areas of Green River; known populations in Yampa River Basin (Naumann 1990).
Narrow-leaf evening primrose	<i>Oenothera acutissima</i>	C2	UT-S, CO-2	Potential occurrence in riparian areas of Green River; known populations in Yampa River Basin (Naumann 1990).
Alcove death camas	<i>Zigadenus vaginatus</i>	3C	UT-S, CO-2	Potential occurrence in riparian areas of Green River; known populations above river level (Naumann 1990).

TABLE 3.11 (Cont.)

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Reptiles				
Utah milk snake	<i>Lampropeltis triangulum taylori</i>	NL	UT-S, CO-NL	Occurs in woody riparian vegetation along Green River (W. Johnson 1992).
Western smooth green snake	<i>Opheodrys vernalis blanchardi</i>	NL	UT-S, CO-NL	Potential occurrence in woody riparian vegetation along Green River (Stebbins 1966).
Birds				
Whooping crane	<i>Grus americana</i>	E	UT-E, CO-E	Potential occurrence in riparian marshes along Green River during migration (BLM 1990).
Greater sandhill crane	<i>Grus canadensis tabida</i>	NL	UT-NL, CO-E	Potential occurrence in riparian marshes along Green River during migration (BLM 1990).
Western snowy plover	<i>Charadrius alexandrinus nevadensis</i>	C2	UT-S, CO-SC	Potential occurrence on river beaches and mudflats along Green River during breeding season and migration (BLM 1990).
Long-billed curlew	<i>Numenius americanus</i>	3C	UT-S, CO-SC	Potential occurrence in riparian marshes along Green River during breeding season and migration (BLM 1990).
Northern goshawk	<i>Accipiter gentilis</i>	C2	UT-S, CO-NL	Potential occurrence year-round in riparian woodlands along Green River (Peterson 1990).

TABLE 3.11 (Cont.)

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Birds (Cont.)				
Swainson's hawk	<i>Buteo swainsoni</i>	NL	UT-S, CO-NL	Potential occurrence in riparian woodlands along Green River (BLM 1990).
Bald eagle	<i>Haliaeetus leucocephalus</i>	E	UT-E, CO-E	Winters along Green River between dam and Jensen (Huffman 1992; Howe 1992); potential nest sites in cottonwood groves along river.
Osprey	<i>Pandion haliaetus</i>	NL	UT-S, CO-NL	Nests in dead trees along Green River near dam (Holden 1992).
Peregrine falcon	<i>Falco peregrinus</i>	E	UT-E, CO-E	Nests on cliffs along Green River in Dinosaur National Monument (Eason 1992a); potential occurrence during winter (USFWS 1977).
Mexican spotted owl	<i>Strix occidentalis lucida</i>	T	UT-S, CO-NL	Potential occurrence year-round in riparian woodlands of canyon areas along Green River (Huffman 1992; W. Johnson 1992).
Western yellow-billed cuckoo	<i>Coccyzus americanus occidentalis</i>	NL	UT-S, CO-NL	Potential occurrence during summer or migration in woody riparian vegetation along Green River (BLM 1990; W. Johnson 1992).
Black-chinned hummingbird	<i>Archilochus alexandri</i>	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).
Lewis's woodpecker	<i>Melanerpes lewis</i>	NL	UT-S, CO-NL	Occurs year-round in woody riparian vegetation along Green River (W. Johnson 1992).

TABLE 3.11 (Cont.)

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Birds (Cont.)				
Willow flycatcher	<i>Empidonax traillii</i>	NL ^d	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).
Loggerhead shrike	<i>Lanius ludovicianus</i>	C2	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
American redstart	<i>Setophaga ruticilla</i>	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
Wilson's warbler	<i>Wilsonia pusilla</i>	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
Yellow-breasted chat	<i>Icteria virens</i>	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).
Mammals				
Dwarf shrew	<i>Sorex nanus</i>	NL	UT-S, CO-NL	Occurs in woody riparian vegetation along Green River (W. Johnson 1992).
Spotted bat	<i>Euderma maculatum</i>	C2	UT-S, CO-NL	Potential occurrence of foraging individuals along Green River (BLM 1990).

TABLE 3.11 (Cont.)

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Mammals (Cont.)				
River otter	<i>Lutra canadensis</i>	NL	UT-S, CO-E	Reintroduced population along Green River (Holden 1992).
Ringtail	<i>Bassariscus astutus</i>	NL	UT-S, CO-NL	Occurs in woody riparian habitat along Green River (W. Johnson 1992).

^a List of species derived from USFWS (1991a,d); BLM (1990); Harris (1991); Holden (1992); Williams (1992); Pague (1992).

^b Federal listing codes: C2 = category 2 candidate, 3C = no longer candidate for listing because common or well protected, E = endangered, NL = not listed, T = threatened (definitions provided in Appendix D, Section D.4.1).

^c State listing codes: CO-1 = Colorado list 1, CO-2 = Colorado list 2, CO-3 = Colorado list 3, CO-E = Colorado endangered, CO-NL = not listed by Colorado, CO-SC = Colorado special concern, UT-E = Utah endangered, UT-NL = not listed by Utah, UT-S = Utah sensitive (definitions provided in Appendix D, Section D.4.3 and D.4.4).

^d Southwestern willow flycatcher (*Empidonax traillii extimus*), proposed for Federal listing as endangered, is not found in the project area (Holden 1992).

Bald Eagle (Endangered)

About 50 bald eagles winter along the Green River below Flaming Gorge Dam each year (Huffman 1992; Howe 1992). Eagles perch in large trees near open, ice-free water and forage for fish and occasionally waterfowl. Concentrations occur in broad, open areas of the valley with cottonwood groves, such as Browns Park and Island Park (Huffman 1992). Use of the Green River corridor by bald eagles is relatively recent and has occurred as eagle populations have increased throughout the western United States over the past decade.

Although nesting by the bald eagle has not been observed in the vicinity of Flaming Gorge Dam or the Green River, it appears possible given documented nesting activity elsewhere in Utah and Colorado (USFWS 1990b; Kjos 1992). Along the Green River, suitable large nest trees (Fremont cottonwood) occur in groves in broad, open areas such as Browns, Island, and Rainbow parks.

Peregrine Falcon (Endangered)

The peregrine falcon occurs along the Green River below Flaming Gorge Dam and is most common in major canyons where potential nest and perch sites exist on cliff faces. The species nests within Dinosaur National Monument (Eason 1992a) along both the Green and Yampa rivers. Numbers of nests have increased within the past two decades; only one active nest site was known within the monument in 1976, but eight nesting pairs fledged a total of 13 young in 1992. Although peregrines usually occur in the area during the breeding season (March-October), some birds could occur during the winter (USFWS 1977). Additional background information on the falcon is presented in Section 3.4.1.3.2.

Mexican Spotted Owl (Threatened)

The Mexican spotted owl is a potential year-round resident along the Green River below Flaming Gorge Dam. The species is thought to occur in Dinosaur National Monument, and there are indications that it has occurred there in the past (Huffman 1992). The monument canyons provide potential habitat for the owl. Additional background information on the species is provided in Section 3.4.1.3.2.

3.4.3 Aspinall Unit

This section describes ecological resources in and along the reservoirs of the Aspinall Unit (Figure 3.19) because hydropower operations affect water levels. Resources below Crystal Dam are not discussed because releases from Crystal Dam are controlled by Reclamation for water regulation, not to produce hydropower.

3.4.3.1 Aquatic Ecology

Flows in the Gunnison River have been regulated since the construction of the Taylor Park Reservoir in 1936. Before construction of the Aspinall Unit reservoirs (begun in 1961), the Gunnison contained most of the currently threatened or endangered fish species of the Upper Colorado River Basin (Tyus et al. 1982). In the vicinity of the Aspinall Unit, the fish community was relatively sparse, with probably no more than nine species native to the Upper Colorado River Basin (Stanford and Ward 1982). Rainbow and brown trout were introduced into the river around 1910, and a world-class trout fishery was established that replaced the native Colorado cutthroat trout.

The most productive pre-dam fishery in the Gunnison River occurred from the mouth of Tomiche Creek downstream to the upper reaches of the Black Canyon (Stanford and Ward 1982). This reach also exhibited the highest production and diversity of aquatic macroinvertebrates. With the construction of the Aspinall Unit dams, this reach was changed to a lake environment that now supports a kokanee salmon fishery. Following construction of the reservoirs, the production and diversity of macroinvertebrates declined, and some species were eliminated (Stanford and Ward 1982).

3.4.3.1.1 Fish

The Aspinall Unit reservoirs contain 16 fish species (Appendix D, Table D.3). Because of the cold water in the reservoirs, the seven trout and salmon species dominate the fish community.

Trout and Salmon

Trout and salmon that occur in the Aspinall Unit reservoirs include kokanee salmon, rainbow trout, brown trout, brook trout, and lake trout (Appendix D, Table D.3). Rainbow trout and kokanee salmon are the most abundant of these (Van Buren and Burkhard 1981).

Kokanee salmon are stocked in Blue Mesa Reservoir and into the East River about 25 mi upstream of the reservoir. Kokanee salmon fingerlings are released into the East River at the Roaring Judy Fish Hatchery each spring, usually in late April; approximately 1.2 million fingerlings were stocked into the East River in 1992 (Hebein 1992). These fingerlings move downstream into the upper Gunnison River and eventually into Blue Mesa Reservoir to mature. In autumn, adult kokanee salmon migrate back upstream to the fish hatchery area to spawn. Colorado Division of Wildlife personnel obtain eggs and roe from the returning kokanee salmon to provide stock for the hatchery for the following year. The young fish produced represent the major source of kokanee salmon for stocking efforts throughout Colorado. Fish raised in this hatchery are also used for fish stocking programs in other states (Hebein 1992). From 50,000 to 100,000 kokanee salmon fingerlings are released yearly into Blue Mesa Reservoir near Red Creek, High Bridge, Dry Creek, and Blue Mesa Dam to provide adequate numbers of adult kokanee salmon for the snagging fishery.

In Blue Mesa Reservoir, kokanee salmon prefer water temperatures of 60°F or less and in summer are most abundant in the deeper (50-100 ft), colder waters near the dam (Van Buren and Burkhard 1981). Because of warm water temperatures, the uppermost Iola Basin (Figure 3.19) of Blue Mesa Reservoir does not provide suitable habitat for kokanee salmon in summer months (Van Buren and Burkhard 1981). Morrow Point Reservoir is colder in summer than Blue Mesa Reservoir, and thus kokanee salmon occur at shallower depths (10-40 ft).

Rainbow trout are stocked annually into Blue Mesa Reservoir — 900,000 in 1992 (Hebein 1992). Little or no stocking of trout and salmon occurs in Morrow Point or Crystal reservoirs, but many of the fish stocked into Blue Mesa Reservoir enter the downstream reservoirs through the Blue Mesa and Morrow Point dams.

Brown trout populations in the reservoirs rely entirely upon natural reproduction for maintenance, since this species is no longer stocked in the reservoirs. Spawning beds have been observed in the Lake Fork inlet of Blue Mesa Reservoir, and other reservoir inlets may also provide suitable spawning habitat.

Other Introduced and Native Fish

Most of the introduced and native species that have been identified from the Gunnison River in the vicinity of the Aspenall Unit (Appendix D, Table D.3) are rare or incidental in the reservoirs, primarily because of the cold water.

Longnose and white suckers are the most abundant of the four introduced species (other than trout and salmon) in the reservoirs (Appendix D, Table D.3). Five native species of fish occur in the reservoirs — the mottled sculpin, Colorado River cutthroat trout, speckled dace, and flannelmouth and bluehead suckers (Stanford and Ward 1982; Hebein 1992). The flannelmouth and bluehead suckers are the most common of these.

3.4.3.1.2 Aquatic Habitats

Fluctuating reservoir levels resulting from hydropower operations alternately expose and inundate shoreline areas, affecting algae and macroinvertebrates that constitute the food base for some fish. For speckled dace, bluehead sucker, flannelmouth sucker, and mottled sculpin, the nearshore areas may serve as spawning sites, nursery areas, and habitats for adults.

The Sapinero Basin of the Blue Mesa Reservoir (Figure 3.19) is located closest to the dam and is the deepest and coldest of the three basins in the reservoir. In the summer, the Sapinero Basin provides important habitat for adult kokanee salmon in the reservoir (Van Buren and Burkhard 1981). In the summer, adult kokanee in Blue Mesa Reservoir are most abundant at depths of 50-100 ft (Van Buren and Burkhard 1981), where preferred water temperatures are most common. The reservoir inlet structure is located at an elevation of

7,348 ft, which is 171 ft below the maximum reservoir surface elevation, and draws water directly from the Sapinero Basin (Van Buren and Burkhard 1981). If the reservoir level is sufficiently low, a potential exists for adult kokanee to be drawn (entrained) into the inlet structure and killed during water releases. Most kokanee salmon entrained at Blue Mesa, Morrow Point, and Crystal reservoirs are young fish less than 1 year old (Van Buren and Burkhard 1981).

Some degree of entrainment will always occur at the dams, and kokanee that have been entrained and passed through Blue Mesa Dam are periodically observed in Morrow Point Reservoir (Hebein 1993). A relatively high amount of entrainment of young kokanee through Blue Mesa Dam was observed in the late spring and early summer of 1993 (Hebein 1993). The cause of this entrainment, as well as the role (if any) of hydropower operations in the observed entrainment, is not known. Sustained high-water releases from Blue Mesa Reservoir may produce a current leading to the reservoir inlet structure of the dam. Young kokanee, which are attracted to currents, could thus be drawn into the inlet structure and killed. The entrainment and fish loss observed in 1993 may have resulted from releases of large amounts of water from Blue Mesa Reservoir because of very high water conditions at the reservoir (Hebein 1993).

The tailwaters below Blue Mesa and Morrow Point dams are the only remaining riverine habitat between the upper end of Blue Mesa Reservoir and Crystal Dam. However, even these areas become lakelike under some conditions. These tailwater areas receive water releases from the dams, and at low surface water elevations in Morrow Point or Crystal reservoirs, the tailwater areas become riverine. At high surface water elevations, the reservoir waters back up into the tailwaters, and a lake environment is formed.

3.4.3.1.3 Aquatic Food Base

The aquatic food base in the Aspinall reservoirs has not been studied. The reservoirs are deep, cold, oligotrophic lakes. In general, oligotrophic lakes and reservoirs are low in nutrients and organic productivity, have nutrient-poor sediments, few rooted aquatic plants, a low production of unattached algae (called phytoplankton), and well-oxygenated deep waters (Cooke et al. 1986). Zooplankton are the major food of the kokanee salmon inhabiting lakes and reservoirs throughout North America (Scott and Crossman 1973; Sigler and Sigler 1987). Young kokanee salmon serve as important food for other fish, including rainbow and cutthroat trout (Scott and Crossman 1973; Sigler and Sigler 1987).

The benthic community in the tailwaters of the Blue Mesa and Morrow Point dams should be similar to the communities present in the Gunnison River above the reservoirs. Macroinvertebrates in the river include chironomids, mayflies, stoneflies, and caddisflies (Stanford and Ward 1982; Fuller and Stewart 1977).

3.4.3.2 Terrestrial Ecology

This section summarizes information on the vegetation and wildlife that occur in riparian areas along Crystal, Morrow Point, and Blue Mesa reservoirs. Species and habitats in adjacent upland areas are not discussed in detail because they are not dependent on water levels in the reservoir and therefore are not affected by hydropower operations.

3.4.3.2.1 Vegetation

The Aspinall Unit is in the Southern Rockies ecoregion (Omernik and Gallant 1987b). The reservoirs occupy areas that, for the most part, had been canyons or, in sections of Blue Mesa Reservoir, somewhat wider steep-walled valleys. Little of the original riparian vegetation escaped inundation upon completion of the dams. At normal reservoir levels, most riparian vegetation occurs along the tributaries of the reservoirs rather than along the shores of reservoirs themselves. Figure 3.25 depicts the riparian habitat found along the reservoirs.

Upland areas surrounding Blue Mesa Reservoir are moderately to steeply sloped and dominated by black sagebrush, Mountain big sagebrush, needlegrasses, Sandberg bluegrass, wheatgrasses, bottlebrush squirreltail, and blue grama (Chapman 1993a). Little riparian vegetation of any kind grows along the Blue Mesa Reservoir, either above or below the normal high-water line (only about 0.03 acre per mile of shoreline and 0-10 ft wide). In most areas, upland vegetation or bare rock occurs down to the water. However, some areas support woody riparian vegetation, mainly near the confluences with tributaries. In such areas, narrowleaf cottonwood, coyote willow, thinleaf alder, and sweet clover may be found. Approximately 10 acres of marsh dominated by sedges occurs where the Gunnison River enters the upstream end of Blue Mesa Reservoir. This marsh receives water when reservoir elevations are relatively high (around 7,510 ft MSL), and water enters the marsh through the boulders and fill material that form a road embankment.

Morrow Point Reservoir is surrounded by steep rocky slopes vegetated with Douglas-fir and white fir, along with aspen, sagebrush, and service berry and, to a lesser extent, pinyon pine, Rocky Mountain juniper, and Gambel oak. Little riparian vegetation of any kind occurs along the Morrow Point Reservoir. Much of the northern shore is unvegetated rocky cliffs; in other areas, upland vegetation extends down to the high water line. Vegetation does not exist between the high- and low-water lines because of repeated exposure and inundation. Pine Creek, Curecanti Creek, Blue Creek, and Round Corral Creek (tributaries to Morrow Point Reservoir) support riparian areas of narrowleaf cottonwood, willow, and thinleaf alder near the reservoir.

Crystal Reservoir also is surrounded by steep rocky slopes that are vegetated primarily with pinyon pine and Rocky Mountain juniper, along with stands of Douglas-fir, white fir, aspen, and Gambel oak. The woody riparian zone of Crystal Reservoir is dominated by box elder, narrowleaf cottonwood, and coyote willow for about 0.5 mi below Morrow Point Dam, where the flow is essentially riverine. Here, the riparian zone is 0-13 ft wide. In this riverine section, where daily fluctuations have ranged from 0 to 5,300 cfs during normal

water years, some marsh vegetation (e.g., spikerush, horsetail, and grasses) occurs within the fluctuation zone. Farther downstream, a distinct riparian zone is lacking. Woody riparian vegetation, including box elder, narrow leaf cottonwood, and willow, occurs along the reservoir shore where Crystal Creek enters the reservoir.

3.4.3.2.2 Wildlife

Although little is known about the nongame species in the areas around the Aspinall reservoirs, species expected to occur there include Woodhouse's toad, leopard frog, milk snake, red-tailed hawk, yellow warbler, lazuli bunting, song sparrow, dusky shrew, least chipmunk, and mountain vole (Garner 1992). Because of the limited amount of riparian vegetation around the reservoir (Section 3.4.3.2.1), these species are not expected to depend on reservoir water level.

Golden eagles and prairie falcons nest annually near the Aspinall reservoirs (Distel 1992; Garner 1992), and several areas along Blue Mesa Reservoir serve as golden eagle roost areas. Both species use cliff sites for nesting and roosting but do not forage over the water or in riparian areas.

The Gunnison River and Aspinall reservoirs provide habitat for the river otter and beaver (Garner 1992). Ten otters were reintroduced in 1979 below Crystal Dam (Klein 1992), but the current status of this species in the area is not known (Garner 1992). Beaver are common in the region and may occur along the reservoirs (Garner 1992).

Several species of waterfowl could occur on the reservoirs during the breeding season, migration, and in the winter (Garner 1992). Ducks and geese that breed in the area include Canada goose, mallard, green-winged teal, blue-winged teal, northern pintail, and American widgeon. Common migrants would include these same species as well as northern shoveler and common goldeneye. It is unlikely that any of these species would occur during the winter since the reservoirs usually freeze over by mid-winter.

Hérons and shorebirds expected to use shoreline habitats (especially fluctuation-zone areas) include great blue heron, killdeer, and spotted sandpiper. These species are fairly common in the area during the breeding season and migration. A great blue heron nesting area occurs at the upstream end of Blue Mesa Reservoir near South Beaver Creek (Garner 1992).

Game mammals that occur in the vicinity of the Aspinall Unit include elk, mule deer, and bighorn sheep (Garner 1992; Tollefson 1992). All of these species are expected to use riparian habitats along the reservoirs, but none is restricted to these habitats at any time of the year.

Elk and mule deer range widely throughout the region. The area immediately surrounding Crystal and Morrow Point reservoirs receives little use from elk or mule deer, while that around Blue Mesa Reservoir serves as summer and winter range for both (Garner

1992). In severe winters, elk and mule deer move closer to Blue Mesa Reservoir and its tributaries but still use a wide area around the reservoir well beyond any riparian habitats.

The range of bighorn sheep includes the entire area along Crystal and Morrow Point reservoirs, but only limited areas around Blue Mesa Reservoir (Lake Fork of the Gunnison River and West Elk Creek arm of the reservoir) (Garner 1992).

3.4.3.3 Threatened and Endangered Species

The current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species along the reservoirs of the Aspinall Unit on the Gunnison River is summarized in this section. Definitions of listing categories maintained by the Federal Government and the state of Colorado are presented in Appendix D, Section D.4; correspondence with the USFWS regarding threatened and endangered species in the area is provided in Section D.4.5.

3.4.3.3.1 Aquatic Species

No Federal or state-listed threatened or endangered fish species occur in the Aspinall Unit reservoirs (Hebein 1992; Rose 1992). One Federal Category 2 species, the flannelmouth sucker, has been reported from Blue Mesa Reservoir (Tyus et al. 1982; Hebein 1992).

3.4.3.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the reservoirs of the Aspinall Unit are listed in Table 3.12. Habitats or locations where these species occur are also included in the table. Federally listed species of the area are discussed below.

Whooping Crane (Endangered)

The small population of whooping cranes that migrates through the area of Flaming Gorge Dam (Section 3.4.1.3.2) also migrates through the region of the Aspinall Unit in the spring and fall. Habitats used during migration by these cranes include agricultural fields, wetlands, and small reservoirs (Rose 1992). Although whooping cranes have not been observed in the area, Blue Mesa Reservoir is in an area of relatively low topographic relief and is a potential stopping point for migrating cranes. The marsh at the upstream end of the reservoir could serve as suitable foraging habitat. The steep canyon walls of Crystal and Morrow Point reservoirs greatly reduce the suitability of these reservoirs to migrating cranes.

TABLE 3.12 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species in the Vicinity of the Aspinall Unit Reservoirs on the Gunnison River

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Plants				
Gunnison milkvetch	<i>Astragalus anisus</i>	NL	CO-3	Observed near end of Soap Creek arm of Blue Mesa Reservoir (Klein 1992).
Skiff milkvetch	<i>Astragalus microcymbus</i>	C2	CO-1	Observed near upper end of Blue Mesa Reservoir (Klein 1992).
Rocky Mountain thistle	<i>Cirsium perplexans</i>	NL	CO-2	Observed near Crystal Reservoir (Klein 1992).
Sierra corydalis	<i>Corydalis casaena brandegei</i>	NL	CO-3	Observed near upper end of Blue Mesa Reservoir (Klein 1992).
Black Canyon gilia	<i>Gilia penstemonoides</i>	3C	CO-1	Observed on cliff faces in vicinity of Aspinall reservoirs and along Gunnison River (Klein 1992; O'Kane 1988).
Colorado desert-parsley	<i>Lomatium concinnum</i>	C2	CO-1	Observed near Crystal Reservoir (Klein 1992).
Hanging garden sullivania	<i>Sullivantia purpusii</i>	3C	CO-4	Observed near Blue Mesa Reservoir (Klein 1992).
Birds				
Whooping crane	<i>Grus americana</i>	E	CO-E	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Rose 1992).
Greater sandhill crane	<i>Grus canadensis tabida</i>	NL	CO-E	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Peterson 1990).
White-faced ibis	<i>Plegadis chihi</i>	C2	CO-NL	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Peterson 1990).

TABLE 3.12 (Cont.)

Common Name ^a	Scientific Name	Federal Status ^b	State Status ^c	Occurrence within Area
Birds (Cont.)				
Bald eagle	<i>Haliaeetus leucocephalus</i>	E	CO-E	Winters along shores of Aspinall reservoirs (Garner 1992; Rose 1992).
Peregrine falcon	<i>Falco peregrinus</i>	E	CO-E	Nests on cliffs along Morrow Point Reservoir; potential nest sites along Crystal and Blue Mesa reservoirs; may winter in area (Distel 1992).
Northern goshawk	<i>Accipiter gentilis</i>	C2	CO-NL	Observed during breeding season along Crystal Reservoir; may nest in woodlands of area (Distel 1992).
Loggerhead shrike	<i>Lanius ludovicianus</i>	C2	CO-NL	Occurs year-round in woody riparian vegetation in the area (Garner 1992).
Mammals				
Spotted bat	<i>Euderma maculatum</i>	C2	CO-NL	Potential occurrence of foraging individuals along reservoirs and Gunnison River (Hoffmeister 1986).
Southwestern river otter	<i>Lutra canadensis sonora</i>	C2	CO-E	River otter (not southwestern subspecies) introduced near Crystal reservoir and Gunnison River (Garner 1992); suitable habitat present for southwestern subspecies.

^a List of species derived from USFWS (1991a,d); Harris (1991); Rose (1992); Klein (1992).

^b Federal listing codes: C2 = category 2 candidate, 3C = no longer a candidate for listing because common or well-protected, E = endangered, NL = not listed (definitions provided in Appendix D, Section D.4.1).

^c State listing codes: CO-1 = Colorado list 1, CO-2 = Colorado list 2, CO-3 = Colorado list 3, CO-E = Colorado endangered, C-NL = not listed by Colorado (definitions provided in Appendix D, Section D.4.3).

Bald Eagle (Endangered)

Bald eagles occur along each of the Aspinall Unit reservoirs in the winter (Garner 1992). Up to 52 eagles have been counted along the reservoirs during annual mid-winter surveys (Distel 1992). During the winter, eagles perch in large trees near open, ice-free water and forage for fish and occasionally waterfowl. Use of the area by bald eagles is relatively recent and has occurred as eagle populations have increased throughout the western United States over the past decade.

Although nesting has not been documented in the vicinity of the Aspinall Unit, nesting activity was reported elsewhere within the region in 1990. Published results of annual bald eagle breeding surveys included 10 nests in Colorado (Kjos 1992). Potential bald eagle nest trees along the Aspinall reservoirs include narrowleaf cottonwood and Douglas-fir.

Peregrine Falcon (Endangered)

The peregrine falcon has been observed in the vicinity of the Aspinall Unit, but it is less common there than in the vicinity of Glen Canyon and Flaming Gorge dams. Potential nest sites occur in cliffs along Crystal and Morrow Point reservoirs, but only one active nest was observed (on Morrow Point Reservoir) in 1991. Competition with golden eagles and great-horned owls may limit the peregrine falcon population in this area (Distel 1992). Although peregrines usually occur in the area during the breeding season (March - October), some individuals (possibly those that breed in the arctic) may be present during the winter (Peterson 1990; USFWS 1977). Additional background information on the peregrine falcon is presented in Section 3.4.1.3.2.

3.5 CULTURAL RESOURCES

This section describes the regional cultural backgrounds and summarizes current information on the presence of (1) prehistoric and historic archaeological sites and structures and (2) Native American cultural resources for each of the affected areas. A Class I Overview was conducted for segments of the Green, Gunnison, and Rio Grande rivers (Moeller et al. 1993a). The Colorado River was covered by the National Park Service in a separate document (Fairley et al. 1991).

3.5.1 Glen Canyon Dam

3.5.1.1 Regional Prehistory, Ethnohistory, and History

The prehistory of northwestern Arizona can be subdivided into three major periods: Palaeoindian, Archaic, and Formative. Remains from the Palaeoindian period (9,000-7,000 B.C.), which reflect an emphasis on the hunting of large mammals (including mammoth and bison) and the manufacture of distinctive lanceolate projectile points (Jennings 1989),

are confined to isolated surface finds in this region (Fairley 1989a, p.89). During the Archaic period (7,000 B.C.-A.D. 300), a more generalized economy based primarily on small game procurement and plant collecting developed in response to the drier environments of the postglacial epoch. In northwestern Arizona, the Archaic period is represented by various point types, sandals, split-twist figurines, and less diagnostic artifacts (Fairley 1989a, pp. 89-100); only sites of the late Archaic are well documented in the Grand Canyon river corridor (Fairley et al. 1991). The Formative period (A.D. 300-1200) is divided into Basketmaker and Pueblo phases and reflects the gradual development of agriculture and pottery (Fairley 1989a). Sites of the Pueblo II phase are particularly well represented and often contain dwelling and storage structures.

After A.D. 1200, puebloan people abandoned northwestern Arizona, and Numic-speaking peoples entered the region. At the beginning of the historic, or Euro-American, period, the Southern Paiute inhabited the Grand Canyon area (Kelly 1964; Euler 1966). Ethnohistoric studies indicate that Southern Paiute bands occupied the plateau areas for plant collecting and large mammal hunting during the warmer months, moving into lower elevations and canyon bottoms during winter and early spring. Horticulture was practiced to a limited extent.

The Euro-American period began in 1540 with the first Spanish exploration of the Colorado River. During the Spanish-Mexican period (1776-1848), the area was visited by Mexican traders and Anglo-American fur trappers. Permanent Euro-American settlement of the region began after 1850 with the appearance of Mormon missionaries, ranchers, and farmers (Fairley 1989b). The U.S. government sponsored explorations of the Colorado River by John Wesley Powell during 1869-1872 (Powell 1875). Miners first entered the Grand Canyon at this time, and extensive mining for gold, copper, and other minerals continued through the 1920s (Fairley et al. 1991).

3.5.1.2 Prehistoric and Historic Archaeological Sites and Structures

The affected area for archaeological sites and structures has been broadly defined as a 255-mi-long corridor extending along the Colorado River from Glen Canyon Dam to Separation Canyon. The minimum width of the corridor corresponds to the 300,000-cfs water level, and the maximum width includes all areas covered with sediment derived from the river (including fluvial sediment reworked by wind action) above that level (Fairley et al. 1991). Corridor width varies significantly according to valley morphology, ranging from narrow segments confined by sheer canyon walls (e.g., Upper Granite Gorge) to broad segments containing alluvial terraces, colluvial deposits, and dunes on high bedrock surfaces (Fairley et al. 1991; Hereford et al. 1993).

Prehistoric remains along the Colorado River were first described by Powell during his exploratory expeditions of 1869-1872 (Powell 1875). Between 1920 and 1953, several archaeological investigations (amateur and professional) were undertaken in the affected area, and a partial inventory of sites was compiled (e.g., Smithsonian Institution 1920; Taylor 1958). More intensive surveys were conducted during 1960-1970, documenting a total of

140 archaeological sites (Schwartz 1963, 1965; Euler and Taylor 1966; Euler 1967). The site inventory has been supplemented in a piecemeal fashion by new discoveries made during monitoring trips and other routine activities by NPS archaeologists since 1974 (Balsom 1985; Fairley et al. 1991).

To compile a more complete inventory of sites and structures for the Glen Canyon EIS, an intensive 100% survey of the entire affected area was undertaken in 1990-1991 (Fairley et al. 1991). The 1990-1991 survey was preceded by a preliminary survey of the corridor between Glen Canyon Dam and Lees Ferry in 1980, which recorded 24 sites and 23 isolated finds (Fairley et al. 1991). In October 1989, a pilot study of site erosion was conducted by NPS, Reclamation, and USGS at a site in the river corridor known as Furnace Flats (Balsom 1989). That study, which confirmed the presence of sites below the historical high water mark and identified a potential link between dam operations and site erosion, set the stage for the 1990-1991 comprehensive survey (Fairley et al. 1991). That survey entailed a surface examination of all accessible portions of the affected area (total area of 10,506 acres) along parallel transects (30-150 ft apart), adjusting to slopes and other landforms as necessary (Fairley et al. 1991). Although some additional sites may remain unrecorded in areas inaccessible due to topography, with poor surface visibility due to dense vegetation, and where remains are completely buried below the ground surface, the comprehensive inventory, which was undertaken in consultation with the Arizona State Historic Preservation Officer (SHPO), the Advisory Council on Historic Preservation, and Native American tribes is adequate for compliance with applicable state and Federal regulations.

A total of 475 prehistoric and historic archaeological sites and structures and 489 isolated finds are currently recorded within the affected area (Fairley et al. 1991). The isolated finds (e.g., charcoal stains without associated artifacts, possible rock alignments) do not warrant further discussion. Archaeological sites containing prehistoric remains include lithic scatters, ceramic scatters, petroglyphs, agricultural features (e.g., check dams), structures (e.g., kivas), and rockshelters. These sites occur in a variety of topographic settings, such as river terraces, alluvial fans, dunes, and rockshelters. Most prehistoric occupations date to the late period (primarily Pueblo), although a few sites contain remains assigned to earlier periods (including late Archaic and Basketmaker II) (Fairley et al. 1991). The 80 sites assigned to the historic or Euro-American period include debris scatters, mining camps, structures (e.g., cabins), graves, inscriptions, and boat wrecks (e.g., the Ross Wheeler wreck).

At the present time, 313 (or 66%) of the 475 prehistoric and historic sites in the affected area have been determined eligible for the *National Register of Historic Places* (NRHP) by the Arizona SHPO. Fourteen sites have been determined ineligible, and nine sites require additional testing in order to complete eligibility determination. One of the sites determined to be ineligible is currently under reevaluation. The remaining sites have not been evaluated.

3.5.1.3 Native American Cultural Resources

Native American cultural resources that could be affected by the hydropower operational scenarios under consideration in this EIS include archaeological sites that represent traditional or sacred properties, sacred locations or areas, landforms of religious or cultural significance, and biotic and abiotic resources of traditional cultural value. Potentially affected Native American cultural resources occupy the same area as potentially affected archaeological sites (Section 3.5.1.2). Native American tribes that have identified or may identify cultural resources in this area include the Havasupai, Hopi, Hualapai, Navajo, Southern Paiute, and Zuni.

Collection and dissemination of information regarding the locations, significance, and other details of Native American cultural resources is restricted by the sensitivity of this information. Nevertheless, some of this information is available for inclusion in this EIS. A total of 75 archaeological sites of traditional cultural significance to the Havasupai and Hualapai tribes have been identified. Cultural resources of importance to the Hopi include springs, Salt Mines (including sacred sand at its base), birds with yellow feathers, all endangered and candidate listed species, aquatic organisms, marsh and riparian vegetation (especially reeds, willows, and cattails), and 156 archaeological sites. The Hualapai have also identified various cultural resources, including sacred locations in side-valley canyons, springs (e.g., Honga), mineral (e.g., hematite) collection areas, plants (specifically cattails, willows, arrowweed, mesquite, catclaw, agave, and yucca), mammals (including sheep, deer, elk, and others), and 75 archaeological sites (Reclamation 1993).

Less information is available regarding sites, areas, and resources of cultural or religious significance to the remaining affected tribes. The Navajo have identified a number of archaeological sites, traditional use areas, and landforms (including the terraces and beaches of the Colorado River) of cultural importance. Sites, areas, and resources of significance to the Southern Paiute (Kaibab, Shivwits, and San Juan) and Zuni are likely to occur in the affected area as well. Additional information regarding these cultural resources will be available in the near future (Reclamation 1993).

3.5.2 Flaming Gorge Dam

3.5.2.1 Regional Prehistory, Ethnohistory, and History

The prehistory of eastern Utah and western Colorado can also be subdivided into the three major periods Palaeoindian, Archaic, and Formative. The Palaeoindian period (9,000-5,000 B.C.), which apparently reflects an emphasis on the hunting of large mammals, is represented by distinctive lanceolate projectile point types (Schroedl 1977; Jennings 1989). In this region, Palaeoindian remains are largely confined to isolated finds (Grady 1984; Truesdale et al. 1989), although late Palaeoindian habitations have been discovered at two sites in Dinosaur National Monument (Breternitz 1970; Leach 1970). During the Archaic period (5,000 B.C.-A.D. 500), a more generalized economy (based heavily on small game

procurement and plant collecting) developed. The Archaic is represented by various point types, as well as groundstone artifacts, basketry, and other items (Jennings 1978), and remains of this period are common in the region (Truesdale et al. 1989). The Formative period (A.D. 300-1300) reflects the introduction of agriculture, although hunting and gathering continued to play a major role in the economy. The Formative (or "Fremont Culture") is also well represented in the region (Breternitz 1970); diagnostic remains include pottery and former pithouses (Jennings 1978; Grady 1984).

During the period A.D. 1000-1300, the Fremont Culture disappeared, and the region was inhabited by the Numic-speaking tribes, including the Southern Paiute-Gosiute and Shoshone-Ute (Euler 1966). Their economy was primarily based on hunting and gathering, but some horticulture was also practiced. During warmer months, small groups exploited resources at higher elevations; larger groups inhabited the southern parts of the region during the winter months (Hughes 1977; Marsh 1982). An account of Ute religion, including burial practices, is provided by Delaney (1989), Marsh (1982), and others.

The first Euro-Americans, including Spanish explorers and early trappers, entered the region between 1776 and 1825 (Hafen 1972). By 1838, Fort Davy Crockett was established as a trading post in Browns Park near the mouth of Vermillion Creek (Eddy et al. 1982). After the decline of the fur trade, the region was traversed by several trails and ferries used in Euro-American settlement of the west after 1840 (Purdy 1959; Tennent 1981; Webb 1986). Cattle ranching began in Browns Park during 1850-1870, and outlaws (including Butch Cassidy) visited the area during these years. Dry farming was attempted between 1900-1930; after this period, residents of Browns Park returned to raising livestock.

3.5.2.2 Archaeological Sites and Historic Structures

Areas containing potentially affected cultural resources are confined to a narrow corridor along the Green River from Flaming Gorge Dam to the mouth of the Yampa River. The minimum width of this corridor is 0.5 mi from each bank of the river, and the maximum width corresponds to the contour interval 60 ft above mean water level (as defined on current USGS topographic maps) (Moeller et al. 1993a). Although many archaeological sites are located on and near the margins of Flaming Gorge Reservoir (Purdy 1959; Day and Dibble 1963), hydropower operations have negligible effects on reservoir levels. Below the Yampa River confluence, any effects of the hydropower operations would be obscured by the impact of the Yampa River. Therefore, cultural resources in these areas are not considered part of the affected environment.

The affected area has been subject to at least 26 archaeological and historic site surveys (Moeller et al. 1993a, Table 2). These surveys included 23 intensive 100% surveys employing pedestrian transect methods (e.g., Lindsay 1986; McFadden 1978), 2 systematic random sampling surveys also employing pedestrian transects (e.g., Madsen and Sargent 1979), and 1 historic inventory (Tennent 1981). Among the systematic random sampling surveys was the Peaking Power Project, which examined a 200-ft-wide corridor on each side of the river (40% sample) between Flaming Gorge Dam and Dinosaur National Monument

(Norman and Merrill 1981). Overall, about 30% of the affected area has been subject to intensive archaeological survey, and approximately 100% has been surveyed with nonintensive or random sampling methods (Moeller et al. 1993a).

An inventory of archaeological sites and historic structures in the affected area was undertaken in 1991 for this EIS (Moeller et al. 1993a). The inventory was based primarily on a review of existing literature and file data, including the surveys described above, but was supplemented with the results of a field study conducted in June 1992 (Moeller et al. 1993b). Seventy-one prehistoric, 26 historic, and 2 combined prehistoric/historic sites are currently recorded in the area. With the exception of one prehistoric site reported from Red Canyon near Flaming Gorge Dam (Day and Dibble 1963, p.77) and a historic cabin (Wade and Curtis Cabin) formerly located in the Canyon of Lodore, sites are absent in the narrow bedrock canyons (Norman and Merrill 1981; Moeller et al. 1993b); although sites do occur within the study corridor on the higher bedrock surfaces above the canyons.

The principal concentrations of sites are found in (1) Little Hole, (2) upper Browns Park (above Swallow Canyon), and (3) lower Browns Park. At least 20 sites are located in the Little Hole area, including prehistoric lithic scatters, a historic mining camp, and combined historic corral/prehistoric lithic scatter. The geomorphic setting of these sites is bedrock or the second terrace level (15 ft above river level). No sites are recorded on the first terrace, 6 ft above river level (Moeller et al. 1993b). In upper Browns Park, at least 26 sites are reported within the corridor boundaries, including prehistoric lithic scatters, a historic irrigation ditch, and the John Jarvie Ranch (Tennent 1981). Although their geomorphic context is largely confined to bedrock or the second terrace, at least two prehistoric lithic scatters are situated on side-valley fan deposits (10-15 ft above river level) that overlie the first terrace (Moeller et al. 1993b), and the John Jarvie Ranch is located on the first terrace. A total of 29 sites are located in lower Browns Park, including prehistoric lithic scatters, petroglyphs, Lodore School, Flynn Cabin, and Fort Davy Crockett. These sites are located on bedrock, the second terrace, and the first terrace (Moeller et al. 1993b). One additional site is located on the first terrace above the confluence of the Yampa and Green Rivers, just below Canyon of Lodore.

Of the sites described above, three of the historic localities are currently listed on the NRHP. An additional 20 prehistoric, 18 historic, and 2 combination prehistoric/historic sites are considered eligible or potentially eligible for the NRHP.

3.5.2.3 Native American Cultural Resources

Native American groups that formerly occupied the affected area may identify sites, areas, or resources of religious or cultural significance within the corridor boundaries. These resources may include former living sites, burials, traditional use areas, sacred sites, and resources of cultural significance (e.g., sacred plants). During preparation of this EIS, representatives of the San Juan Southern Paiute, Southern Ute Tribe, Ute Mountain Tribe, and Ute Indian Tribe (Uintah and Ouray Reservation) were contacted for identification of cultural resources (Sabo 1992a,b).

3.5.3 Aspinall Unit

3.5.3.1 Regional Prehistory, Ethnohistory, and History

The regional prehistory and ethnohistory for the affected area is the same as that presented for Flaming Gorge Dam (Section 3.5.2.1). However, local history for the Gunnison River differs to some degree from that of the Green River. Spanish explorers and traders first reached the Gunnison River in 1765 and returned in 1776, 1805, and 1813 (Hafen 1948). During the 1830s, a fur trading post (Fort Robidoux) was constructed on the Gunnison River near the mouth of the Uncompahgre River (Hafen 1948). Increased Euro-American settlement of the area, which began with the influx of gold miners after 1859 and continued with the establishment of cattle ranches during 1871-1874, eventually led to conflicts with the Ute. In 1880, the Ute ceded most of their lands in Colorado and were removed to the Uintah Reservation in Utah (Fritz 1941). The discovery of coal in the area in 1879 encouraged further mining exploitation, and in 1881-1882, railroad lines reached the town of Gunnison (founded in 1874). The growth of fruit agriculture led to the establishment of other towns in the area, including Montrose, Grand Junction, and Delta. By the 1890s it had become the primary fruit producing area of the state. Large-scale irrigation projects were developed to support the agricultural industry, and in 1904-1909, Reclamation excavated a tunnel through the Uncompahgre Mountains to divert water from the Gunnison River to the Uncompahgre River for irrigation (Fritz 1941).

3.5.3.2 Archaeological Sites and Historic Structures

Areas containing potentially affected cultural resources are confined to the margins of the Blue Mesa Reservoir and a narrow corridor extending from Blue Mesa Dam to Crystal Dam. The minimum width of this corridor is 0.5 mi from each bank of the river, and the maximum width corresponds to the contour level 60 ft above river/reservoir level (as indicated on USGS topographic maps) (Moeller et al. 1993a). Because Crystal Dam functions as a reregulation dam, areas downstream of this unit were eliminated from consideration.

The affected area has been subject to six archaeological and historic site surveys (Moeller et al. 1993a, Table 5). They include an early unsystematic survey of Blue Mesa Reservoir (Lister 1962); a 100% intensive survey of Curecanti National Recreation Area, employing fifteen 150-ft pedestrian transects (Stiger 1977, 1980); two small intensive surveys (NPS 1990b; Weber 1991); and two unsystematic surveys below Blue Mesa Dam (Buckles 1964; Breternitz 1974). About 80% of the affected area has been intensively surveyed (Moeller et al. 1993a).

Archaeological sites and historic structures in the affected area were inventoried (Class I) in 1991 for this EIS. The inventory was based on a review of existing literature and file data (primarily derived from the surveys described above) (Moeller et al. 1993a). A total of 144 sites are currently recorded within the corridor boundaries; 92% of them are located along the margins of Blue Mesa Reservoir (Stiger 1977, 1980). The remaining sites are on

high bedrock surfaces above the river between Blue Mesa Dam and Morrow Point Dam. Two exceptions are a section house and other structures associated with the Denver and Rio Grande Railroad near the mouth of Curecanti Creek and a prehistoric site; both are located at the bottom of the canyon. No sites are recorded between Morrow Point Dam and Crystal Dam.

As in the case of the Green River (Section 3.5.2.2), archaeological surveys indicate that few remains are located in the canyon bottoms (Buckles 1964; Breternitz 1974; Stiger 1977, 1980). Within the corridor boundaries, 133 sites are concentrated around Blue Mesa Reservoir. They include 130 prehistoric sites, most of which are classified as lithic scatters or campsites. Several of these sites are associated with features, including traces of former structures, or stone quarries. Five of the prehistoric sites may also contain historic remains. The three historic sites include steel bridges and a trash scatter. Prehistoric sites are located on bedrock and alluvial sediment and are often associated with tributary streams. Thirteen sites are completely submerged, three are partially submerged, and seven sites occur within 20 ft of the high water level (as indicated on USGS topographic maps).

Of the sites described above, 67 occur within the Curecanti National Register District; these sites are listed as a collective unit on the NRHP. Eligibility determinations have not been made for the remaining sites, although at least some of them (77) appear potentially eligible.

3.5.3.3 Native American Cultural Resources

Native American cultural resources of the affected area are the same as those described for Flaming Gorge Dam in Section 3.5.2.3.

3.6 LAND USE

Public lands dominate land ownership in the states of Utah, Colorado, Arizona, and Wyoming, through which the Colorado, Gunnison, and Green rivers flow. A large portion of the public land is Federally owned and consists primarily of national parks, monuments, forests, and reservation lands. The state of Utah alone contains all or part of eight national forests, five national parks, five national monuments, five Native American reservations, three national wildlife refuges, and two national recreation areas. The Bureau of Land Management (BLM) administers the largest portion of Federal land in each of the four states. Recreation is a key component in the management of the region's public lands and plays a critical role in the area's physical, social, and economic environment.

3.6.1 Glen Canyon Dam

The affected area for Glen Canyon Dam is a 255-mi-long Colorado River segment that meanders through Coconino and Mohave counties in northwestern Arizona and stretches continuously from Glen Canyon Dam through the Lees Ferry reach of Glen Canyon National

Recreation Area and through Grand Canyon National Park into the headwaters of Lake Mead near Separation Canyon (Figure 3.27). The corridor includes the river and a narrow strip of land along each side of the river that extends up to 500 ft beyond either shoreline.

Recreation is the dominant land use in the affected area. The largest urban area within 75 mi of the affected area is Flagstaff, Arizona, about 80 mi southeast of the city of Grand Canyon. In 1990, the population of Flagstaff was 45,857 persons (U.S. Bureau of the Census 1991a). Page, Arizona (1990 population of 6,598) is located on a mesa above the Colorado River, about 2 mi southeast of Glen Canyon Dam.

The affected section of the Colorado River runs exclusively through public and tribal lands. Beginning at Glen Canyon Dam, the river flows south through the lower reaches of Glen Canyon National Recreation Area (Glen Canyon NRA), and through most of Grand Canyon National Park. The river passes below sections of the Navajo Indian Reservation and the Hualapai Indian Reservation before flowing into Lake Mead NRA. Glen Canyon NRA, Grand Canyon National Park, and Lake Mead NRA are administered by the National Park Service (NPS).

Land in Grand Canyon National Park is managed according to zoning classifications defined in the park's Statement for Management (NPS 1985). Most of the park's 1.2 million acres is zoned under a "natural" classification. Approximately 95% of the park is currently under consideration for designation as a wilderness (NPS 1993). About 2% of the park is controlled by the Navajo Nation. This land, located on the eastern side of the river in Marble Canyon, supports some grazing. A few inactive, privately owned mining claims totaling 357 acres are located on the northern bank of the Colorado River below Grandview overlook. The Grand Canyon National Park Statement for Management (NPS 1985) includes a map of zoning categories in the park. A new management plan is being developed.

Most of the land in Coconino and Mohave counties in Arizona is Federally owned. Native American reservation lands account for 37% of the land in Coconino County; the U.S. Forest Service (USFS) manages about 30%; the NPS controls 7%; and about 15% is privately owned (Aber 1992). The BLM is the principal landowner in Mohave County, with jurisdiction over about 50% of the land in the county. NPS lands account for 12% of the land in the county, and about 20% is privately owned (White 1992). Grazing is the primary agricultural activity on private lands in Coconino and Mohave counties, but no agricultural activity occurs in the affected area. The Coconino County comprehensive plan was last updated in 1990 (Aber 1992). An updated version of the Mohave County comprehensive plan is expected to be completed by the end of 1993.

Agency land and resource management plans, county comprehensive plans, and other land use control guidelines or documents that govern the Colorado River segment examined in this EIS are listed in Table 3.13.

FIGURE 3.27 Land Use in the Vicinity of the Glen Canyon Dam

TABLE 3.13 Land Use Planning and Management Documents Pertaining to the Glen Canyon Dam Area

Jurisdiction	Agency	Document Title	Year Updated
Coconino County (Arizona)	County	Comprehensive Plan	1990
		Zoning Ordinance	1981
City of Page (Arizona)	City	Zoning Code	1981
		Community Master Plan	1989
		Gateway Area Specific Development Plan	1989
Mohave County (Arizona)	County	Comprehensive Plan	1993
Grand Canyon National Park (Arizona)	National Park Service	Final Master Plan	1976
		Statement for Management	1985
		Colorado River Management Plan	1989

The regional transportation network includes two interstate highways (I-15 and I-40), two other Federal highways (U.S. 180 and U.S. 89), three Arizona state highways (Routes 64, 67, and 98), and several county roads. Commercial airline service is available in Page, Flagstaff, and Grand Canyon National Park.

3.6.2 Flaming Gorge Dam

The affected area of the Green River is in the eastern sections of Dagget and Uintah counties in northeastern Utah and the western portion of Moffat County in northwestern Colorado (Figure 3.28). The affected area consists of a narrow corridor about 95 mi long from Flaming Gorge Dam to a point upstream of Jensen, Utah. The width of the corridor includes the river and extends 500 ft inland from either shoreline. Vernal, Utah, about 40 mi south of Flaming Gorge Dam, had a population of 6,644 persons in 1990 (U.S. Bureau of the Census 1991b) and is the largest urban area in the vicinity. Recreational activities dominate land use within the affected area.

Except for a few small privately owned ranches, the affected area consists primarily of public lands under the jurisdiction of the state of Utah and several Federal agencies. Included are portions of Flaming Gorge NRA, the state of Utah's Browns Park Waterfowl Management Area, Browns Park National Wildlife Refuge, and Dinosaur National Monument (Figure 3.28).

Management of public lands along the Green River between the dam and the Colorado state border (about 29 mi) is governed by a 1983 interagency agreement between

the USFS, BLM, and Utah Division of Wildlife Resources (BLM 1991). The USFWS administers Browns Park National Wildlife Refuge. Dinosaur National Monument, which occupies about 211,000 acres in Moffat County, Colorado, and Uintah County, Utah, is managed by the NPS (NPS 1986a).

Grazing is the principal agricultural activity on private lands in the three counties containing the affected area, with crop production occurring on less than 5% of the private land in each county. Although little agricultural activity occurs within the affected area, some grazing allotments have been issued near the river. These allotments are administered by the BLM in the upper reaches of the corridor and by the NPS in the parcels in Dinosaur National Monument. No mining or logging occurs near the river. All three counties have master plans or other planning documents.

Special land uses in or adjacent to the affected area include a nationally recognized historic ranch and a wilderness study area (Figure 3.28). The John Jarvie Ranch, a national historic site administered by the BLM, is on the northern shore of the Green River in Browns Park. The Diamond Breaks Wilderness Study Area is a 3,900-acre tract bounded by the Green River on the north and by Browns Park National Wildlife Refuge and Dinosaur National Monument on the east. The study area is administered by the BLM according to interim management policy criteria, which provide direction until Congress either approves a Wilderness Area designation for Diamond Breaks or drops it from consideration (BLM 1991).

The Green River from Flaming Gorge Dam to a point just beyond Split Mountain campground in Dinosaur National Monument is being considered for inclusion in the National Wild and Scenic Rivers System (Eason 1992b). If the river stretch is included, the USFS, BLM, and NPS would retain administrative control of the river but would modify existing land management policies to comply with regulations associated with a change in designation. Most of the study area segment located in Dinosaur National Monument is also being considered for designation as a Wilderness.

All agency land and resource management plans, statements for management, county comprehensive plans, or other land use control guidelines or documents that govern the affected area are listed in Table 3.14.

The transportation network that provides access to the Green River area below Flaming Gorge Dam consists of state and Federal highways and county roads. U.S. 191 runs north from Vernal over Flaming Gorge Dam and into Wyoming. U.S. 40 is an east-west artery that runs through Vernal and links the area with Salt Lake City (175 mi west) and Denver (330 mi east). Commercial airline service is available in Vernal.

3.6.3 Aspinall Unit

The Aspinall Unit is within the boundaries of the Curecanti NRA in southwestern Colorado. Curecanti NRA contains Blue Mesa, Morrow Point, and Crystal reservoirs

TABLE 3.14 Land Use Planning and Management Documents Pertaining to the Flaming Gorge Dam Area

Jurisdiction	Agency	Document Title	Year Updated
Flaming Gorge National Recreation Area (Utah and Wyoming)	Forest Service	Management Plan	1977
Diamond Mountain Resource Area (Utah)	Bureau of Land Management	Resource Management Plan	1992
Little Snake Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1989
Green River, from dam to Utah/Colorado state line	Forest Service	Green River Scenic Corridor Management Plan	1985
Dinosaur National Monument (Colorado)	National Park Service	Statement for Management General Management Plan	1990 1986
Uintah County (Utah)	County	Interim Land Use Policy Plan Community Development and Housing Needs Policy Plan	1991 1992
Moffat County (Colorado)	County	Comprehensive Plan	1982

(Figure 3.29). Black Canyon of the Gunnison National Monument borders the Curecanti NRA on the west. Grand Junction, Colorado, with 29,034 residents in 1990, is the largest urban area within 75 mi of the Aspinall Unit (U.S. Bureau of the Census 1991c). Recreation is the dominant land use at the Aspinall Unit and on the public lands that surround it.

The Curecanti NRA is in southwestern Colorado on the Gunnison River between the cities of Gunnison and Montrose. The national recreation area occupies about 40,500 acres in the southwestern section of Gunnison County and the eastern reaches of Montrose County (NPS 1990a). Large portions of both counties consist of state and Federally owned land (Figure 3.29). The affected area includes the reservoirs of Curecanti NRA and a strip of land, 500 ft wide, that surrounds each reservoir. It consists of Federal lands under the jurisdiction of Reclamation and the NPS. Since 1965, the NPS has administered recreational use and development of land in the Curecanti NRA (Reclamation 1992).

Land in Curecanti NRA is managed under four broad zoning categories — park development, natural, historic, and special use zones. The park development zone includes

boat ramps, marinas, visitor centers, and campgrounds. Most of the recreation area is zoned under the "natural" classification. The Curecanti National Recreation Area General Management Plan (NPS 1980) contains a map and descriptions of these zoning categories.

Most of Gunnison County consists of Federally owned land. The USFS has jurisdiction over about 60% of the county land (Schmidt 1992). The county has no comprehensive or master plan, but private lands are governed by land use resolutions that were last amended in 1989 (Williams 1993).

Montrose County contains the western edge of Curecanti NRA and all of the Black Canyon of the Gunnison National Monument. The BLM owns more than 40% of the land in the county (Schmidt 1992). The county's master plan, adopted in 1987, applies to the eastern half of the county.

Most of the private land in the two-county region is used for livestock grazing. Some grazing has occurred in the recreation area, but such use has been limited and may eventually be eliminated (NPS 1990a). Crop production accounts for less than 10% of the land in both counties (U.S. Bureau of the Census 1989).

A small portion of land in the region is developed for commercial and light industrial uses. Two commercial recreation complexes are located north of U.S. 50 just beyond the Curecanti NRA in the Iola Basin portion of Blue Mesa Reservoir. Both complexes are located within a quarter mile of the reservoir and have developed campgrounds, full recreational vehicle hookups, and food services.

Agency land and resource management plans, county comprehensive plans, and other relevant documents governing land use in the affected area are listed in Table 3.15.

The transportation network in the vicinity of the Aspinall Unit includes an interstate highway, state and Federal highways, and county roads (Figure 3.29). Interstate 70 runs west from Denver and passes north of the affected area. U.S. 50 runs east-west along the southern edge of Curecanti NRA before crossing Blue Mesa Reservoir near Dillon Pinnacles. State Highway 92 parallels the northern edge of the recreation area. State Highway 149 enters Curecanti NRA from the south and joins U.S. 50 on the eastern end of Blue Mesa Reservoir. State Highway 437 provides indirect access to the east portal of Curecanti NRA. Commercial airline service is available in Montrose, Gunnison, and Grand Junction.

3.7 RECREATION

The recreational resources and recreational activity use rates on the Colorado River below Glen Canyon Dam, on the Green River below Flaming Gorge Dam, and on the reservoirs of the Aspinall Unit are described in Sections 3.7.1, 3.7.2, and 3.7.3, respectively. Recreational resources include boat ramps, riverside campsites, campgrounds, beaches, and river rapids.

TABLE 3.15 Land Use Planning and Management Documents Pertaining to the Aspinall Unit Area

Jurisdiction	Agency	Document Title	Year Updated
Gunnison Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1992
Uncompahgre Basin Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1988
Curecanti National Recreation Area (Colorado)	National Park Service	General Management Plan Statement for Management	1980 1990
Gunnison County (Colorado)	County	Land Use Resolution	1989
Montrose County (Colorado)	County	Uncompahgre Valley Master Plan	1988

3.7.1 Glen Canyon Dam

The affected environment for Glen Canyon Dam consists of a corridor containing the Colorado River that begins at the dam in the southern reaches of the Glen Canyon National Recreation Area (Glen Canyon NRA) and runs approximately 255 mi downstream through most of Grand Canyon National Park and into the headwaters of Lake Mead near Separation Canyon (Figure 3.2).

A major trout fishery is located between the dam and Lees Ferry (15.5 mi below the dam), and fishing and boating are the dominant recreational activities within this reach. In 1991, almost 210,000 anglers, boaters, raft-bound floaters, and hikers — approximately 7% of the 3,210,890 that visited Glen Canyon NRA that year — used this segment of the river (Doland 1992). Recreational facilities include 18 primitive beach campsites and a fully developed campground at Lees Ferry. Six of the primitive campgrounds are not available at flows exceeding 15,000 cfs (Reclamation 1993).

Boat access to the Colorado River in Glen Canyon NRA is limited to a dock below the dam and to the boat ramp at Lees Ferry; only commercial launches are allowed at Glen Canyon Dam. Day floaters (i.e., those who float downstream between the dam and Lees Ferry for all or part of a day) usually launch from the dock. However, dock use is restricted to flows below 29,500 cfs (Bishop et al. 1987). At higher flows, day floaters launch at Lees Ferry and motor upstream to a point near the dam before floating downriver. Anglers typically launch at Lees Ferry and move up and down the river according to fish-movement

patterns. The facilities at Lees Ferry are shared by users of Glen Canyon NRA and Grand Canyon National Park.

Below Lees Ferry, the river runs through almost 240 mi of Grand Canyon National Park. One of the nation's most popular natural attractions, the park drew over 4 million visitors in 1991 (NPS 1992a). According to NPS estimates, approximately 10% of all annual visitors engage in some activity below the canyon's rims (NPS 1985).

Recreational use along the river within Grand Canyon National Park is dominated by white-water boating. An internationally recognized white-water river, the Colorado River in the park contains more than 150 rapids. The prime white-water boating season is May 1 through September 30. In 1991, 19,427 commercial and 3,281 private passengers ran the river in Grand Canyon National Park for all or part of its length (Cherry 1993). The NPS limits white-water boating in the park to 169,950 user days per year. Access to the river within the park is limited to a few trails (most notably Bright Angel and Kaibab) and to boat ramps at Lees Ferry, Diamond Creek, and Pearce Ferry. Lees Ferry is the launching point for trips down the river, whereas Diamond Creek and Pearce Ferry are usually used as take-out points.

In addition to the trails and boat ramps, recreational resources in the affected portion of Grand Canyon National Park include a developed campground (Bright Angel) and approximately 250 beach campsites. The number and size of beach campsites varies with flow regimes.

3.7.2 Flaming Gorge Dam

The affected environment below Flaming Gorge Dam consists of a corridor containing the Green River from Flaming Gorge Dam in Flaming Gorge NRA through Dinosaur National Monument (Figure 3.28). The river below Dinosaur National Monument has relatively few recreational users or facilities and is not examined in this analysis.

Opportunities for developed and dispersed recreation are abundant in the affected corridor and surrounding area. Developed recreational facilities include visitor centers, amphitheaters, picnic grounds, and fully equipped campgrounds. Dispersed recreation opportunities in areas of minimal or no development include backcountry trails, primitive campgrounds, and isolated spots along the water. Examples of dispersed recreational activities in the river corridor include angling, boating (e.g., rafts and drift boats), hiking, hunting, camping, and wildlife observation. Of these, angling and boating are most directly affected by changes in stream flow.

Because the composition of recreational activities varies by location, the Green River was divided into two segments for purposes of analysis. The upper segment runs from Flaming Gorge Dam to the Colorado border. The lower segment consists of that portion of the river that flows from the Colorado border through Dinosaur National Monument.

3.7.2.1 Flaming Gorge Dam to the Colorado Border

The portion of the Green River that extends from the spillway below Flaming Gorge Dam in Flaming Gorge NRA to the Colorado border is approximately 29 mi long and was visited by an estimated 115,000 persons in 1991 (Sams 1992). Individuals engage in a variety of recreational activities along this stretch of the river, including shore and boat angling, nonangler boating (such as rafts and canoes), hiking, and camping.¹⁰ However, shore and boat angling are the dominant recreational activities, accounting for an estimated 104,650 user days in 1991 (Pratt et al. 1991). This figure reflects a large surge in the popularity of trout angling on the Green River, which resulted from the implementation of regulations in 1985 designed to improve the quality of the sport (Pratt et al. 1991).

Nonangler boating is far less important than angler boating as a primary recreational activity, accounting for approximately 5,750 user days in 1991 (Pratt et al. 1991). The vast majority of nonangling boaters are only on the river for all or part of a given day, usually launching at the spillway ramp and leaving the river at Little Hole. This segment of the Green River is made up almost entirely of Class I and Class II rapids (only one rapid is Class III). Class I and II rapids usually generate waves less than 1 ft high and are considered ideal for novice boaters; rapids with a designation of Class III or above require more advanced white-water skills. Typically, the recreational quality of a rapid is diminished in flows that are very low or relatively high.¹¹ Because the Green River has relatively low flows during the peak boating season, few experienced boaters are drawn to it. Consequently, most of the nonangling boaters using this segment of the Green River are novices.

Water levels on the Green River can fluctuate by several feet over the course of a day. Optimal flows for recreation vary according to activity. For shore fishing, low flows between 800 and 1,100 cfs are preferred because they allow wading into the river to cast. For boat fishing, flows close to 1,500 cfs are ideal. According to USFS officials administering recreation on the Green River between Flaming Gorge Dam and the Colorado border, flows exceeding 5,000 cfs pose a safety threat to novice boaters, and flows in excess of 6,000 cfs are considered dangerous for experienced boaters and rafters (Yates 1992b). Flows exceeding 6,000 cfs rarely occur between the dam and the Yampa River and were last recorded in 1984. Flow rates are generally lower in summer and higher in spring, particularly late spring. The Green River flow regimes are discussed in Section 3.3.2.

The peak use times for angling and nonangler boating are fairly distinct (Pratt et al. 1991). The two peak angling seasons are the spring season from April to mid-June and the fall season from September through October; the fall season attracts fewer anglers (9-15%) than the spring season (30-35%). The peak season for nonangler boating begins in mid-June

¹⁰ Most camping, hiking, and sightseeing activities occurring on the Green River between Flaming Gorge Dam and the Colorado border are associated with floating or fishing.

¹¹ In low flows, exposed rocks or sandbars can become obstacles to boats; in high flows, rapids can become submerged or dangerous.

and runs through Labor Day. About 60% of all nonangler boating occurs during this period (Pratt et al. 1991).

An estimated 89% of the shore angling, boat angling, and nonangler boating on the Green River between the dam and the Colorado border occurs in the first 7 mi of the river, between the spillway and Little Hole (Pratt et al. 1991). In addition to several Class I and II rapids, this section of the river contains the best fishing within the affected area. Most of the recreational activity that takes place on the river between Little Hole and the Colorado border consists of fishing (shore and boat) and seasonal hunting.

Recreation on the river between Flaming Gorge Dam and the Colorado border is supported by a number of developed facilities. The tailwaters area has a concrete ramp and improved facilities (toilets and water). Little Hole has two sets of twin concrete ramps, modern restrooms, running water, several picnic tables, and parking areas that were expanded and paved in the summer of 1992. Riverside camping is prohibited above Little Hole.

For those boating on the river below Little Hole, several primitive riverside campgrounds and boat ramps are available. Most of these campgrounds are located high enough above the river level to be spared from the effects of floods. None of these riverside campgrounds are affected by the flows associated with dam operations. The campgrounds at Indian Crossing and Bridge Hollow offer well water and are the most developed. An inventory of river rapids, campgrounds, and boat ramps available on the Green River between Flaming Gorge Dam and the Colorado border is presented in Figures 3.30 through 3.32.

Currently, only commercial fishing and rafting require a permit on this segment of the river. However, a study commissioned by the USFS (Pratt et al. 1991) recommended the establishment of daily use limits for two segments of the river. For the segment running from the dam to Little Hole, a limit of 750 persons per day would be imposed during the peak floating season. River use would be limited to 600 persons per day during the spring fishing season and to 350 persons per day during the off-season. A use limit of 400 persons per day was recommended by Pratt et al. (1991) for all seasons on the segment from Little Hole downstream to the Bridge Hollow campground (approximately 9 mi). The USFS is currently considering these recommendations and may act on them before the 1993 floating season begins (Yates 1992a).

3.7.2.2 Colorado Border through Dinosaur National Monument

The segment of the Green River that runs through Browns Park National Wildlife Refuge was not included in the analysis because of the limited amount of recreation that occurs in the area (Carlson 1992). The majority of recreational use occurring on the river below the Colorado border takes place in Dinosaur National Monument, which is administered by the NPS. The monument's major attractions are an internationally recognized paleontological quarry and exhibit and the Green and Yampa rivers and the

FIGURE 3.30 Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 1
 (Sources: Adapted from Evans and Belknap 1973; Hall 1992)

FIGURE 3.31 Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 2
(Sources: Adapted from Evans and Belknap 1973; Hall 1992)

FIGURE 3.32 Green River Recreational Resources from Flaming Gorge Dam to the Colorado Border: Map 3
 (Sources: Adapted from Evans and Belknap 1973; Hall 1992)

canyons through which they flow. The Green River enters the monument just above the Gates of Lodore (Figure 3.33) and runs in a southwesterly direction for approximately 55 mi before exiting downstream of Split Mountain in the western reaches of the monument. The Yampa River flows into the Green River in the central part of the monument.

Dinosaur National Monument had more than 465,000 visitors in 1991 (NPS 1991) and more than 507,000 visitors in 1992 (Eason 1993b). Most visitors spend less than one day there, engaging in such activities as a visit to the quarry or a self-guided sightseeing tour of the canyon country on Harpers Corner Scenic Drive. Most overnight visitors are campers in one of the developed drive-in campgrounds or rafters on the Green River who typically spend three to five days and two to four nights in the river corridor. Estimates of total visitation and the number of overnight stays for 1988-1991 are presented in Table 3.16.

Recreation on the Green and Yampa rivers primarily consists of nonmotorized boating or rafting. Both rivers contain several Class II and III rapids. In addition, both rivers contain rapids ranking as Class IV and V, depending upon location and water levels. The primary or high-use boating season within Dinosaur National Monument runs from early May to mid-September. River running on the Yampa River is limited to the early part of the season. Low flows usually restrict recreational activity on the Yampa River by mid-July. In 1991, boating in the monument consisted of 35,704 user-days (NPS 1992b). Although raft trips can begin on both the Green and Yampa rivers, most trips through the monument ultimately end on the Green River, usually at Split Mountain. Most trips on the Green River begin at the Gates of Lodore.

In order to raft the Green River within the monument, individuals must either go through a commercial outfitter or receive a permit for a private raft trip. Currently, 11 commercial outfitters are authorized to undertake a combined total of 300 launches during the high-use season. An equal number of permits for private launches are distributed through a lottery conducted during January of each year. Commercial launches usually involve 15 to 20 persons, whereas the average for private launches is somewhat lower. The NPS also authorizes a limited number of "special population" trips for individuals, including persons with disabilities and persons engaged in various forms of therapy (Carlson 1992).

Although releases from Flaming Gorge Dam determine flow rates on the Green River in the upper part of Dinosaur National Monument, flow rates below the confluence with the Yampa River can change substantially according to Yampa River flows. A minimum flow rate of approximately 800 cfs is considered adequate for rafting on the Green River in Dinosaur National Monument; however, higher flow rates are preferred (Eason 1992c). Typically, flow rates on the Green River above the Yampa River confluence drop to the 800-cfs threshold by late June or early July.

Boating user days in Dinosaur National Monument fell by approximately 11% between 1988 and 1989 (NPS 1992b) because of dry conditions. Since that time, use rates have steadily risen toward their former levels, and the monthly distribution of use rates has remained fairly stable. Demand for permits has consistently exceeded the available supply.

FIGURE 3.33 Recreational Resources and Facilities in Dinosaur National Monument
(Sources: Adapted from NPS undated, 1986b; Evans and Belknap 1973)

Although user days represent combined use rates for the Green and Yampa rivers, they are applicable to an analysis of the effects of flow change on the Green River because almost everyone who rafts within the monument spends at least some time on that river.

The monument offers several primitive riverside campgrounds and five developed drive-in campgrounds. A sixth drive-in campground, Split Mountain, is located on the Green River in the southwestern corner of the monument and is seasonally closed to the public. Its boat ramp, however, is used as a termination point for most raft trips. Most of the primitive riverside campgrounds are located on small terraces a few feet above the river in zones well

TABLE 3.16 Annual Visitation and Overnight Use at Dinosaur National Monument, 1988-1991

Year	Annual Visitors	Overnight Stays ^a
1988	493,651	46,611
1989	455,816	55,132
1990	469,378	72,374
1991	468,392	69,098

^a Based on estimates of persons camping in drive-in campgrounds, boat-in campgrounds, and nondesignated areas (picnic areas, overlooks, etc.).

Sources: National Park Service, Monthly Public Use Reports (NPS 1988, 1989, 1990c, 1991).

above the reach of hydropower releases. In Lodore Canyon, the majority of campgrounds and camp landings would be affected only by flows exceeding 13,000 cfs, a value well above normal and historic hydropower operations. Below the Yampa confluence, several campgrounds and camp landings would be affected only by flows exceeding approximately 40,000 cfs (Eason 1993a). An inventory of the monument's recreational resources (including principal rapids, campgrounds, boat ramps, and scenic overlooks) is presented in Figure 3.33.

Several beach areas along the river could be affected by fluctuations in flow related to hydropower generation. The largest of these include a broad beach at the confluence of the Yampa and Green rivers in Echo Park and smaller beaches at Rippling Brook, Rainbow Park, and Split Mountain. At lower flows (800 to 2,000 cfs), other beachlike areas become exposed at numerous spots along the river.

3.7.2.3 Miscellaneous Recreation

Hiking along or near the Green River is a popular pastime for many of the visitors to the area. Several trails provide access to the Green River within the confines of the affected area. Most of these are located in the upper 20 mi of the corridor and in Dinosaur National Monument. The Little Hole National Recreation Trail runs from Flaming Gorge Dam to Little Hole for approximately 7 mi. It is the most heavily used of the area trails. Parts of it become submerged at flows exceeding 5,000 cfs, which is above maximum power plant capacity. Dinosaur National Monument has self-guiding nature trails near the river at Gates of Lodore and Split Mountain. The Jones Hole Creek Trail, which is also self-guiding, runs along Jones Creek, beginning near the Jones Hole Fish Hatchery and terminating at the confluence of Jones Creek and the Green River (Figure 3.33). Echo Park, which is located at the confluence of the Green and Yampa rivers, offers hiking, camping,

fishing, and top-quality sightseeing; it is one of the more popular destinations in Dinosaur National Monument.

Other recreational attractions in the affected area include the Lodore Cemetery and Schoolhouse and the John Jarvie Ranch Historic Site (Section 3.6.2). In addition to a small museum, the Jarvie Ranch features a shaded riverside picnic area that can accommodate up to 30 persons. The Jarvie Ranch is located on the north side of the Green River in the Utah portion of Browns Park, approximately 0.25 mi upstream of the Taylor Flat Bridge.

3.7.3 Aspinall Unit

The affected environment for the Aspinall Unit consists of Blue Mesa, Morrow Point, and Crystal reservoirs and their respective shorelines. The entire affected area is located within the confines of the Curecanti NRA (Figures 3.34 and 3.35), which is administered by the NPS. It is surrounded by national forests and is adjacent to Black Canyon of the Gunnison National Monument. Recreationists participate in a variety of activities ranging from wind surfing on Blue Mesa Reservoir to gold medal¹² trout fishing on the Gunnison River below Crystal Dam. Fishing, boating (motorized, nonmotorized, and sailing), camping, wind surfing, sightseeing, snowmobiling, and ice fishing are the area's most popular recreational activities. Several trails are also available that provide a wide range of hiking experiences. Curecanti NRA was visited by 1,089,929 persons in 1991 and is one of Colorado's most popular summer spots (Zichterman 1992a). Peak recreational use in Curecanti NRA occurs from late May through the second week of September.

Recreational opportunities on the Blue Mesa, Morrow Point, and Crystal reservoirs are discussed in Sections 3.7.3.1, 3.7.3.2, and 3.7.3.3, respectively. An inventory of recreational resources and facilities available in Curecanti NRA is provided in Figures 3.34 and 3.35.

3.7.3.1 Blue Mesa Reservoir

Blue Mesa Reservoir is the largest constructed lake in Colorado (NPS 1990a) and accounts for about 80% of total annual visitation in Curecanti NRA (Zichterman 1992c). The reservoir consists of three large basins that support a variety of recreational activities and facilities: Sapinero Basin, Cebolla Basin, and Iola Basin (Figure 3.34). Fishing and boating are the dominant recreational activities in Sapinero Basin, which is located directly behind the dam and is the deepest (approximately 300 ft) and largest of the basins. Sailing, wind surfing, and water skiing are popular on Cebolla Basin, which is approximately 200 ft deep and is east of Sapinero. Fishing, boating, water skiing, and wind surfing are the primary activities on Iola Basin, which occupies the eastern section of Blue Mesa Reservoir and is approximately 100 ft deep.

¹² A "gold medal" designation is given by the Colorado Wildlife Commission to those rivers and streams that offer large trout and outstanding angling (Colorado Division of Wildlife 1991)

3 of 5

FIGURE 3.34 Recreational Resources in Blue Mesa Reservoir

FIGURE 3.35 Recreational Resources in Crystal and Morrow Point Reservoirs

Blue Mesa Reservoir's recreational facilities include two marinas, five concrete boat ramps, several developed and boat-in campgrounds, numerous hiking trails, and a visitor's center at Elk Creek (Figure 3.34). The marinas at Lake Fork and Elk Creek have tapered boat ramps and feature floating docks and stores to compensate for fluctuating reservoir levels.

3.7.3.2 Morrow Point Reservoir

Morrow Point Reservoir, which had over 112,000 visitors in 1991 (Zichterman 1992b), is a narrow fiordlike body of water that stretches for 11 mi below Blue Mesa Dam. The Pine Creek, Curecanti Creek, and Hermits Rest trails provide the only access to the shores of Morrow Point Reservoir. Boats are allowed on the reservoir, but these are limited to small carry-in boats such as rafts, canoes, and kayaks. Fishing (boat and shore) and hiking are the major recreational activities occurring on and along Morrow Point Reservoir. Two primitive boat-in campgrounds are located near the reservoir's shore. A 32-passenger tour boat operates on the reservoir (Figure 3.35), and it becomes stranded at water levels below an elevation of 7,151 ft. However, in 1994, the NPS plans to either eliminate the tour boat or replace it with two pontoon boats that can operate on reservoir levels above an elevation of 7,147 ft (Chapman 1993b).

3.7.3.3 Crystal Reservoir

Crystal Reservoir, approximately 6 mi in length, is narrow and is accessible only from the Mesa Creek and Crystal Creek trails (Figure 3.35). Fishing is the principal recreational activity on Crystal Lake, and boating activity is limited to small hand-carried craft. A single boat-in campground is located east of the Crystal Creek inlet. The reservoir was visited by 1,421 persons in 1991 (Frank 1993).

3.8 VISUAL RESOURCES

The physical attractiveness of a particular region, area, or place contributes to its aesthetic value. Although sounds and smells are important factors in aesthetic value, visual elements exert the most influence. Almost every natural visual element and landscape typical of the west-central United States occurs in the areas affected by the Glen Canyon, Flaming Gorge, and Aspinall Unit dams. Some natural features, such as the Grand Canyon of the Colorado River or the Black Canyon of the Gunnison River, are recognized worldwide for their unique scenic value.

The USFS and BLM have developed visual resource management systems to classify and administer viewsheds (USFS 1973, 1974; BLM 1991). These systems identify three viewing proximity zones that define the distance between an observer and an object or feature. The visual resource analysis in this Power Marketing EIS includes viewing proximity zones that differ only slightly from those defined in the USFS and BLM systems.

The foreground viewing zone consists of the view from between the edge of the feature or collective features and 0.25 mi; the middle-ground zone stretches from 0.25 to 3 mi; and the background zone radiates outward from 3 mi. The affected area for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit consists of the foreground and middle-ground viewing zones only; views from beyond 3 mi would not be affected by hydropower operations.

3.8.1 Glen Canyon Dam

The Colorado River corridor is visually unique because of its variety in landform, texture, and color. The Grand Canyon forms a chasm that is 1 mi deep and up to 18 mi wide. A visitor can view its impressive physical beauty from several perspectives — standing on one of its rims, descending a canyon trail, or standing along the river's edge. Spectacular vistas are available throughout the region.

The affected area consists of the entire canyon and its north and south rims. Prominent viewpoints on the south rim of the canyon include Hopi, Mohave, and Pima points. Bright Angel Point and Cape Royal overlook the canyon and beyond from the north rim. Vegetation in the forests surrounding the affected area consists of spruce, pine, fir, and quaking aspen. Tamarisk, mesquite, apache plume, and coyote willow are some of the common species of vegetation that inhabit the inner canyon and are found near the river.

No official inventory of visual resources has been conducted for the affected area of Glen Canyon Dam. The NPS does not have a program that classifies landscapes.

3.8.2 Flaming Gorge Dam

Just below Flaming Gorge Dam, the Green River flows through the steep rose-colored walls of Red Canyon. Vegetation is dominated by small shrubs, pinyon pine, and Utah juniper. Stands of box elders are located intermittently along the river. White water occurs on this stretch of the river through a series of riffles and rapids.

After leaving Red Canyon, the river meanders slowly through Browns Park. Browns Park is characterized by pale, rolling hills that give way to mesas and terraces near the river's shore. The desertlike landscape is dominated by sagebrush, greasewood, and other small shrubs. Tamarisk stands and cottonwood groves of varying sizes are scattered along the edge of the river. White water is relatively scarce on the Browns Park segment of the river.

The Green River and surrounding area offer many views, vistas, and observation points. Harpers Corner Scenic Drive offers several views of Dinosaur National Monument canyon country. As the river enters Dinosaur National Monument, it flows through deep canyons. Steamboat Rock, which towers over the confluence of the Yampa and Green rivers and has a large beach area, is one of the monument's most prominent landmarks. In Island Park, the river loops through a broad, flat area. Here the landscape is dominated by

mountains in the distance, desert shrubs away from the river, and stands of box elder or cottonwoods inside the bends of the river.

Visual intrusions into the natural environment of the study corridor include boat ramps, bathrooms, vault toilets, and two bridges. Other intrusions include two pipelines and several irrigation-related structures located along the river's edge (USFS 1984).

A partial inventory of visual resources in the affected area has been conducted by the USFS and BLM; the stretch of river flowing from the Utah-Colorado border through Dinosaur National Monument has not been inventoried. However, the segment of the river running through the monument has been identified as meeting all criteria for qualifying as a wild river under wild and scenic status. Under the USFS Visual Management System, the portion of the Green River located in Flaming Gorge NRA below Flaming Gorge Dam has a "retention" classification (Baird 1992), which means that management activities and human imprints (such as fences, paths/roads, and facilities) do not significantly alter or detract from the natural landscape. According to BLM Visual Resource Management criteria, the section of the Green River that flows between the eastern edge of Flaming Gorge NRA and the Utah-Colorado border is categorized as Class II (BLM 1991). Some altering of the landscape can occur in Class II areas, but management activities and structures should not attract a viewer's attention.

3.8.3 Aspinall Unit

No official inventory of visual resources has been conducted for the lands adjacent to the Aspinall reservoirs or Curecanti NRA, although a variety of visual elements are present. Blue Mesa Reservoir provides a scenic contrast to the surrounding terrain, with bays that reach into remote and steep canyons. Light-colored barren hills that surround Blue Mesa give way to mesas containing sparse stands of fir. The Curecanti Needle and Dillon Pinnacles are spires sculpted from volcanic deposits by the forces of erosion. Mountain meadows offer a variety of floral displays, and local vegetation varies in type and color with changes in elevation. Sagebrush and desert shrubs dominate near the reservoir, and cottonwood trees grow near the mouths of creeks draining into Blue Mesa.

Morrow Point Reservoir and Crystal Reservoir are narrow bodies of water enclosed by the towering dark walls of Black Canyon. Vegetation is dominated by intermittent stands of Douglas and white fir that grow from the water's edge to the top of the canyon. Scattered communities of pinyon-juniper surround the reservoirs.

State Highway 92, which runs north of Morrow Point Reservoir, is a scenic highway that features several vistas and an overlook area above Blue Mesa Dam. The stretch of U.S. 50 that runs along the southern shore of Blue Mesa Reservoir has been designated the West Elk Scenic Byway.

4 ENVIRONMENTAL CONSEQUENCES

This chapter presents the impacts of the commitment-level alternatives and operational scenarios that are considered in this EIS. The presentation is divided into two major parts. Section 4.1 discusses the impacts of the commitment-level alternatives on each of the resource categories and attributes described in Chapter 3. Section 4.2 discusses the effects of the operational scenarios at each hydrogeneration facility on the same set of resource categories and attributes. Because commitment-level alternatives vary considerably in their impact on socioeconomics but differ little in their impact on the natural environment, the socioeconomic implications of the proposed action are addressed first in this chapter.

4.1 CONSEQUENCES OF COMMITMENT-LEVEL ALTERNATIVES

The major focus of Section 4.1 is on the impacts of each alternative on socioeconomic variables, including regional population, income, employment, and output; the financial condition of the affected utilities; retail rates; and selected economic sectors. The potential impacts of the commitment-level alternatives on air resources are also considered in detail.¹

While the natural resource categories introduced in the previous chapter are also addressed, the discussion is limited to describing, in general terms, the indirect impacts of each commitment-level alternative on the resource in question. Indirect impacts could result from differences among alternatives with regard to the need for new or replacement generating capacity. Such need would arise from the loss of cost-effective hydropower resources. These indirect impacts would be site-specific, and the resources affected and level of impacts could vary widely. Consequently, it is not possible to conduct a more thorough impact assessment for these resources at this time. However, any new construction or any other new action that would result in additional resource impacts beyond those already addressed would be subject to an environmental review before the proposed action was implemented.

4.1.1 Socioeconomics

4.1.1.1 Introduction

This section examines the impacts that each of the commitment-level alternatives could have on the range of economic conditions of the affected environment (as described in Chapter 3). The purpose of the socioeconomic impact analysis is to determine the effects of changes in Western's commitment levels on the economies and populations of the localities

¹ This analysis assumes that Western adjusts its firm power rate for each commitment-level alternative so that required payments to the U.S. Treasury from the Federal projects are unaffected by choice of alternative.

and communities that receive electrical power provided by Western. Impacts were measured by computing the effects of changes in commitment levels on the financial viability of the utility customers served by Western, the rates charged to the ultimate end users, and the effects of these changes on regional economic conditions. The analysis was based on a series of models of (1) the systems of the major utilities purchasing power from Western, (2) the financial conditions of the utilities purchasing power from the Western system, (3) the present status of electricity rates in the subregions covered, (4) the status of SLCA/IP project repayment, and (5) the subregional economies affected by the action. The analyses and inputs required for the economic impact assessment are illustrated schematically in Figure 4.1.

As Figure 4.1 illustrates, the analysis began with the specification of a commitment-level alternative. The commitment-level alternatives analyzed in this EIS represent various amounts of capacity and energy that Western could supply to electric utilities on a long-term basis. Utilities combine this capacity and energy with their other electrical resources to meet demands. The task of ensuring that total generating resources are sufficient to meet current and future demand is accomplished through a process called power resource planning. Analysis of an individual utility's power resource plans was accomplished with a power systems analysis model. The analysis produced a generating capacity expansion plan for each utility system. This expansion plan projects future additions to generating capacity needed to meet demand. Alternatives associated with low commitment levels produced power expansion plans that called for utilities to add more new generating capacity facilities than did alternatives associated with high commitment levels.

The result of the power systems analysis was an estimate of the change in generation and purchased power costs incurred by Western's customers attributable to each of the commitment-level alternatives. Secondary impacts could also be experienced by noncustomers (e.g., investor-owned utilities within the region). Some of these impacts could be positive. However, because such impacts would be smaller than the direct impacts, they are not described here. (The power systems analysis method is summarized in Section A.2 of Appendix A; details of the method and results are provided in Veselka et al. [1994a].) Various SLCA/IP commitment-level alternatives would also result in different SLCA/IP firm power rates. Western's Power Repayment Study model was used to estimate the SLCA/IP firm power rate corresponding to each commitment-level alternative. As is shown in Figure 4.1, the changes in auxiliary power costs and the SLCA/IP firm rate were then combined to determine the change in a customer's wholesale power costs.

The estimated changes in individual customers' wholesale power costs were used as input to the rate impacts and financial viability analysis. Available information was used to estimate the change in electricity rates by class of customer and to predict any effects the situation could have on the financial conditions of the utilities. Estimates of the price

FIGURE 4.1 Components of the Economic Impact Analysis

elasticity of demand, which plays a key role in both rate setting and financial viability, were also included in the financial analysis.² Details of the price elasticity analysis are provided with the demand analysis documented in Morey and Ungson (1993). The methods used in the financial analysis are summarized in Appendix A, Section A.3.1, and details of the rate impacts and financial viability analysis are provided in Bodmer et al. (1994).

The impact of commitment-level alternatives on conservation and renewable energy programs undertaken by long-term firm sale utility customers was also evaluated. Although these activities often include energy consumption efficiency, peak load reductions, use of renewable energy sources, and cogeneration, only consumption efficiency and load management activities were considered likely to be affected. The analysis of the impact of commitment-level alternatives on these programs focused on commitment-level alternative 4, which would result in the largest increase in electricity rates. Conservation measures that may occur in addition to those induced by changes in electricity rates were not considered as part of the analysis conducted for the EIS. More information on the methods of analysis can be found in Section A.4 of Appendix A.

Electricity is used in the production of most goods and services. Thus, a change in the price of electricity could cause firms, factories, farms, and other industrial and commercial establishments to alter their production techniques and possibly increase or decrease production. In addition, new firms could be created or existing firms could go out of business. Thus, a change in retail rates for electricity could change regional economic conditions. With the REMI modeling system, the regional economic analysis translated the rate effects at the utility level into consequent impacts on population, income, GRP, and employment for each of the subregions considered in this assessment. (Details of the regional analysis are provided in Appendix A, Section A.5, and Allison and Griffes [1994].)

In addition to allowing the commitment levels to vary, it was necessary to assume specific supply options. Three different supply options, consisting of operational scenarios at each dam and corresponding purchases or exchanges of energy and/or capacity required for Western to meet each of the commitment-level alternatives, were chosen.³ The three supply options, designated as A, B, and C, were selected so as to cover the range of dam operations that could occur.

Supply option A consists of historical flows at Glen Canyon Dam, year-round fluctuating flows at Flaming Gorge Dam, and fluctuating flows at the Aspinall Unit. Supply option B consists of low fluctuating flows at Glen Canyon Dam, year-round fluctuating flows

² The price elasticity of demand is a measure of the responsiveness of quantity demanded to a change in price; e.g., the percentage change in the amount of electricity purchased by end-use customers resulting from a percent change in retail rates.

³ As discussed in Section 2, a supply option consists of two components: the hydropower component and any purchases or exchanges of energy from alternative sources, such as fossil-fuel units. Fixing the operational scenario at each dam simultaneously determines the amount of purchases needed for each commitment-level alternative.

at Flaming Gorge Dam, and fluctuating flows at the Aspinall Unit. Supply option C consists of seasonally adjusted steady flows at Glen Canyon Dam, seasonally adjusted steady flows at Flaming Gorge Dam, and steady flows at the Aspinall Unit.

4.1.1.2 Utility Industry Impacts

Impacts were estimated for each of the utility systems served by Western that could be affected by the commitment-level alternatives. The simulation methods and the level of modeling detail employed for each of the system size categories differed significantly. Large systems were rigorously modeled in order to quantify the impacts of changes in Western's commitment levels on the generation and transmission companies that purchase and resell Western's power. On the other hand, small systems (i.e., those with little or no generating capacity of their own) were analyzed less formally with spreadsheet models that estimated increased costs from alternative power suppliers.

The modeling process for large systems estimated growth in generating capacity (incorporating demand-side management programs) and provided estimates of production costs by simulating the operations of each utility. The major modeling functions in this portion of the analysis included (1) making a risk assessment of long-term firm capacity and energy on the basis of hydrologic resources; (2) estimating Western's hourly firm loads; (3) formulating integrated resource plans for large systems; (4) simulating hourly dispatch and spot market sales for affected utility systems, including the SLCA/IP; (5) estimating alternative supplier costs for small systems on the basis of short- and long-term marginal costs; and, (6) performing feasibility checks.

These electric utility simulation models were integrated and configured so that the modeling system projected the future behavior of electric utilities under baseline conditions and measured the impacts of changes in Western's commitment levels under various supply option constraints. Estimates of spot market transactions between companies were modeled and simulated to estimate the short-term wholesale market. A more detailed description of the modeling techniques is provided in Veselka et al. (1994a).

The crux of the utility impact assessment is the rate and financial viability analysis. The purpose of that analysis was to quantify the full range of impacts that changes in the costs and quantities of Western's power could have on its utility customers. These impacts might appear as changes in the financial health of the reselling utility and/or changes in price and the quantities consumed by residential, commercial, industrial, and other retail consumers. In essence, this portion of the analysis estimated the economic impacts that could arise in cases where changes in Western's commitment levels might create financial difficulties for a utility.

Alternative commitment levels could change the cost of power to Western's customers, since Western's wholesale rates must be adjusted to meet its debt repayment obligations. In addition to producing changes in Western's rates, different commitment levels might also affect the cost of alternative power and the capacity expansion plans of the

utilities (as estimated by the power systems analysis). These increasing costs would be manifested through increases in consumer rates, through deterioration of the utility's financial condition, or both. For this reason, there is a direct link between the financial condition of the utilities that sell power and the prices that consumers pay for electricity. For example, if costs increased and rates stayed constant, the impact of the cost increase would appear as a deteriorating financial condition of the utility. Alternatively, if the entire cost increase was passed on to the customers of the utility in the form of higher electric rates, there would be no financial impact on the utilities. As changes in costs occur, the utility manager decides (on the basis of multiple constraints) whether to increase or decrease the utility's financial health or to increase or decrease rates to utility customers. This decision process was simulated through the rate and financial analysis. A short description of this simulation model is provided in Appendix A, Section A.3, with more detail available in Bodmer et al. (1994).

The impacts presented below are based on the results of the entire utility modeling process, including the power systems analysis of the large utility systems and the rate and financial viability analysis of all of the utility systems by category. A general finding of the analysis of the potential impacts to each of the utilities for each of the commitment-level alternatives is that the magnitude of the impact, measured as a change in the utility's retail rates, varies directly with the degree to which the utility system relies on Western for long-term firm capacity and energy and the price of the customer's auxiliary utility supplier. This relationship is illustrated schematically in Figure 4.2, which shows average rate impacts (in terms of percentage changes) as a function of reliance level.⁴ The impacts discussed below and summarized in Tables 4.1 through 4.5 are described more fully in Bodmer et al. (1994). Table 4.6 compares average rates charged by Western customer utilities with the average rates charged by all utilities in the six main states in which Western power is sold. The no-action commitment-level alternative, combined with supply option A, constitutes the baseline for the socioeconomic impacts for the EIS.

4.1.1.2.1 No Action

Combined with supply option B, the no-action commitment-level alternative would result in a weighted average increase in retail rates of approximately 1% (Table 4.1). High-reliance municipals in New Mexico would see their rates increase by the largest percentage, to \$105/MWh in 2008 (Table 4.3). Under supply option C, the weighted average increase in rates would be 8%, with high-reliance municipals in New Mexico experiencing the largest percentage increase, to \$112/MWh in 2008 (Table 4.4).

⁴ Figure 4.2 is a schematic representation of the relationship between the change in a utility's retail rate that could result from a change in Western's firm commitment levels and the degree to which the utility relies on Western to meet its energy needs. It is not a precise representation of this relationship. Furthermore, it is applicable to those cases in which a commitment-level alternative would be expected to cause rates to increase.

FIGURE 4.2 Schematic Representation of the Relationship between Percentage Change in Average Retail Rates and Percentage Reliance on Long-Term Firm Capacity and Energy from Western

As indicated in Table 4.5, under supply options B and C, the number of low- and high-reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. In contrast, there would be one additional low-reliance utility with a coverage ratio of less than 1.1 under these same supply options. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option B and by three under supply option C.

4.1.1.2.2 Commitment-Level Alternative 1

Combined with supply option A, commitment-level alternative 1 would result in a weighted average increase in retail rates of just over 1% (Table 4.1). High-reliance cooperatives in Arizona would see their rates increase by the largest percentage, to \$74/MWh in 2008; while high-reliance municipals in Utah would see their rates decline approximately 12% to \$64/MWh (Table 4.2). Under supply option B, rates would rise by a weighted average 3%, with high-reliance municipals in New Mexico experiencing the largest percentage increase, to \$105/MWh in 2008; while high-reliance municipals in Utah would see their rates decline approximately 11% to \$65/MWh (Table 4.3). Under supply option C, the weighted average increase in rates would be 5%. High-reliance cooperatives in Arizona would experience the largest percentage increase, with an average rate of \$81/MWh in 2008 (Table 4.4).

TABLE 4.1 Financial Impacts of Alternative/Operational Scenario Combinations

Alternative ^a / Supply Option ^b	Weighted Average Rate in 2008 (1994\$/MWh)	% Change from Baseline	State/Utility Category ^c with Largest Rate Increase	% Change of Average Price ^d in 2008 from Baseline
NA-A (baseline)	73	-	Not applicable	-
NA-B	74	1	New Mexico/HRM	6
NA-C	79	8	New Mexico/HRM	13
1A	74	1	Arizona/HRC	1
1B	75	3	New Mexico/HRM	6
1C	77	5	Arizona/HRC	11
2A	74	1	Utah/HRM	12
2B	76	3	Utah/HRM	15
2C	78	6	Utah/HRC	18
3A	75	3	Utah/HRM	12
3B	77	5	Utah/HRM	14
3C	79	8	Utah/HRM	19
4A	83	13	Utah/HRM	30
4B	84	14	Utah/HRM	32
4C	85	15	Utah/HRM	41
5A	81	10	Utah/HRC	26
5B	83	12	Utah/HRC	28
5C	85	15	Utah/HRC	31
6A	76	4	New Mexico/HRM	13
6B	77	5	New Mexico/HRM	16
6C	80	10	New Mexico/HRM	19

^a No action (NA) = 1,291 MW of capacity and 5,700 MWh of energy; alternative

1 = 1,449 MW of capacity and 6,156 MWh of energy; alternative 2 = 1,450 MW of capacity and 3,330 MWh of energy; alternative 3 = 1,225 MW of capacity and 4,000 MW of energy; alternative 4 = 550 MW of capacity and 3,300 MWh of energy; alternative 5 = 625 MW of capacity and 5,475 MWh of energy; and alternative 6 = 1,000 MW of capacity and 4,750 MWh of energy.

^b Supply option A consists of historical flows at Glen Canyon, year-round fluctuating flows at Flaming Gorge, and fluctuating flows at the Aspinall Unit; supply option B consists of low fluctuating flows at Glen Canyon, year-round fluctuating flows at Flaming Gorge, and fluctuating flows at the Aspinall Unit; supply option C consists of seasonally adjusted steady flows at Glen Canyon and Flaming Gorge, and steady flows at the Aspinall Unit.

^c HRM = high-reliance municipals; HRC = high-reliance cooperatives.

^d Percentage change based on prices in 1994 dollars.

Source: Bodmer et al. (1994).

TABLE 4.2 Predicted Retail Rates (1994 \$/MWh) and Percentage Change from No-Action Alternative (Baseline) by State and Utility Category: Supply Option A

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
No Action												
Low reliance												
Municipals	107	105	63	57	NA ^a	NA	68	65	72	66	72	67
Cooperatives	63	73	76	66	94	110	74	74	67	63	94	110
High reliance												
Municipals	53	60	64	71	NA	NA	97	99	NA	NA	76	73
Cooperatives	81	73	NA	NA	NA	NA	81	73	NA	NA	87	102
Alternative 1												
Low reliance												
Municipals	107	105	63	57	NA	NA	69	65	72	64	71	66
	(0) ^b	(0)	(0)	(0)			(1.5)	(0)	(0)	(-3.0)	(-1.4)	(-1.5)
Cooperatives	64	72	76	66	91	107	74	74	65	60	91	107
	(1.6)	(-1.4)	(0)	(0)	(-3.2)	(-2.7)	(0)	(0)	(-3.0)	(-4.8)	(-3.2)	(-2.7)
High reliance												
Municipals	53	59	63	69	NA	NA	97	100	NA	NA	75	64
	(0)	(-1.7)	(-1.6)	(-2.8)			(0)	(1.0)			(-1.3)	(-12.3)
Cooperatives	81	74	NA	NA	NA	NA	81	73	NA	NA	78	96
	(0)	(1.4)					(0)	(0)			(-10.3)	(-5.9)
Alternative 2												
Low reliance												
Municipals	110	108	63	57	NA	NA	69	65	71	61	71	66
	(2.8)	(2.9)	(0)	(0)			(1.5)	(0)	(-1.4)	(-7.6)	(1.4)	(-1.5)
Cooperatives	65	72	75	64	92	109	74	73	65	62	92	109
	(3.2)	(-1.4)	(1.3)	(-3.0)	(-2.1)	(0.9)	(0)	(-1.4)	(-3.0)	(-1.6)	(-2.1)	(-0.9)
High reliance												
Municipals	54	61	63	70	NA	NA	107	109	NA	NA	82	82
	(1.9)	(1.7)	(-1.6)	(-1.4)			(10.3)	(10.1)			(7.9)	(12.3)
Cooperatives	80	76	NA	NA	NA	NA	80	76	NA	NA	83	99
	(-1.2)	(4.1)					(-1.2)	(4.1)			(-4.6)	(-2.9)

TABLE 4.2 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 3												
Low reliance												
Municipals	109 (1.9)	107 (1.9)	63 (0)	57 (0)	NA	NA	69 (1.5)	65 (0)	72 (0)	63 (-4.5)	72 (0)	67 (0)
Cooperatives	64 (1.6)	72 (-1.4)	76 (0)	65 (-1.5)	96 (2.1)	112 (1.8)	74 (0)	74 (0)	67 (0)	64 (1.6)	96 (2.1)	112 (1.8)
High reliance												
Municipals	55 (3.8)	61 (1.7)	63 (-1.6)	69 (-2.8)	NA	NA	107 (10.3)	109 (10.1)	NA	NA	80 (5.3)	82 (12.3)
Cooperatives	81 (0)	73 (0)	NA	NA	NA	NA	81 (0)	76 (4.1)	NA	NA	94 (8.0)	106 (3.9)
Alternative 4												
Low reliance												
Municipals	110 (0)	108 (2.9)	63 (0)	58 (1.8)	NA	NA	70 (2.9)	66 (1.5)	71 (-1.4)	65 (-1.5)	75 (4.2)	69 (3.0)
Cooperatives	63 (0.2)	73 (0)	76 (0)	66 (0)	109 (16.0)	123 (11.8)	75 (1.4)	74 (0)	72 (7.5)	71 (12.7)	109 (16.0)	123 (11.8)
High Reliance												
Municipals	59 (11.3)	65 (8.3)	69 (7.8)	75 (5.6)	NA	NA	121 (24.7)	121 (22.2)	NA	NA	80 (5.3)	95 (30.1)
Cooperatives	83 (2.5)	78 (6.8)	NA	NA	NA	NA	83 (2.5)	78 (6.8)	NA	NA	121 (39.0)	131 (28.4)
Alternative 5												
Low reliance												
Municipals	108 (0.9)	106 (1.0)	63 (0)	57 (0)	NA	NA	73 (7.4)	67 (3.1)	72 (0)	63 (-4.5)	75 (4.2)	69 (3.0)
Cooperatives	63 (0)	72 (-1.4)	77 (1.3)	67 (1.5)	108 (14.9)	122 (10.9)	75 (1.4)	74 (0)	68 (1.5)	64 (1.6)	108 (14.9)	122 (10.9)
High reliance												
Municipals	59 (11.3)	64 (6.7)	69 (7.8)	75 (5.6)	NA	NA	124 (27.8)	123 (24.2)	NA	NA	74 (-2.6)	70 (-4.1)
Cooperatives	85 (4.9)	77 (5.5)	NA	NA	NA	NA	85 (4.9)	77 (5.5)	NA	NA	118 (35.6)	128 (25.5)

TABLE 4.2 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 6												
Low reliance												
Municipals	108 (0.9)	107 (1.9)	63 (0)	57 (0)	NA	NA	70 (2.9)	66 (1.5)	72 (0)	64 (-3.0)	75 (4.2)	69 (3.0)
Cooperatives	64 (1.6)	73 (0)	76 (0)	66 (0)	100 (6.4)	116 (5.5)	75 (1.4)	74 (0)	68 (1.5)	64 (1.6)	100 (6.4)	116 (5.5)
High reliance												
Municipals	56 (5.7)	62 (3.3)	64 (0)	71 (0)	NA	NA	111 (14.4)	112 (13.1)	NA	NA	77 (1.3)	77 (5.5)
Cooperatives	82 (1.2)	75 (2.7)	NA	NA	NA	NA	82 (1.2)	76 (4.1)	NA	NA	109 (25.3)	114 (11.8)

^a Not applicable.

^b Numbers in parentheses are percentages.

Source: Bodmer et al. (1994)

TABLE 4.3 Predicted Retail Rates (1994 \$/MWh) and Percentage Change from No-Action Alternative/Supply Option A (Baseline) by State and Utility Category: Supply Option B

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
No Action												
Low reliance												
Municipals	107 (0) ^b	106 (1.0)	63 (0)	57 (0)	NA ^a	NA	69 (1.5)	65 (0)	73 (1.4)	66 (0)	72 (0)	67 (0)
Cooperatives	63 (0)	73 (0)	77 (1.3)	56 (0)	95 (1.1)	110 (0)	75 (1.4)	74 (0)	68 (1.5)	64 (1.6)	95 (1.1)	110 (0)
High reliance												
Municipals	54 (1.9)	60 (0)	65 (1.6)	71 (0)	NA	NA	104 (7.2)	105 (6.1)	NA	NA	77 (1.3)	74 (1.4)
Cooperatives	81 (0)	74 (1.4)	NA	NA	NA	NA	81 (0)	74 (1.4)	NA	NA	89 (2.3)	103 (1.0)
Alternative 1												
Low reliance												
Municipals	107 (0)	105 (0)	63 (0)	57 (0)	NA	NA	70 (2.9)	65 (0)	73 (1.4)	65 (-1.5)	72 (0)	66 (-1.5)
Cooperatives	64 (1.6)	73 (0)	77 (1.3)	67 (1.5)	91 (-3.2)	107 (-2.7)	74 (0)	74 (0)	68 (1.5)	64 (1.6)	91 (-3.2)	107 (-2.7)
High reliance												
Municipals	54 (1.9)	60 (0)	63 (-1.6)	70 (-1.4)	NA	NA	104 (7.2)	105 (6.1)	NA	NA	76 (0)	65 (-11.0)
Cooperatives	83 (2.5)	75 (2.7)	NA	NA	NA	NA	83 (2.5)	74 (1.4)	NA	NA	82 (-5.7)	98 (-3.9)
Alternative 2												
Low reliance												
Municipals	110 (2.8)	108 (2.9)	63 (0)	57 (0)	NA	NA	69 (1.5)	66 (1.5)	72 (0)	66 (0)	72 (0)	66 (-1.5)
Cooperatives	66 (4.8) (3.2)	72 (-1.4)	76 (0)	65 (-1.5)	92 (-2.1)	108 (-1.8)	74 (0)	74 (0)	67 (0)	64 (1.6)	92 (-2.1)	108 (-1.8)
High reliance												
Municipals	55 (3.8)	62 (3.3)	64 (0)	71 (0)	NA	NA	109 (12.4)	111 (12.1)	NA	NA	84 (10.5)	84 (15.1)
Cooperatives	82 (1.2)	77 (5.5)	NA	NA	NA	NA	82 (1.2)	77 (5.5)	NA	NA	86 (-1.1)	101 (-1.0)

TABLE 4.3 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 3												
Low reliance												
Municipals	109 (1.9)	107 (1.9)	63 (0)	57 (0)	NA	NA	69 (1.5)	66 (1.5)	72 (0)	66 (0)	73 (1.4)	68 (1.5)
Cooperatives	65 (3.2)	73 (0)	77 (1.3)	66 (0)	97 (3.2)	112 (1.8)	74 (0)	74 (0)	67 (0)	64 (1.6)	97 (3.2)	112 (1.8)
High reliance												
Municipals	56 (5.7)	62 (3.3)	63 (-1.6)	70 (-1.4)	NA	NA	111 (14.4)	112 (13.1)	NA	NA	81 (6.6)	83 (13.7)
Cooperatives	82 (1.2)	75 (2.7)	NA	NA	NA	NA	82 (1.2)	77 (5.5)	NA	NA	98 (12.6)	108 (5.9)
Alternative 4												
Low reliance												
Municipals	110 (2.8)	108 (2.9)	64 (1.6)	58 (1.8)	NA	NA	71 (4.4)	66 (1.5)	73 (1.4)	64 (-3.0)	75 (4.2)	69 (3.0)
Cooperatives	64 (1.6)	73 (0)	77 (1.3)	66 (0)	112 (19.1)	126 (14.5)	75 (1.4)	74 (0)	68 (1.5)	64 (1.6)	112 (19.1)	126 (14.5)
High Reliance												
Municipals	59 (11.3)	65 (8.3)	69 (7.8)	75 (5.6)	NA	NA	123 (26.8)	121 (22.2)	NA	NA	81 (6.6)	96 (31.5)
Cooperatives	83 (2.5)	78 (6.8)	NA	NA	NA	NA	83 (2.5)	78 (6.8)	NA	NA	122 (40.2)	132 (29.4)
Alternative 5												
Low reliance												
Municipals	108 (0.9)	107 (1.9)	63 (0)	57 (0)	NA	NA	74 (8.8)	68 (4.6)	73 (1.4)	61 (-7.6)	76 (5.6)	70 (4.5)
Cooperatives	64 (1.6)	72 (-1.4)	78 (2.6)	69 (4.5)	109 (16.0)	123 (11.8)	75 (14)	74 (0)	70 (4.5)	65 (3.2)	109 (16.0)	123 (11.8)
High reliance												
Municipals	60 (13.2)	65 (8.3)	70 (9.4)	76 (7.0)	NA	NA	127 (30.9)	125 (26.3)	NA	NA	77 (1.3)	72 (-1.4)
Cooperatives	87 (7.4)	79 (8.2)	NA	NA	NA	NA	87 (7.4)	79 (8.2)	NA	NA	122 (40.2)	130 (27.5)

TABLE 4.3 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 6												
Low reliance												
Municipals	109 (1.9)	107 (1.9)	63 (0)	57 (0)	NA	NA	71 (4.4)	66 (1.5)	72 (0)	64 (-3.0)	76 (5.6)	70 (4.5)
Cooperatives	64 (1.6)	73 (0)	77 (1.3)	67 (1.5)	102 (8.5)	116 (5.5)	75 (1.4)	74 (0)	68 (1.5)	64 (1.6)	102 (8.5)	116 (5.5)
High reliance												
Municipals	57 (7.5)	63 (5.0)	65 (1.6)	71 (0)	NA	NA	115 (18.6)	115 (16.2)	NA	NA	79 (3.9)	79 (8.2)
Cooperatives	84 (3.7)	76 (4.1)	NA	NA	NA	NA	84 (3.7)	77 (5.5)	NA	NA	113 (29.9)	116 (13.7)

^a Not applicable.

^b Numbers in parentheses are percentages.

Source: Bodmer et al. (1994).

TABLE 4.4 Predicted Retail Rates (1994 \$/MWh) and Percentage Change from No-Action Alternative/Supply Option A (Baseline) by State and Utility Category: Supply Option C

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
No Action												
Low reliance												
Municipals	109 (1.9) ^b	107 (1.9)	64 (1.6)	58 (1.8)	NA ^a	NA	71 (4.4)	66 (1.5)	72 (0)	67 (1.5)	74 (2.8)	68 (1.5)
Cooperatives	64 (1.6)	74 (1.4)	81 (6.6)	69 (4.5)	99 (5.3)	114 (3.6)	75 (1.4)	74 (0)	70 (4.5)	65 (3.2)	99 (5.3)	114 (3.6)
High reliance												
Municipals	57 (7.5)	62 (3.3)	68 (6.3)	73 (2.8)	NA	NA	114 (17.5)	112 (13.1)	NA	NA	84 (10.5)	78 (6.8)
Cooperatives	87 (7.4)	79 (8.2)	NA	NA	NA	NA	87 (7.4)	79 (8.2)	NA	NA	98 (12.6)	110 (7.8)
Alternative 1												
Low reliance												
Municipals	109 (1.9)	105 (0)	64 (1.6)	58 (1.8)	NA	NA	71 (4.4)	66 (1.5)	75 (4.2)	66 (0)	75 (4.2)	68 (1.5)
Cooperatives	64 (1.6)	73 (0)	81 (6.6)	70 (6.1)	95 (1.1)	111 (0.9)	75 (1.4)	74 (0)	72 (7.5)	67 (6.3)	95 (1.1)	111 (0.9)
High reliance												
Municipals	57 (5.7)	62 (3.3)	66 (3.1)	72 (1.4)	NA	NA	110 (13.4)	109 (10.1)	NA	NA	83 (9.2)	68 (-6.8)
Cooperatives	88 (8.6)	81 (11.0)	NA	NA	NA	NA	88 (8.6)	79 (8.2)	NA	NA	99 (11.5)	105 (2.9)
Alternative 2												
Low reliance												
Municipals	111 (3.7)	109 (3.8)	64 (1.6)	58 (1.8)	NA	NA	70 (2.9)	66 (1.5)	73 (1.4)	62 (-6.1)	72 (0)	68 (1.5)
Cooperatives	66 (4.8)	72 (-1.4)	78 (2.6)	67 (1.5)	95 (1.1)	111 (0.9)	74 (0)	74 (0)	70 (4.5)	65 (3.2)	95 (1.1)	111 (0.9)
High reliance												
Municipals	57 (7.5)	63 (5.0)	66 (3.1)	72 (1.4)	NA	NA	113 (16.5)	114 (15.2)	NA	NA	89 (17.1)	86 (17.8)
Cooperatives	84 (3.7)	80 (9.6)	NA	NA	NA	NA	84 (3.7)	80 (9.6)	NA	NA	91 (4.6)	105 (2.9)

TABLE 4.4 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 3												
Low reliance												
Municipals	110 (2.8)	108 (2.9)	64 (1.6)	58 (1.8)	NA	NA	70 (2.9)	66 (1.5)	73 (1.4)	64 (-3.0)	75 (4.2)	69 (3.0)
Cooperatives	65 (3.2)	73 (0)	79 (3.9)	68 (3.0)	100 (6.4)	115 (4.5)	75 (1.4)	74 (0)	70 (4.5)	66 (4.8)	100 (6.4)	115 (4.5)
High reliance												
Municipals	58 (9.4)	63 (5.0)	65 (1.6)	71 (0)	NA	NA	117 (20.6)	116 (17.2)	NA	NA	87 (14.5)	87 (19.2)
Cooperatives	86 (6.2)	78 (6.8)	NA	NA	NA	NA	86 (6.2)	79 (8.2)	NA	NA	108 (24.1)	112 (9.8)
Alternative 4												
Low reliance												
Municipals	110 (2.8)	108 (2.9)	64 (1.6)	58 (1.8)	NA	NA	72 (5.9)	67 (3.1)	70 (-2.8)	66 (0)	76 (5.6)	70 (4.5)
Cooperatives	64 (1.6)	73 (0)	78 (2.6)	68 (3.0)	114 (21.3)	127 (15.5)	75 (1.4)	74 (0)	68 (1.5)	78 (7.9)	114 (21.3)	127 (15.5)
High Reliance												
Municipals	60 (13.2)	65 (10.0)	71 (10.9)	76 (7.0)	NA	NA	130 (34.0)	127 (28.3)	NA	NA	86 (13.2)	103 (41.1)
Cooperatives	85 (4.9)	80 (9.6)	NA	NA	NA	NA	85 (4.9)	80 (9.6)	NA	NA	126 (44.8)	135 (32.4)
Alternative 5												
Low reliance												
Municipals	109 (1.9)	107 (1.9)	64 (0)	58 (0)	NA	NA	76 (11.8)	69 (6.2)	72 (0)	67 (1.5)	77 (6.9)	70 (4.5)
Cooperatives	64 (1.6)	72 (1.4)	80 (2.6)	71 (4.5)	111 (18.1)	124 (12.7)	75 (1.4)	74 (0)	71 (6.0)	67 (6.3)	111 (18.1)	124 (12.7)
High reliance												
Municipals	61 (15.1)	66 (10.0)	72 (9.4)	77 (7.0)	NA	NA	124 (27.8)	122 (23.2)	NA	NA	81 (6.6)	75 (2.7)
Cooperatives	90 (11.1)	81 (11.0)	NA	NA	NA	NA	90 (11.8)	81 (11.0)	NA	NA	126 (44.8)	134 (31.4)

TABLE 4.4 (Cont.)

Commitment-Level Alternative/System	Arizona		Colorado		Nevada		New Mexico		Wyoming		Utah	
	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008	2000	2008
Alternative 6												
Low reliance												
Municipals	110 (2.8)	108 (2.9)	64 (1.6)	58 (1.8)	NA	NA	72 (5.9)	67 (3.1)	74 (2.8)	65 (-1.5)	78 (8.3)	71 (6.0)
Cooperatives	64 (1.6)	73 (0)	80 (5.3)	69 (4.5)	104 (10.6)	119 (8.2)	75 (1.4)	74 (0)	71 (6.0)	66 (4.8)	104 (10.6)	119 (8.2)
High reliance												
Municipals	59 (11.3)	64 (6.7)	67 (4.7)	73 (2.8)	NA	NA	120 (23.7)	118 (19.2)	NA	NA	84 (10.5)	82 (12.3)
Cooperatives	87 (7.4)	79 (8.2)	NA	NA	NA	NA	87 (7.4)	80 (9.6)	NA	NA	123 (41.4)	120 (17.6)

^a Not applicable.

^b Numbers in parentheses are percentages.

Source: Bodmer et al. (1994).

TABLE 4.5 Coverage Ratio (CR) by Utility Category and Commitment-Level Alternative in 2008

Commitment-Level Alternative	Supply Option	Number of Firms, by Category					
		Low Reliance			High Reliance		
		CR < 1.1	1.1 ≤ CR < 2	CR ≥ 2	CR < 1.1	1.1 ≤ CR < 2	CR ≥ 2
No Action	A	5	7	10	3	5	13
	B	6	6	10	4	4	13
	C	6	6	10	6	2	13
Alternative 1	A	5	7	10	3	5	13
	B	5	7	10	3	5	13
	C	5	7	10	3	5	13
Alternative 2	A	7	5	10	4	4	13
	B	7	5	10	4	4	13
	C	7	5	10	5	3	13
Alternative 3	A	6	6	10	4	4	13
	B	6	6	10	4	4	13
	C	6	6	10	5	3	13
Alternative 4	A	7	5	10	6	2	13
	B	7	5	10	6	2	13
	C	7	5	10	6	2	13
Alternative 5	A	6	6	10	5	3	13
	B	6	6	10	6	2	13
	C	7	5	10	6	2	13
Alternative 6	A	6	6	10	4	4	13
	B	6	6	10	4	4	13
	C	6	6	10	5	3	13

Source: Bodmer et al. (1994).

As indicated in Table 4.5, under supply options A, B, and C, the distribution of both low- and high-reliance utilities with respect to coverage ratio ranges would remain unchanged.

4.1.1.2.3 Commitment-Level Alternative 2

Combined with supply option A, commitment-level alternative 2 would result in a weighted average increase in retail rates of just over 1% (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage, to \$82/MWh in 2008 (Table 4.2). Under supply option B, rates would rise by a weighted average 3%, with high-reliance municipals in Utah experiencing the largest percentage increase, to \$84/MWh in 2008 (Table 4.3). Under supply option C, the weighted average increase in rates would be

TABLE 4.6 Average 1991 Electricity Retail Rates by State and End-User Class

Location	Utilities	Rates (\$/MWh) by End-User Class		
		Residential	Commercial	Industrial
Arizona	All utilities	91	83	56
	Western customers	85	73	46
Colorado	All utilities	71	57	46
	Western customers	69	62	46
Nevada	All utilities	59	63	49
	Western customers	56	53	58
New Mexico	All utilities	91	82	48
	Western customers	98	78	53
Utah	All utilities	71	61	38
	Western customers	64	61	46
Wyoming	All utilities	60	52	35
	Western customers	66	55	44
U.S. average		80	75	48

6%. High-reliance cooperatives in Utah would experience the largest percentage increase, with an average rate of \$86/MWh in 2008 (Table 4.4).

As indicated in Table 4.5, under supply options A, B and C, the distribution of low-reliance utilities with respect to coverage ratio ranges would remain unchanged. The number of high-reliance utilities with a coverage ratio of 2.0 or more would also remain unchanged under supply options A, B and C. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.2.4 Commitment-Level Alternative 3

Commitment-level alternative 3 would result in a weighted average increase in retail rates ranging from 3% (supply option A) to 5% (supply option B) and 8% (supply option C) (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to \$82/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to \$83/MWh (Table 4.3) and \$87/MWh, respectively (Table 4.4).

Under supply options A, B and C, the distribution of low-reliance utilities with respect to coverage ratio ranges would remain unchanged (Table 4.5). The number of high-reliance utilities with a coverage ratio of 2.0 or more would also remain unchanged under

supply options A, B and C. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.2.5 Commitment-Level Alternative 4

Commitment-level alternative 4 would result in a weighted average increase in retail rates ranging from 13% (supply option A) to 14% (supply option B) and 15% (supply option C) (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to \$95/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to \$96/MWh (Table 4.2) and \$103/MWh (Table 4.4).

As indicated in Table 4.5, under supply options A, B, and C, the distribution of both low- and high-reliance utilities with respect to coverage ratio ranges would remain unchanged.

4.1.1.2.6 Commitment-Level Alternative 5

Commitment-level alternative 5 would result in a weighted average increase in retail rates ranging from 10% (supply option A) to 12% (supply option B) and 15% (supply option C) (Table 4.1). High-reliance cooperatives in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to \$128/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to \$130/MWh (Table 4.3) and \$134/MWh (Table 4.4).

As indicated in Table 4.5, under supply options B and C, the number of low- and high-reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. The number low-reliance utilities with a coverage ratio of less than 1.1 would increase by one under supply option C. The number of high reliance utilities with a coverage ratio less than 1.1 would increase by one under supply options B and C.

4.1.1.2.7 Commitment-Level Alternative 6

Commitment-level alternative 6 would result in a weighted average increase in retail rates ranging from 4% (supply option A) to 5% (supply option B) and 10% (supply option C) (Table 4.1). High-reliance municipals in New Mexico would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to \$112/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to \$115/MWh (Table 4.3) and \$118/MWh, respectively (Table 4.4).

As indicated in Table 4.5, under supply options A, B and C, the number of low- and high-reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. The number low-reliance utilities with a coverage ratio of less than 1.1 would also remain

unchanged under all three supply options. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.3 Conservation and Renewable Energy Analysis

The impact of commitment-level alternatives on conservation and renewable energy programs was evaluated by examining the impacts on consumption efficiency and load management activities by long-term firm sale utility customers. The analysis of the impact of commitment-level alternatives on these programs focused on commitment-level alternative 4, which would result in the largest increase in electricity rates. Conservation measures that may occur in addition to those induced by changes in electricity rates were not considered as part of the analysis conducted for the EIS.

The analysis indicated that commitment-level alternatives would not differ significantly in their impacts on conservation and renewable energy activities by long-term firm sale utility customers. This situation is due to the narrow variation in the hourly marginal system costs under each alternative after accounting for power purchased by customers from Western. This narrow variation from hour to hour does not permit cost-effective implementation of peak-load management activities. Furthermore, the low cost of power supplied by Western, along with the excess baseload capacity of many customers, results in few cost-effective energy conservation programs and no significant difference among alternatives with respect to cost-effectiveness. A full discussion of methods and findings can be found in Cavallo et al. (1994).

As indicated in Tables 4.2 through 4.4, the majority of commitment-level alternatives and supply options would cause retail rates for electricity to increase and lead to a decrease in electricity consumption, the magnitude of which would depend on demand elasticities. For the majority of impact scenarios, this increase in price would provide consumers with an incentive to undertake conservation measures in order to minimize the overall increase in their electrical bill. Where rates are predicted to stay constant or fall slightly, as is the case with alternative 1, additional measures designed to encourage energy conservation might also be warranted. The impacts of commitment-level alternatives on non-price-induced conservation measures undertaken by consumers were not included in the analysis of socioeconomic impacts in the EIS.

4.1.1.4 Regional Economic Impacts

As was discussed in the previous section, a change in Western's commitment levels could result in a change in rates charged to electricity consumers. This change could in turn affect the level of economic activity and, consequently, growth in the affected subregions. The REMI modeling system was used to measure the potential impacts of a change in electricity rates on the economies of each subregion by examining trends in population, income, gross regional product (GRP), and employment. None of the impact estimates in the regional analysis was found to be statistically different from zero.

Higher electricity rates could have caused an increase in the cost of doing business that in turn could have lead to (1) a decline in competitiveness in products made by industries within each subregion, and (2) the substitution by existing customers toward products made outside the affected region. In extreme cases, rate increases could have created an incentive for some businesses to move out of the affected region, or discouraged new businesses from moving in. Both effects would have adversely affected employment, income, and GRP. As higher electricity rates consequently changed the geographic distribution of employment opportunities, population growth and in-migration could have been discouraged. The magnitude of these possible effects would have depended on the importance of electricity prices in production decisions, as well as in locational decisions made by households. With respect to industry relocation, existing research suggests that threshold levels of changes must be exceeded before such impacts would occur (Calzonetti et al. 1991).

The results of the regional analysis with the REMI modeling system are summarized in Table 4.7 (rounded to two significant digits) to show the subregions in which the maximum impacts are estimated to occur. The impacts of changes in Western's commitment levels on households with annual incomes of less than \$30,000 in each subregion were also analyzed. Further explanation is provided in Section A.5 of Appendix A. A full discussion of the impacts of each alternative in each subregion for each of the variables can be found in Allison and Griffes (1994).

4.1.1.4.1 Population, GRP, Disposable Income, and Employment

The regional analysis indicates that over the forecast period, a change in Western's commitment levels would have a very minimal (if any) impact on aggregate economic activity in each of the nine subregions. This conclusion also applies to each of the supply options that were considered in the analysis.

The impacts of electricity rate changes that would occur on population, GRP, income, and employment are projected to be different in each of the nine subregions. Estimates show that, in absolute terms, impacts would be largest in the Colorado Metropolitan, Utah Metropolitan, and Great Basin subregions for each commitment-level alternative. The Wyoming Metropolitan Subregion failed to show measurable impacts for any of the commitment-level alternatives or supply options for the four variables considered. Impacts in this subregion therefore represent the minimum of the range of impacts for each commitment-level alternative and supply option. A detailed description of the distribution of impacts across each of the subregions and over the entire forecast period is provided in Allison and Griffes (1994).

Even with the lack of any statistically significant regional economic impacts, the fact that retail rates would increase under most combinations of commitment-level alternatives and supply options suggests that there are likely to be localized impacts to employment and income. However, the areas in which such impacts are likely to occur are small relative to the subregions that were constructed to conduct the regional analysis. Consequently, any

TABLE 4.7 Maximum Estimated Impacts of Commitment-Level Alternatives and Supply Options on Population, Gross Regional Product, Disposable Income, and Employment^a

Alternative	Population		Gross Regional Product		Disposable Income		Employment	
	Region ^b	Percent Change	Region ^b	Percent Change	Region ^b	Percent Change	Region ^b	Percent Change
NA/B	2	-0.02	2	-0.03	2	-0.05	2	-0.02
NA/C	2	-0.13	2	-0.20	2	-0.15	2	-0.13
1A	9	+0.05	5,9	+0.05	9	+0.09	9	+0.05
1B	9	+0.04	9	-0.04	9	+0.08	5	+0.04
1C	2	-0.13	2	-0.20	2	-0.15	2	-0.13
2A	2	+0.13	2	+0.20	2	+0.15	2	+0.14
2B	5	-0.10	5	-0.10	5	-0.14	5	-0.08
2C	5	-0.13	5	-0.13	5	-0.19	5	-0.11
3A	2	+0.07	2	+0.10	2	+0.08	2	+0.07
3B	5	-0.07	5	-0.08	5	-0.11	5	-0.06
3C	5	-0.12	2	-0.13	5	-0.18	5	-0.09
4A	9	-0.16	9	-0.16	9	-0.27	9	-0.14
4B	9	-0.17	9	-0.18	9	-0.29	9	-0.14
4C	5	-0.21	5	-0.23	5	-0.36	5	-0.19
5A	9	-0.09	9	-0.06	9	-0.15	9	-0.06
5B	9	-0.12	2	-0.09	9	-0.19	9	-0.08
5C	9	-0.15	2	-0.16	9	-0.24	9	-0.10
6A	2	+0.07	2	-0.05	9	-0.08	9	-0.04
6B	9	-0.06	9	-0.06	9	-0.09	9	-0.04
6C	9	-0.11	2	-0.15	9	-0.14	9	-0.07

^a The data were estimated using the REMI model, which is described in Appendix A (Section A.5), and are rounded to two significant digits.

^b 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains Subregion, and 9 = Great Basin Subregion.

impacts that might occur at the local level could be undetected when impacts are measured at the regional level.

In addition to the impact on aggregate economic activity in each subregion, electricity rate changes also have the potential to differentially affect activity in specific sectors. Analysis of the effects of changes in retail rates on employment in specific manufacturing and service industries, however, did not reveal impacts that were statistically significant. No attempt is made, therefore, to discuss the sectoral impacts of Western's commitment-level alternatives.

4.1.1.4.2 Impacts on Irrigated Agriculture

As a result of a change in Western's long-term firm commitments, irrigation districts and cooperatives with a high reliance on Western power could experience changes in the costs of electricity and the costs associated with electrical irrigation. For example, in the case of a price increase, farmers typically reduce water use rates and acreage in marginally profitable crops and increase use of other inputs, including surface water, chemical applications, and management labor. The analysis of impacts on irrigated agriculture indicates that a change in commitment-level alternative/supply option combinations could induce some slight adjustments in agricultural production practices for many farmers.

Table 4.8 summarizes the maximum estimated impacts of the commitment-level alternative/supply option combinations on state agricultural net income in the year 2008. For each commitment-level alternative/supply option combination, the state that would experience the largest impact was determined by comparing percentage changes in state net agricultural income between the baseline and the results under each commitment-level alternative/supply option combination. According to Table 4.8, the largest impacts would occur under alternative/option 4C in Utah. Under this commitment-level alternative/supply option combination, net income would fall by about \$779,000 — a reduction of 1.2% of total state net agricultural income. Most of this reduction would be accounted for by a reduction of slightly more than \$650,000 in net income from irrigated hay. This amount would account for about 84% of the reduction in total state agricultural income. The impacts attributable to commitment-level alternative/supply option combinations 4A and 4B would be similar, but slightly smaller in magnitude. As is indicated in Table 4.8, the impacts to net agricultural income associated with each of the other commitment-level alternative/supply option combinations would be smaller than those attributed to alternative/option 4C for each of the six states included in the analysis.

Table 4.9 summarizes the maximum estimated impacts of the commitment-level alternative/supply option combinations on acreage planted, ground water use, and surface water usage in the year 2008. For each commitment-level alternative/supply option combination, the high-impact crop is the one accounting for the largest share of the change in net income for the state. As with the case above, the largest impacts would occur under alternative/option 4C in Utah. These impacts are characterized by a movement away from

TABLE 4.8 Maximum Estimated Impacts of Commitment-Level Alternative/Supply Option Combinations on Agricultural Output and Net Revenues in the SLCA/IP Service Area in 2008

Alternative/ Supply Option	State	Net Revenue Change, State (1994\$)	Net Revenue Change, State (%)	High Impact Crop	Net Revenue Change, Crop (1994\$)	Share of Total State Impact from High Impact Crop (%)
NA/B	Arizona	-57,500	-0.04	Cotton	-37,700	65.5
NA/C	Arizona	-462,900	-0.34	Cotton	-303,700	65.6
2A	Arizona	-299,000	-0.22	Cotton	-196,100	65.6
2B	Arizona	-419,500	-0.31	Cotton	-275,200	65.6
2C	Arizona	-596,400	-0.43	Cotton	-391,300	65.6
4A	Utah	-709,700	-1.08	Hay	-597,300	84.1
4B	Utah	-734,600	-1.12	Hay	-618,200	84.1
4C	Utah	-778,000	-1.19	Hay	-655,400	84.1
5A	Arizona	-449,500	-0.33	Cotton	-294,900	65.6
5B	Arizona	-569,100	-0.41	Cotton	-373,400	65.6
5C	Arizona	-723,700	-0.53	Cotton	-474,900	65.6

Source: Flaim et al. (1994).

irrigated cropping and toward dryland cropping. Irrigated acreage would decline by an estimated 4,500 acres, a reduction of 0.5% below the baseline. This movement away from irrigated cropping would involve a reduction in electrically pumped groundwater of almost 45,000 acre-feet, or about 8.7% below the baseline. Use of surface water and other groundwater would also decline, but to a much smaller degree. Impacts attributable to the remaining commitment-level alternatives/supply option combinations would be smaller than those associated with alternative/option 4C.

4.1.2 Air Resources

The potential impacts of Western's commitment-level alternatives have been assessed with regard to local and regional air quality, regional emissions of greenhouse gases, and the acoustic environment. In response to the different capacity and energy-level commitments by Western under various commitment-level alternatives (Table 2.1), the levels and mix of electric energy produced with different fuels by generating units owned by the region's utility systems would change, causing changes in the associated air pollutant emissions and associated air quality impacts. The assessment presented here was based on the results of (1) a series of analyses to estimate changes in capacity factors and air pollutant emissions

TABLE 4.9 Maximum Estimated Impacts of Commitment-Level Alternative/Supply Option Combinations on Irrigated Acreage Planted, Surface Water Use, and Groundwater Use in the SLCA/IP Service Area in 2008

Alternative/ Supply Option	State	Change in Irrigated Acreage		Change in Surface Water Use		Change in Groundwater Use, Electric Pumped		Change in Groundwater Use, Other	
		Acres	Percent	Acre-Feet	Percent	Acre-Feet	Percent	Acre-Feet	Percent
NA/B	Arizona	0	0	200	0.01	-3,500	-0.2	20	0.01
NA/C	Arizona	0	0	1,800	0.08	-27,800	-1.6	260	0.07
2A	Arizona	0	0	1,200	0.06	-18,000	-1.0	170	0.05
2B	Arizona	0	0	1,600	0.08	-25,200	-1.4	240	0.07
2C	Arizona	0	0	1,900	0.09	-36,200	-2.1	230	0.06
4A	Utah	-4,000	-0.44	-2,400	-0.16	-41,000	-8.3	-340	-0.24
4B	Utah	-4,200	-0.45	-2,500	-0.16	-42,300	-8.3	-350	-0.25
4C	Utah	-4,500	-0.48	-2,600	-0.18	-44,700	-8.7	-380	-0.27
5A	Arizona	0	0	1,600	0.08	-27,200	-1.5	210	0.05
5B	Arizona	0	0	2,000	0.10	-34,300	-1.9	260	0.07
5C	Arizona	0	0	2,600	0.12	-43,500	-2.5	330	0.09

Source: Flaim et al. (1994).

for individual generating units owned by the region's utility systems affected by Western's commitment-level alternatives and (2) air quality modeling to estimate ambient air quality impacts of individual generating units.

The analyses, information, and input data required for the air quality assessment are shown schematically in Figure 4.3. The analyses used the results of power systems modeling performed for this EIS for the period 1993 through 2008, including (1) projected data for electric energy production and fuel use at existing and projected new generating units, (2) electric energy purchases by the region's utilities affected by Western's commitment-level alternatives, (3) Western's long-term and short-term firm sales commitments, and (4) Western's hydroelectric generation. Computations of changes in electric energy generation, capacity factors, and air pollutant emissions of individual generating units were made for selected commitment-level alternatives — (1) the no-action alternative, moderate power and high energy; (2) alternative 2, high power and low energy; (3) alternative 4, low power and low energy; and (4) alternative 5, low power and high energy — in the selected years 1993, 1998, and 2008. In addition to commitment-level alternatives, three supply options described in Section 4.1.1.1 were also considered. Air pollutant emissions were calculated by multiplying the projected data for fuel use at individual generating units or electric energy purchases of individual utilities by appropriate emission factors.

For the local air quality assessment, additional analyses involved (1) air quality impact modeling for selected new generating units, using the Industrial Source Complex Model recommended by the EPA (1986); typical plant parameters; and meteorological data for selected locations within the six-state study region and (2) a subsequent assessment based on the results of the air quality modeling and the significance of capacity factor changes at individual generating units under the selected commitment-level alternatives.

Assessments of potential impacts on regional air quality and greenhouse gas emissions also required (1) estimation of emissions associated with changes in electricity generation by the region's utilities to compensate for changes in Western's hydroelectric generation from long-term and short-term firm sales commitments and to cover Western's long-term firm purchases and (2) a subsequent comparison of the differences in net totals of those emissions among selected commitment-level alternatives. Details of the input data and information and the analyses conducted for air quality impact assessments are provided in Chun et al. (1994).

The projected new generating capacity additions needed to replace retired units and to meet the region's growing power demands include diesel engines, gas turbines, combined cycle units, and pulverized coal power plants of various sizes (Chun et al. 1994). Construction and operation of these new generating units would result in (1) emissions of air pollutants, including those from fossil-fuel combustion, and (2) noise emissions from equipment. Detailed assessments of potential air quality and noise impacts would be needed once individual facilities are proposed at specific sites, but such detailed, site-specific assessments are beyond the scope of this EIS.

FIGURE 4.3 Components of Air Quality Impact Assessment (Source: Chun et al. 1994)

4.1.2.1 Air Quality

4.1.2.1.1 Local Air Quality

Potential impacts on local air quality of Western's commitment-level alternatives were assessed for existing generating plants as well as for projected new units. The existing peaking plants with units having more than a 10% change in the annual capacity factor relative to the no-action alternative during any one of the three years evaluated are all small plants that have an individual total plant generating capacity of 19 MW or less and are located in relatively small cities. The percent changes in annual capacity factor⁵ from the no-action alternative range from 0 to -7% for alternative 5 in 1993 to 30 to 73% for alternative 4 in 2008. However, none of these plants have annual capacity factors greater than 85% in any of the three years considered. Because air quality impacts of these small peaking plants are small even at a 100% annual capacity factor (Chun et al. 1994), projected changes in the annual capacity factors at these plants are not expected to result in any significant ambient air quality impacts.

The existing intermediate- and baseload plants with units having more than a 10% change in annual capacity factor from the no-action alternative during any one of the three years evaluated are all coal-fired plants that have a total plant generating capacity between 235 and 2,268 MW and are located in rural areas of Colorado, New Mexico, Utah, or Wyoming. The percent changes in annual capacity factor from the no-action alternative (on a plant-wide basis) are 5% or less, except for one plant with an annual capacity factor change ranging from -1% under alternative 5 in 2008 to 11% under alternative 2 in 1998. However, this amount of change in annual capacity factor is not expected to result in significant ambient air quality impacts because of the total generating capacity of the plant and because it meets the New Source Performance Standards (Chun et al. 1994).

The projected new peaking units having more than a 10% change in annual capacity factor from the no-action alternative during 1998 and 2008 include gas turbines with a unit generating capacity between 8 and 69 MW and diesel engines with a unit generating capacity between 1.5 and 11 MW. The percent changes in annual capacity factor from the no-action alternative range from -11 to 0% for alternative 2 in 1993 to -15 to 28% for alternative 4 in 2008. However, none of these units have annual capacity factors greater than 28% in 1998 or 2008. Because air quality impacts of these peaking units are small even at 100% annual capacity factor, the projected changes in annual capacity factors at these units are not expected to result in any significant ambient air quality impacts (Chun et al. 1994).

The projected new intermediate-load and baseload plants with units having more than a 10% change in annual capacity factor from the no-action alternative during 1998 and 2008 are all gas-fired combined cycle units with a unit generating capacity between 13 and

⁵ The annual capacity factor is the ratio of the energy produced by a power plant during one year compared with the energy it could have produced at maximum capacity under continuous operation during the whole year.

186 MW. The percent changes in annual capacity factor range from -43 to 18% for alternative 5 in 2008 to 43 to 91% for alternative 2 in 1993. Because the air quality impacts of these gas-fired combined cycle units are small even at 100% annual capacity factor, the projected changes in annual capacity factors of these plants are not expected to result in any significant ambient air quality impacts (Chun et al. 1994).

4.1.2.1.2 Regional Air Quality

The estimated annual air pollutant emissions from the region's 17 utility systems resulting from the various commitment-level alternatives, and their percent changes from the no-action alternative, are presented in Appendix B, Table B.7. Projected changes in SO₂, NO_x, TSP, and CO₂ for alternatives 2, 4 and 5 under supply options A, B, and C are within 1% of the values for the no-action alternative. These changes in the emissions of precursors causing regional acid deposition (SO₂ and NO_x), pollutants causing regional visibility impairment (SO_x, NO_x, and TSP), and greenhouse gas (CO₂) from the region's 17 utility systems are not considered significant.

4.1.2.2 Noise

Changes in operating levels and the mix of generating units owned by the region's utility systems under Western's various commitment-level alternatives could result in changes in levels and patterns of noise generation at these units. Because baseload units generally have large capacities and operate continuously, a change in power generation from baseload units would mean a change in load factors rather than a shutting down or starting up of units. Thus, noise generation from baseload unit operations should change little as long as the units are in operation.

Peaking units generally have relatively small capacities, so a change in power generation from peaking units usually means starting up additional units or shutting down operating units. Even if the number of operating units were changed, the number of such units would be relatively small at any particular generating facility because the changed peaking power demand would be covered by a number of the region's utility systems. Furthermore, even if all existing peaking units at a particular site were operating, the noise generated would be no higher than the maximum level already experienced at the site. Only the frequency and duration of maximum noise levels might increase. However, because of the timing of peak demand, such potential increases in noise would not occur at night when noise impacts are considered more serious. Thus, changes in commitment-level alternatives would not result in adverse noise impacts in the vicinity of the region's electric power generating facilities whose operations are affected by Western's operations.

4.1.3 Other Resources

Most of the direct impacts to water, ecological, cultural, land use, recreation, and visual resources from Western's power marketing program would result from operation of the

hydroelectric facilities that supply much of the power sold by Western. For the most part, the impacts would occur downstream of those facilities, and the magnitude of the impacts would depend on Reclamation's and Western's operations of the facilities. Each commitment-level alternative could result in a wide range of environmental impacts that are dependent on the operational scenario implemented at each of the hydropower facilities being considered in this EIS. Under worst-case conditions, each alternative could result in the most adverse impacts to each resource, as identified and discussed in Section 4.2.

In addition to the direct impacts of hydropower operations, indirect impacts could result from fulfilling the need for additional capacity under each commitment-level alternative. This need for additional capacity could be met by building new power plants, by expanding existing ones, or by methods that have minimal environmental effects. Construction and operation would result in additional impacts to the natural resources in the vicinities of the new or expanded facilities. This section briefly discusses the types of impacts that could occur. A more detailed discussion of specific impacts cannot be presented here because the significance and nature of any such impacts would depend on the specific plans and locations for the new or expanded facilities. An environmental review providing full consideration of environmental impacts would be required before construction of any new facilities or modification of existing facilities.

4.1.3.1 Water Resources

During construction of new power plants, water resources could be impacted by such processes as site clearing (including dredge or fill activities in water bodies), surface or groundwater withdrawal for construction activities, and discharge or spillage of fluids during the construction process. Indirect impacts also could result from the erosion of construction sites and the runoff of sediment into adjacent water bodies. During power plant operations, impacts to water resources could result from surface or groundwater withdrawal for cooling or moderating during power production, as well as from the discharge of waste fluids during normal operations. Withdrawals or discharges associated with abnormal events (accidents) could also impact nearby water resources.

4.1.3.2 Ecological Resources

Construction and operation of new power plants could cause a variety of impacts to ecological resources, including aquatic and terrestrial resources, wetlands, and threatened and endangered species (see USFWS 1978 for review). The types of impacts that could occur would depend on such factors as the location, type, and size of facilities and the nature of the resources in the area. Direct impacts of construction to ecological resources could include dredge or fill activities in wetlands or aquatic habitats, destruction or modification of terrestrial or aquatic habitats during site clearing, displacement of animal populations in construction areas, and disturbance of animals in adjacent habitats by construction activities. Indirect construction impacts could include degradation of adjacent habitats by site erosion and runoff.

Impacts that could result from operations include (1) degradation of aquatic habitats during withdrawal of cooling water from nearby water bodies; (2) entrainment of aquatic organisms during water withdrawal; (3) degradation of aquatic habitats by discharge of heated cooling water to aquatic systems; (4) disturbance of terrestrial animals in adjacent habitats; and (5) harming vegetation by deposition of salts in cooling tower drift on vegetation.

4.1.3.3 Cultural Resources

Depending on the specific locations, construction of new or expanded power plants could damage or destroy archaeological sites, historic structures, or Native American cultural resources (as generally defined in Section 3.5). Direct impacts would be from construction-related activities. Indirect impacts would be from visual impacts and erosion at construction sites.

4.1.3.4 Land Use

The construction of any new power plants could alter land use in the immediate vicinity of the facilities. The magnitude of impacts to land use would depend entirely on the nature of land use before construction. Any such impacts would be very localized.

4.1.3.5 Recreation

The construction and operation of new power plants could affect recreation in several ways. Perhaps most important would be the potential for a change in the perception of the quality of recreational experiences available in the vicinities of the new facilities. A negative perception could result in a decline in use rates for those recreational activities that require a relatively pristine environment. Such activities include hiking, scenic viewing, and nature photography. Other impacts could include modification of existing recreational resources (e.g., water bodies used as recreation sites) either during construction (e.g., by dredge, fill, channelization) or operation (e.g., effects on water levels, water temperature, water quality). The magnitude of impacts would be dependent on the nature of the area in which the facilities were built, the level of recreational use, and the nature of the recreational resource.

4.1.3.6 Visual Resources

Visual impacts could occur during construction and operation of any new power plants. Such impacts could include (1) reduction of visibility by fugitive dust generated during site clearing and construction; (2) degradation of views by land disturbance and other construction activities; (3) generation of smoke and steam plumes during operations that could be visible at long distances; and (4) intrusion of industrial-type facilities in previously

scenic viewsheds. The magnitude of any such impacts would depend on the size and design of the facilities and the visual quality of the areas in which they were built.

4.2 CONSEQUENCES OF HYDROPOWER OPERATIONS

This section presents the impacts to resources that would result from operation of the Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Blue Mesa and Morrow Point dams) hydropower facilities. At the Glen Canyon and Flaming Gorge facilities, impacts of hydropower operations would be limited primarily to resources downstream of the dams. Fluctuations in water releases to produce power would change flows below the dams but would not be sufficiently large to cause significant changes in water levels in the reservoirs above the dams. The Aspinall Unit, however, has relatively small reservoirs that can fluctuate in depth as a result of releases of water for hydropower operations.

Different operational scenarios that span the range of possible operating modes for each facility (as described in Section 2.3) were formulated to identify the types of impacts that could result from hydropower operations. For purposes of assessment, it was assumed that daily release patterns within an operational scenario would (1) be identical within a season or period; (2) reach the maximum variation possible, as defined by the operational scenario, each day; and (3) use a one-hour period to switch between minimum and maximum releases. In addition, the volume of water released each month would either follow the historical pattern of release or be seasonally adjusted to achieve particular resource objectives (e.g., those established in the Biological Opinion for Flaming Gorge Dam [USFWS 1992b]). In either case, the annual amount of water released from a particular facility would be nearly the same for each operational scenario. As in the past, future monthly and annual release volumes would be determined each year by the Bureau of Reclamation and identified in their Annual Operating Plan.

For Glen Canyon Dam, the nine alternatives being considered in the Glen Canyon EIS (Reclamation 1993) are considered here as operational scenarios. These scenarios are (1) continuation of historical operations (the no-action alternative of the Glen Canyon EIS), (2) operation at maximum power plant capacity, (3) restricted high fluctuation (the high fluctuation alternative of the Glen Canyon EIS), (4) moderate fluctuation, (5) modified low fluctuation, (6) interim low fluctuation, (7) existing monthly volume steady flow, (8) seasonally adjusted steady flow, and (9) year-round steady flow.

For Flaming Gorge Dam, four hydropower operational scenarios were formulated: (1) year-round high fluctuation (similar to historical hydropower operations), (2) seasonally adjusted high fluctuation, (3) seasonally adjusted moderate fluctuation, and (4) seasonally adjusted steady flow. Seasonal adjustments were made in release patterns for the latter three scenarios to bring them into compliance with the recently issued Biological Opinion for the Flaming Gorge facility. The year-round high fluctuation operational scenario is included to permit comparison with impacts that would result from continuation of past operations.

For the Aspinall Unit, two hydropower operational scenarios are considered: (1) seasonally adjusted high fluctuation and (2) seasonally adjusted steady flows. For both of these scenarios, the seasonal adjustments refer to a shifting of water release patterns from the historical pattern to that which would be considered in the Gunnison River EIS. In addition, both scenarios incorporate steady flows from Crystal Dam, the lowermost dam of the unit. Thus, releases from Crystal Dam would not be altered for hydropower production, and resources below this dam need not be considered in an assessment of hydropower impacts.

4.2.1 Socioeconomics

4.2.1.1 Financial and Regional Economic Variables

Section 4.1.1 summarized the impacts of various combinations of commitment-level alternatives and supply options on a range of socioeconomic variables. Each of the supply options consists of purchases and different combinations of operational scenarios at each of the dams. In addition, each of the supply options was selected in such a manner that the full range of socioeconomic impacts attributable to changes in operational scenarios (for a given commitment-level alternative) would be captured. As was noted in Section 4.1.1, the supply options (including steady flows at all of the affected dams) would have, at most, minimal impacts on each of the regional economies studied. Changing dam operations at one site (e.g., reducing fluctuations at Glen Canyon), while leaving dam operations unchanged at the other sites would result in even smaller impacts to these regional economies. Thus, it can be concluded that there would be little, if any, impact to the regional economies from an isolated change in operation of any one of the dams.

In contrast, the results reported in Section 4.1.1 suggest that the different supply options could have varying impacts on the retail rates paid by the utilities' customers. According to the results presented in Tables 4.1 through 4.4, impacts, as measured by changes in the retail rates charged by the affected utilities, would increase as more restrictions are placed on the operations of each dam. For example, depending upon the commitment-level alternative in question, retail customers of low-reliance utilities could experience rate changes ranging from -7.6% under supply option A to +15.5% under supply option C. In a similar manner, customers of high-reliance utilities could see their rates change by amounts ranging from -10.3% under supply option A to +41.1% under supply option C.

4.2.1.2 Recreation and Nonuse Values

The use values of angling and white-water boating are affected by such factors as the number of recreationists (i.e., the quantity of recreation) and the perceived quality of the recreational experience (see Appendix A, Section A.6, and Carlson [1994] for a more detailed discussion of this relationship). Quality is, in turn, influenced by such factors as river flows,

catch rates (in the case of angling), and scenic beauty. A change in the operational scenario at each dam could affect the level of river flows, as well as fluctuations in river flows. In turn, these changes could affect the use value of recreation. The magnitude of this change would depend on the magnitude of the changes in the number of recreationists that visited a site and/or the quality of the recreational experience.

To the extent that there is a change in the quantity of recreation, the local economy would also experience impacts. In particular, at some average level of expenditures per recreationist, a change in use levels would result in a change in total recreation-related expenditures, and, therefore, the total amount of local economic activity attributable to recreation.

As part of its analysis in support of the Glen Canyon Dam EIS, Reclamation is sponsoring a study of nonuse values associated with the riparian environment below Glen Canyon Dam. The preliminary results of focus group sessions conducted for the study suggest that some individuals may attach nonuse values to this environment. Moreover, some evidence suggests that such values may be sensitive to impacts to vegetation and associated wildlife, native fish, Native American Groups, and archeological sites (Reclamation 1993). To the extent that different operational scenarios result in such impacts, a change in dam operations could result in a change in nonuse values as well. However, it is not clear whether some individuals might also attach nonuse values to the hydroelectric power generated at Glen Canyon Dam. If this is the case, the same operational scenario could possibly affect this latter category of nonuse values. Furthermore, it is possible that the potential changes in the nonuse values for hydropower could somewhat offset those for environmental resources. In any event, evidence now available is insufficient to support any definitive conclusions about the magnitude of nonuse values associated with the different operational scenarios. Consequently, changes in nonuse values were not considered further for this EIS.

4.2.1.2.1 Glen Canyon Dam

Following the approach used by Bishop et al. (1987), it was noted that the demand for permits to raft the Colorado River below Glen Canyon Dam far exceeds the available supply. In addition, no evidence suggests that angling use rates would be substantially altered by a change in flow regimes below the dam. Consequently, it was concluded that there would be no change in boating or angler user days as a result of a change in dam operations. Since use rates were assumed to remain constant, it is reasonable to assume that recreation-related expenditures in the local economy would remain unchanged as well. Thus, no estimation was made of regional economic impacts attributable to changes in recreation use rates and expenditures.

In the case of changes in the use value of recreation, however, the study by Bishop et al. (1987) produced strong evidence that such values would change as flows change. According to their results, the use values of white-water rafting and angling increase as the degree of daily fluctuations in flows decreases. In addition, use values for angling reach a

maximum at a flow level that is considerably less than the flow level required to maximize the value of white-water boating. However, given the structure of the questions used in the study by Bishop et al., inferences on the effects of fluctuations in flows were limited to fluctuations greater than or less than 10,000 cfs. As a result, it was not possible to distinguish between certain operational scenarios, as indicated below. In addition, recreation values were limited to angling and commercial and private white-water boating, since these were the activities found to be sensitive to changes in flows.

The results of the study by Bishop et al. (1987) were used as the basis for the estimates of the net economic value of recreation for each of the operational scenarios at Glen Canyon Dam. The values reported for each of the operational scenarios discussed below are summarized in Table 4.10. These values were all taken from the Glen Canyon EIS (Reclamation 1993).

Angling

As indicated in Table 4.10, use values for angling decrease as hydrological conditions change from dry to wet under each of the nine operational scenarios. In addition, the historical flow, maximum power plant capacity flow, and restricted high fluctuating flow operational scenarios would yield the same amount of use value to anglers under each hydrological condition. The moderate fluctuating flow scenario would yield similar use values under moderate and wet hydrological conditions and slightly higher angler use values under dry hydrological conditions. All four scenarios would yield angler use values lower than those associated with the other operational scenarios.⁶

The interim low fluctuating flows and existing monthly volume steady flow scenarios would also yield equivalent use values to anglers for each of the three hydrological conditions. In addition, the modified low fluctuating flow and seasonally adjusted steady flow scenarios would yield angler use values approximately equal to those associated with interim low fluctuating flows and existing monthly volume steady flows. Minor differences would arise under moderate and wet hydrological conditions. All four of these operational scenarios would represent an improvement for anglers compared with the four scenarios previously discussed. Under moderate hydrological conditions, the interim low fluctuating flow and existing monthly volume steady flow scenarios would maximize the use value of angling relative to the seven other operational scenarios.

Of the nine operational scenarios, year-round steady flows would yield the maximum use value to anglers under dry and wet hydrological conditions. Under moderate hydrological conditions, this scenario would yield use values equal to those under the seasonally adjusted steady flow scenario, and only slightly less than those under the interim low fluctuating flow

⁶ The similarity of the estimated use values for these four operational scenarios results from the inability of the model developed by Bishop et al. (1987) to distinguish among the flow regimes associated with each of these scenarios.

TABLE 4.10 Summary of Recreation Use Values Associated with Each Operational Scenario at Glen Canyon Dam

Operational Scenario/ Hydrological Condition	Use Value by Recreational Activity (10 ⁶ 1994 \$)					Percent Change from Historical Flows
	Angling	Commercial White- Water Boating	Private White- Water Boating	White-Water Boating below Diamond Creek	Total ^a	
Historical Flows						
Dry	1.4	5.7	1.2	0.11	8.41	—
Moderate	1.3	6.7	1.3	0.13	9.43	—
Wet ^b	1.2	11.9	1.9	0.26	15.26	—
Maximum power plant capacity flows						
Dry	1.4	5.7	1.2	0.11	8.41	0.00
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.26	15.26	0.00
Restricted high fluctuating flows						
Dry	1.4	5.7	1.2	0.11	8.41	0.00
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.26	15.26	0.00
Moderate fluctuating flows						
Dry	1.6	5.5	0.9	0.10	8.10	-0.04
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.22	15.22	0.00
Modified low fluctuating flows						
Dry	1.9	6.6	1.1	0.12	9.72	15.58
Moderate	1.4	9.6	1.7	0.18	12.88	36.59
Wet	1.2	14.0	2.2	0.26	17.66	15.73
Interim low fluctuating flows						
Dry	1.9	7.0	1.2	0.13	10.23	21.64
Moderate	1.8	9.9	1.8	0.18	13.68	45.07
Wet	1.4	14.1	2.2	0.26	17.96	17.69
Existing monthly volume steady flows						
Dry	1.9	7.0	1.2	0.13	10.23	21.64
Moderate	1.8	9.9	1.8	0.18	13.68	45.07
Wet	1.4	14.1	2.2	0.26	17.96	17.69
Seasonally adjusted steady flows						
Dry	1.8	7.1	1.1	0.13	10.13	20.45
Moderate	1.7	10.4	1.9	0.20	14.20	50.58
Wet	1.4	13.5	2.2	0.26	17.36	13.76

TABLE 4.10 (Cont.)

Operational Scenario/ Hydrological Condition	Use Value by Recreational Activity (10 ⁶ 1994 \$)				Total ^a	Percent Change from Historical Flows
	Angling	Commercial White- Water Boating	Private White- Water Boating	White-Water Boating below Diamond Creek		
Year-round steady flows						
Dry	2.0	6.1	1.1	0.12	9.32	10.82
Moderate	1.7	10.4	1.9	0.20	14.20	50.58
Wet	1.4	13.6	2.3	0.26	17.56	15.07

^a Values in rows may not sum to total due to rounding.

^b The values reported for wet hydrological conditions are a simple arithmetic average of the three values for wet years reported in the Glen Canyon EIS.

Source: Reclamation (1993).

and existing monthly volume steady flow scenarios. These results reflect the preference anglers have for constant flows over fluctuating flows, all other variables held constant.

White-Water Boating

As summarized in Table 4.10, use values for white-water boating increase as hydrological conditions change from dry to wet under each of the nine operational scenarios. This reflects the preference boaters have for higher flows, as opposed to lower flows, over a wide range of flow levels. The historical flow, maximum power plant capacity flow, and restricted high fluctuating flow operational scenarios would yield the same amount of use value to commercial and private white-water boaters and to boaters below Diamond Creek under each hydrological condition. The moderate fluctuating flow scenario would yield similar use values under moderate and wet hydrological conditions, and slightly lower boater use values under dry hydrological conditions. All four scenarios would yield lower boater use values than those associated with the remaining operational scenarios.⁷

The interim low fluctuating flow and existing monthly volume steady flow scenarios would yield equivalent use values to boaters under each hydrological conditions. In addition, boater use values would be higher under either of these scenarios than under the four scenarios discussed above. However, of the nine operational scenarios considered here, seasonally adjusted steady flows would yield the maximum use value to boaters under dry hydrological conditions. Under moderate hydrological conditions, seasonally adjusted steady

⁷ The similarity of the estimated the values for these four operational scenarios results from the inability of the model developed by Bishop et al. (1987) to distinguish among the flow regimes associated with each of these scenarios.

flows and year-round steady flows would yield the maximum flow volumes to boaters. Under wet hydrological conditions, low fluctuating flows and existing monthly volume steady flows would yield the maximum boater use values. These results reflect the preference boaters have for constant flows over fluctuating flows, all other variables held constant.

4.2.1.2.2 Flaming Gorge Dam

Section 4.2.7 presents the assessment of the impacts of different operational scenarios at Flaming Gorge Dam on angling and day rafting between the dam and the Colorado-Utah border and on white-water rafting in Dinosaur National Monument. Although it is possible to state, qualitatively, the effects of each operational scenario on recreation, there is insufficient data and information on the relationship between flows and use rates to estimate changes in use rates attributable to each scenario. However, it is still possible to gain insights into the potential effects that each operational scenario could have on the level of activity in the local economy.

As was noted in Section 3.1.2.3.1, angling, day floating, and white-water rafting on the Green River between Flaming Gorge Dam and Jensen, Utah, accounted for an estimated \$24.8 million (1994 dollars) of output in the local economy⁸ in 1991. In addition, these activities resulted in an estimated \$12.6 million of personal income and 513 jobs (Rose and Frias 1993).⁹ These values amount to 0.22%, 0.22%, and 0.38% of total output, income, and employment in the six-county region in the same year. If all three of these recreational activities were to be eliminated, output, income, and employment would decline by these percentages.¹⁰ However, it is virtually certain that even for the worst-case operational scenario, (year-round high fluctuating flows), use rates would decline by considerably less than 100%. In turn, regional economic impacts would decline compared with the extreme case noted above. Thus, for example, if use rates for each of the three activities fell by 50%, output, income, and employment would fall by 0.1%, 0.1%, and 0.2%. In a similar manner, a 10% decrease in use rates would cause the same three measures of economic activity to decline by 0.02%, 0.02%, and 0.04%.¹¹

The effects of each operational scenario on the use value of recreation below Flaming Gorge Dam were calculated on the basis of existing estimates of such use values and the

⁸ The local economy around the Green River below Flaming Gorge Dam was defined to include Uintah and Daggett counties in Utah, Sweetwater and Uinta counties in Wyoming, and Moffat and Rio Blanco counties in Colorado.

⁹ The data reported in Rose and Frias (1993) had to be adjusted for the use rates below Flaming Gorge Dam reported in Carlson (1994).

¹⁰ This assumes that use rates are relatively stable over time. This assumption is supported by recent data (see Table 3.16).

¹¹ Note that an increase in use rates would result in an increase in output, income, and employment. The amount of change in each variable would depend on the change in each of the three use rates.

relationship between use values and flows that was developed in the Glen Canyon EIS (Reclamation 1993). The study by Bishop et al. (1987) found no significant relationship between flows and the value of day rafting. Consequently, the value of this activity was not included in the estimates of use values associated with each operational scenario at Glen Canyon Dam. This same approach was used to estimate the use value associated with different operational scenarios at Flaming Gorge Dam. The values reported here (as summarized in Table 4.11) are limited to angling below the dam and commercial and private white-water rafting in Dinosaur National Monument. For a discussion of the methods used to develop the estimates in Table 4.11, see Appendix A and Carlson (1994).

Angling

As indicated in Table 4.11, use values for angling are maximized under moderate hydrological conditions for each of the four operational scenarios. The range of use values associated with year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and moderately fluctuating flows is relatively small. This result is due, in large part, to the constraints on monthly volumes imposed by the Biological Opinion. Use values would vary by less than 6% under all three scenarios and hydrological conditions. Angler use values would be largest under the seasonally adjusted steady flows scenario. This result reflects the preference anglers have for steady flows compared to fluctuating flows.

White-Water Boating

Use values for white-water boating increase as hydrological conditions change from dry to wet under each of the four operational scenarios (Table 4.11). Under moderate hydrological conditions, white-water boater use values would be highest under the seasonally adjusted high fluctuating flow scenario because of the relatively high flows and lack of fluctuations during daylight hours within Dinosaur National Monument under this scenario. Use values would be highest under the combination of year-round high fluctuations and wet hydrological conditions because of the large volumes that would occur in the prime boating months and the absence of fluctuations in flows in Dinosaur National Monument in most months during daylight hours (see Section 4.2.7.2.2).

4.2.1.2.3 Aspinall Unit

As is discussed in Section 4.2.7, neither of the operational scenarios (i.e., seasonally adjusted high fluctuating flows and seasonally adjusted steady flows) would affect recreation use rates or the quality of recreation in the vicinity of the Aspinall Units. Consequently, there would be no economic impacts to recreation.

TABLE 4.11 Summary of Recreation Use Values Associated with Each Operational Scenario at Flaming Gorge Dam

Operational Scenario/ Hydrological Condition	Use Value by Recreational Activity (10 ⁶ 1994 \$)				Percent Change from Year-Round High Fluctuating Flows
	Angling	Commercial White-Water Boating	Private White-Water Boating	Total	
Year-round high fluctuating flows					
Dry	4.019	0.090	0.013	4.122	
Moderate	4.027	0.090	0.027	4.144	NA ^a
Wet	2.965	0.546	0.245	3.756	NA
Seasonally adjusted high fluctuating flows					
Dry	3.873	0.211	0.111	4.195	1.77
Moderate	3.974	0.279	0.151	4.404	6.27
Wet	3.118	0.300	0.110	3.528	-6.07
Seasonally adjusted moderate fluctuating flows					
Dry	3.873	0.127	0.030	4.030	-2.23
Moderate	3.953	0.254	0.125	4.332	4.54
Wet	2.958	0.333	0.135	3.426	-8.79
Seasonally adjusted steady flows					
Dry	4.655	0.132	0.032	4.819	16.81
Moderate	4.962	0.189	0.058	5.209	25.70
Wet	3.205	0.290	0.106	3.601	-4.13

^a NA indicates not applicable.

Source: Carlson (1994).

4.2.2 Air Resources

The potential impacts of Western's hydroelectric generating plant operational scenarios have been assessed with regard to local and regional air quality, regional emissions of greenhouse gases, and the acoustic environment in the vicinity of Western's hydroelectric generating facilities and other electric generating units in the region. Three sets of operational scenarios under each of the commitment-level alternatives were considered in power systems modeling. These scenarios — supply options A, B, and C — provided input data for this assessment (see Section 4.1.1.1 for operational scenarios included in each supply option). A hydroelectric operational change from high fluctuating flow to lower fluctuating flow means that power production at Western's hydroelectric generating units would be made more uniform throughout the day. Compared with the high fluctuating flows typical of historical operations, hydroelectric power production would be decreased during the peak

demand period and increased during the off-peak demand period. Under reduced fluctuating flows at Western's facilities, more baseload electric energy (with generally higher emission factors) would be replaced by Western's hydroelectric energy; as a result, a net decrease in air pollutant emissions could occur. Thus, the air pollutant emissions by the region's utility systems would be expected to decrease in general as hydroelectric operations changed from high fluctuating flows to steady flows. The potential impacts on air quality of Western's operational scenarios were assessed on the basis of the same analyses conducted for assessing the potential impacts of Western's commitment-level alternatives (Section 4.1.2.1).

4.2.2.1 Air Quality

4.2.2.1.1 Local Air Quality

Potential effects of Western's commitment-level alternatives on local air quality were analyzed with the data on electric energy produced by the region's individual generating units under selected commitment alternatives, projected by the power systems modeling conducted for this EIS (Section 4.1.2.1.1). Because power systems modeling was not specifically performed to evaluate potential effects of Western's operational scenarios on the electric energy produced by individual generating units, such effects were estimated by comparing the effects of the various commitment-level alternatives and operational scenarios on the total electric energy produced from nonhydroelectric units. (It was assumed that the smaller the effects on total electric energy production from nonhydroelectric units, the smaller the effects on electric energy generation from individual generating units.)

Because the projected effects of operational scenarios on total electric energy produced from nonhydroelectric units are less than those projected for the commitment-level alternatives (Chun et al. 1994), differences in electric energy production at individual generating units and associated local air quality impacts under supply options A, B and C would be less than the differences among commitment-level alternatives, which are considered not significant (Section 4.1.2.1.1).

4.2.2.1.2 Regional Air Quality

The estimated annual air pollutant emissions from the region's utility systems under Western's supply options A, B, and C are provided in Appendix B, Table B.8. The percent change in annual emissions of SO₂, NO_x, TSP, and CO₂ varies by about 1% or less across the three supply options under each of the four commitment-level alternatives evaluated. Thus, regional air quality impacts resulting from changes in operational scenarios would not be significant.

4.2.2.2 Noise

Western's operational scenarios could also affect the pattern of noise emissions from various noise-generating equipment at Western's and Reclamation's hydroelectric generating facilities as well as other electric generating units in the region whose operations are affected by Western's operations. Major noise sources at Western's and Reclamation's hydroelectric generating facilities include turbine-generators, step-up transformers, and substation transformers (Section 3.2.3). The number of operating turbine-generators and step-up transformers at multiunit facilities (Glen Canyon and Flaming Gorge) would depend on the level of electric power generated because more units would be turned on as more power generation was desired. However, substation transformers are expected to be in continuous operation as long as some level of hydroelectric power is transmitted to the connected power grid.

Because noise production from a given transformer is independent of load (Gordon et al. 1978, 1980), noise generation from substation transformers would not be affected by changes in the level of hydroelectric generation. Thus, the only changes in noise levels at those facilities would result from changes in the number of operating turbine-generators and step-up transformers. However, turbine-generators and step-up transformers have little effect on noise levels in areas beyond canyon rims because they are located near canyon bottoms and because turbine-generators are also enclosed inside concrete plant buildings (Section 3.2.3). Therefore, the diurnal generating patterns of the units would have little impact on the environmental noise levels in areas above canyon rims.

Changes in diurnal generating patterns of hydroelectric facilities could also change the diurnal patterns of noise generation at the region's baseload and peaking units whose operations are affected by Western's operations. As hydroelectric operations changed from high fluctuating flows to steady flows, more electric energy would have to be generated by the region's peaking units during the peak demand period (daytime) and less electric energy from the region's baseload units during off-peak hours (nighttime). Because changes in the pattern of power plant operations would not result in significant noise impacts in the vicinity of the plant (see discussion in Section 4.1.2.2), changes in hydropower operations would not cause any significant noise impacts in the vicinity of the region's electric power generating facilities whose operations are affected by Western's operations.

4.2.3 Water Resources

Impacts of hydropower operational scenarios on water resources associated with Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are discussed in Sections 4.2.3.1, 4.2.3.2, and 4.2.3.3, respectively. Areas of concern include flow, stage, sediment, temperature, and floodplains.

4.2.3.1 Glen Canyon Dam

Impact analyses for Glen Canyon Dam were derived from results presented in the preliminary draft Glen Canyon Dam EIS (Reclamation 1993) and its supporting documents. The Glen Canyon Dam EIS examined hydrological impacts for nine alternatives: no action; maximum power plant capacity; high fluctuating flows; moderate fluctuating flows; modified low fluctuating flows; interim low fluctuating flows; existing monthly volume steady flows; seasonally adjusted steady flows; and year-round steady flows. These alternatives are described in detail in the Glen Canyon Dam EIS (Reclamation 1993). The flow alternatives of the Glen Canyon Dam EIS are referred to as hydropower operational scenarios in this Power Marketing EIS. The Glen Canyon Dam EIS no-action alternative is referred to in this document as continuation of historical flows to distinguish it from the no-action commitment-level alternative; and the high fluctuating flow alternative is referred to as restricted high fluctuating flows to distinguish it from other high fluctuation operations.

The impacts of alternatives analyzed in the Glen Canyon Dam EIS include elements unrelated to hydropower operations — for example, impacts caused by the presence of Glen Canyon Dam, annual and monthly releases that are controlled by Reclamation, mitigation strategies, and beach/habitat building flows. The basis for the analysis was 20 years of projected flows for probabilistic, short-term impacts and 50 years of projected flows for long-term effects (Reclamation 1993). Because the time frame of this Power Marketing EIS is 15 years, impacts associated with the operational scenarios are based on the short-term studies (20 years), where possible. If short-term effects were not available, the results of the 50-year studies were used.

4.2.3.1.1 Flow and Stage

Flow

The principal impact of hydropower operations on flow results from the daily water release patterns, including maximum daily fluctuations and releases. Although flow varies downstream of the dam, no data are provided in the Glen Canyon Dam EIS to assess flow impacts at locations other than the dam. However, the magnitude of the changes in flow would be maximized at the dam.

A continuation of historical flows would produce the largest amount of daily fluctuation in flow (Table 4.12). Adverse impacts attributed to large daily fluctuations include potential removal of sediment from exposed beaches and other sand deposits, and increased rates of growth of the Lake Mead delta; the larger the fluctuation, the more adverse the impact. For continued historical flows, impacts would be moderate between the Paria River and the Little Colorado River. In Lake Mead and upstream of the Paria River and downstream of the Little Colorado River, the impacts would be slight. Although these adverse impacts would be expected for fluctuating flows, some minor beneficial impacts would

TABLE 4.12 Summary of Projected Daily Fluctuations and Maximum Releases from Glen Canyon Dam

Operational Scenario	Percent in Fluctuation Range							Maximum Release ^a (cfs)	% Diff. ^b
	<5,000 cfs	5,000 to 5,999 cfs	6,000 to 7,999 cfs	8,000 to 12,099 cfs	12,100 to 15,999 cfs	16,000 to 20,000 cfs	>20,000 cfs		
Continuation of historical flows	2.7	0.6	1.9	8.9	20.4	52.1	13.3	31,500	0
Maximum power plant capacity	2.6	0.5	2.0	8.6	19.2	43.5	23.7	33,200	5
Restricted high fluctuating flows	3.3	0.9	3.3	15.8	36.4	38.4	1.9	31,500	0
Moderate fluctuating flows	7.2	3.9	47.2	41.8	0	0	0	31,500 ^c	0
Modified low fluctuating flows	26.7	19.6	23.5	30.2	0	0	0	20,000 ^c	-37
Interim low fluctuating flows	26.7	19.6	23.5	30.2	0	0	0	20,000	-37
Existing monthly volume steady flows	0	0	0	0	0	0	0	14,800	-53
Seasonally adjusted steady flows	0	0	0	0	0	0	0	18,000 ^c	-43
Year-round steady flows	0	0	0	0	0	0	0	11,400	-64

^a May be exceeded during high-water years.

^b Percent difference compared with continuation of historical flows.

^c Exceeded during habitat-maintenance flows.

Source: Reclamation (1993).

also result from high fluctuations — including the reworking of debris fans, the creation of a large active zone (a zone in which changes in water level impact the sand deposit) that would promote the removal of vegetation and maintenance of backwaters and wet marshes, and potential aggradation of deposits downstream of the Little Colorado River.

Larger releases would result in higher water levels (stage) which would, in general, produce adverse impacts on sand deposits in the reach between the Paria River to the Little Colorado River, particularly if sediment input from the Paria River were low. Lower releases would result in less reworking of debris fans but also lower rates of erosion from the riverbed, banks, and bars.

Stage

Stage in the Colorado River downstream of Glen Canyon Dam is a function of location, time, and operational scenario. The highest stages would be produced by the highest flows in the narrowest segments of the river; the lowest stages would be associated with the lowest flows and the widest portions of the channel. Maximum stage changes above the minimum water elevation are summarized in Table 4.13. Negative percent changes relative to continued historical flows indicate a decrease in stage, whereas positive values indicate an increase.

Of the operational scenarios analyzed in the Glen Canyon Dam EIS, continued historical flows and maximum power plant capacity flows would produce the highest stages (Table 4.13). Restricted high fluctuating flows would be similar to continued historical flows (1 ft less stage change than continued historical flows [-8%]). Other than year-round steady flows, modified low fluctuating flows and interim low fluctuating flows would produce the lowest stage change of any of the scenarios and the largest difference from continued historical flows (up to 9 ft less [-75%]). Year-round steady flows would produce the least change in river stage (1 ft).

The importance of the difference in stage produced by the hydropower operational scenarios is directly tied to changes in sediment stored in elevated sandbars. Higher flows can either erode or aggrade elevated sandbars — depending on the suspended load in the river, the local geology, and the time of year; they can also produce intermittent flooding of low-elevation river segments, such as backwaters, and impact vegetation.

4.2.3.1.2 Sediment

Impacts to sediment resources were evaluated for the Colorado River between Glen Canyon Dam and Lake Mead. Impacts would occur with changes in flow and stage, including aggradation and erosion of sandbars, changes in sand storage in the riverbed, movement of debris from rapids, changes in the size and pattern of recirculation zones below aggraded fans, and changes in the sediment deposition pattern in the Lake Mead delta (Reclamation

TABLE 4.13 Summary of Daily Maximum Stage above the Minimum Water Elevation below Glen Canyon Dam

Operational Scenario	Maximum Water Elevation above Minimum Flow (ft)	% Diff. ^a
Continuation of historical flows (daily flow = 1,000 to 24,000 cfs)	12	0
Maximum power plant capacity (daily flow = 1,000 to 24,000 cfs)	12	0
Restricted high fluctuating flows (daily flow = 3,000 to 23,000 cfs)	11	-8
Moderate fluctuating flows (daily flow = 5,000 to 13,200 cfs)	5	-58
Modified low fluctuating flows (daily flow = 5,000 to 10,000 cfs)	3	-75
Interim low fluctuating flows (daily flow = 5,000 to 10,000 cfs)	3	-75
Existing monthly volume steady flows (annual flow = 8,000 to 14,000 cfs)	5	-58
Seasonally adjusted steady flows (annual flow = 8,000 to 18,000 cfs)	7	-42
Year-round steady flows (annual flow = 10,000 to 12,000 cfs)	1	-92

^a % Diff. is the percent difference from continued historical flows.

Source: Reclamation (1993).

1993). Sand between the Paria River and the Little Colorado River is the most critical sediment parameter because, above the confluence of the Paria River, the river channel is armored and, below the confluence with the Little Colorado River, a near-equilibrium condition is established because of sediment from inflowing tributaries. Above or below this reach, impacts of the operational scenarios would be the same as those for continued historical flows.

For the Glen Canyon Dam EIS, the only sources of sand considered in the sediment transport calculations were from the Paria and Little Colorado rivers; sands from ungaged tributaries, flash floods, and debris flows were assumed to be negligible (Reclamation 1993). In addition, sand contributions from the dam to Lees Ferry were assumed to be insignificant

because of armoring, and the shapes of the discharge water waves from the dam were assumed to remain constant as the waves travel downstream. These assumptions provide an overestimate of the sand in the river and an underestimate of riverbed sand storage, particularly for fluctuating flows. Impacts to sandbars were correlated with a loss of riverbed sand and determined from the principles of slope stability (Reclamation 1993). Sediment impacts for the operational scenarios are summarized in Table 4.14.

The highest probability of a net gain in sand in the reach between the Paria and Little Colorado rivers over the next 20 years would occur under year-round steady flows (82%; 74% greater than continued historical flows); however, the other steady flow scenarios and the interim low fluctuating flow scenarios would all have probabilities of about 70% (Table 4.14). Continued historical flows and maximum power plant capacity flows would produce the smallest probabilities of a net gain in sand (about 45%). Steady flow or reduced fluctuating flow scenarios would therefore have the most beneficial impacts on this critical reach. Although a ranking of the scenarios is not warranted because the uncertainty in the sediment transport modeling has not been evaluated, most sediment models have a large degree of uncertainty. On the basis of this anticipated level of uncertainty, all of the

TABLE 4.14 Summary of Sediment Impacts for Glen Canyon Dam

Operational Scenario	Probability of Net Gain in Riverbed Sand between Paria and Little Colorado Rivers after 20 Years		Maximum Active Width of Sandbars		Maximum Height of Sandbars	
	%	% Diff. ^a	ft	% Diff. ^a	ft	% Diff. ^a
Continuation of historical flows	47	0	74	0	15	0
Maximum power plant capacity	45	-4	77	4	16	7
Restricted high fluctuating flows	55	17	70	-5	15	0
Moderate fluctuating flows	58	23	47	-36	10	-33
Modified low fluctuating flows	59	26	41	-45	9	-40
Interim low fluctuating flows	70	49	41	-45	9	-40
Existing monthly volume steady flows	77	64	19	-74	5	-67
Seasonally adjusted steady flows	64	36	29	-61	7	-53
Year-round steady flows	82	74	0	-100	1	-93

^a % Diff. is the percent difference from continuation of historical flows.

Source: Reclamation (1993).

scenarios except for continued historical flows and maximum power plant capacity would be essentially the same.

The maximum power plant capacity scenario would produce the highest elevation sandbars (16 ft; 1 ft higher than continued historical flows) (Table 4.14). The lowest elevation sandbars relative to continued historical flows would be produced by the three steady flow scenarios (-67, -53, and -93%, respectively for existing monthly volume steady flows, seasonally adjusted steady flows, and year-round steady flows). Although higher deposits of sand would normally be beneficial, the high percentage of large fluctuations that produce the highest deposits (Table 4.12) would also produce rapid erosion and, therefore, these elevated deposits would be ephemeral. On the other hand, the lowest elevation deposits produced by steady flows would be very stable but easily encroached upon by vegetation and less usable for camping.

In addition to producing the highest elevation sandbars, the maximum power plant capacity scenario would also produce sandbars with the largest active widths (Table 4.14). The predicted width of the active zone for this operational scenario would be 77 ft (4% greater than continued historical flows). Year-round steady flows would produce the smallest active widths (0 ft; 100% less than continued historical flows). Because sandbar stability is inversely related to the width of the active zone, the least stable bars would be produced by maximum power plant capacity flows, whereas the most stable bars would be produced by year-round steady flows.

Eddy backwaters, which are important to Colorado River fish, depend on the formation of reattachment bars. With time, the number and size of backwaters would tend to fill with sediment and later reform during flood releases. Operational scenarios with greater seasonal or daily fluctuations (e.g., continued historical flows, maximum power plant capacity flows, and restricted high fluctuating flows) would maintain backwaters longer than scenarios with relatively few fluctuations (e.g., year-round steady flows).

None of the operational scenarios would have maximum discharges that are sufficiently high to move the largest boulders in debris fans (Table 4.12). However, the capability to rework other deposits in the fans would be least for year-round steady flows (maximum flows less than 62% of continued historical flows) and greatest for maximum power plant capacity (maximum flows greater than 5% of continued historical flows). Eventually, debris fans would be expected to aggrade under all of the operational scenarios and further constrict rapids (Reclamation 1993). Over the 15-year time period for this EIS, impacts to debris fans would be slight.

In Lake Mead, the rate of growth of the Colorado River delta would vary by operational scenario (Reclamation 1993). For 20 years of projected operations, sediment delivery to Lake Mead would be higher under fluctuating flows than under steady flows. The highest rates of delta growth would occur for continued historical and maximum power plant capacity flows. Year-round steady flows would produce the smallest growth rates in the deltas because this scenario would deliver the least amount of sand to Lake Mead (116% less sand from the reach from the Paria to Little Colorado rivers). The importance of this impact

would be very slight because the life expectancy for Lake Mead is more than 500 years (Reclamation 1993).

4.2.3.1.3 Temperature

The hydropower operational scenarios would not affect the location of the water withdrawal from Lake Powell. Therefore, the temperature of the water released from Glen Canyon Dam would be the same for all scenarios. Once in the Colorado River channel, higher dam releases would travel faster than slow releases and would transport cold water farther downstream. However, the combined effects of mixing with unregulated tributaries and solar heating would minimize the effects of the cold water, especially below the Little Colorado River.

4.2.3.1.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios at Glen Canyon Dam on the floodplain of the Colorado River. The approximate 100-year floodplain for the Colorado River below Glen Canyon Dam was assumed to correspond to the water level of a 91,400-cfs release (Section 3.3.1.4). Each of the nine operational scenarios evaluated (Section 4.2.3.1.1) would produce impacts within the 100-year floodplain of the Colorado River below the dam. The maximum water release (Table 4.12) for any of the operational scenarios (33,200 cfs), however, would be less than 40% of the postulated 100-year flood release. Impacts to the 100-year floodplain would range from moderate to slight (Sections 4.2.3.1.1 through 4.2.3.1.3) at low topographical elevations (up to a water surface elevation corresponding to a release of 33,200 cfs) and would be very slight to negligible at higher floodplain elevations.

4.2.3.2 Flaming Gorge Dam

The impacts of hydropower operational scenarios on water resources below Flaming Gorge Dam were assessed for three representative hydrologic years: moderate dry, and wet. On the basis of stream-flow records, the years 1987, 1989, and 1983 were selected as representative moderate, dry, and wet water years, respectively. (A water year begins on October 1 of the preceding calendar year and ends on September 30 of the current calendar year.)

Four hydropower operational scenarios for Flaming Gorge Dam are evaluated in this EIS — year-round high fluctuating flows, seasonally adjusted high fluctuating flows, seasonally adjusted moderate fluctuating flows, and seasonally adjusted steady flows. The year-round high fluctuating flow scenario assumes that the monthly total reservoir releases would be the same as historical releases and no changes would be made to the current operating constraints. This operational scenario would not comply with the USFWS Biological Opinion (USFWS 1992b). The remaining seasonally adjusted scenarios would

comply with the Biological Opinion and would include high flows in the spring and limited hourly fluctuations, especially in summer and autumn releases.

4.2.3.2.1 Flow and Stage

Reservoir Release Patterns

Reservoir release patterns for an average day in each month, or partial month where necessary to comply with the Biological Opinion, are summarized in Appendix C, Tables C.1 through C.3, for the four operational scenarios. The release patterns for each scenario were developed for the three representative moderate, dry, and wet years (1987, 1989, and 1983, respectively). Each release pattern has a minimum release starting at midnight, ramp up to a maximum release in one hour, hold at the maximum for the on-peak duration, and then ramp down to the minimum release. The on-peak period is assumed to center around 4:00 p.m. The derivation of the release patterns are briefly discussed in Appendix C. Further details on the development of the release patterns are presented in Yin (1994a,b).

Flow

Flows in the Green River resulting from reservoir releases under the four operational scenarios were estimated for five locations below Flaming Gorge Dam for the three representative hydrologic years (Yin 1994a,b). The five locations are Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 3.16). Historical releases for power generation ranged from 800 to 4,200 cfs (Figure 3.12).

Year-Round High Fluctuating Flow Scenario. The daily maximum and minimum flows in the moderate hydrologic year (1987) under the year-round high fluctuating flow scenario and the seasonal average inflow of the Yampa River, which joins the Green River 65 mi below the dam between Hells Half Mile and Jones Hole, are given in Appendix C, Table C.6. Under this operational scenario, the maximum daily reservoir release fluctuation would be 3,900 cfs year-round. The fluctuation at Gates of Lodore would be reduced to about 30 to 82% of that below the dam. The difference in the magnitudes of reduction is mainly influenced by the on-peak duration of the reservoir release. A relatively short on-peak period, such as the two-hour duration in March — or a relatively long period, such as the 17-hour duration in November and December (Table C.1) — tends to reduce the flow fluctuation more rapidly. A medium on-peak period, such as the 10-hour duration in October, tends to maintain a high fluctuation for a longer distance down the river. At downstream locations, further reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 29 to 80% of that at the dam. At the Jensen gage, the fluctuation would be 27 to 77%.

The maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and the Jensen gage are shown in Figure 4.4. The flow fluctuations do not change much between

FIGURE 4.4 Maximum and Minimum Flows under the Year-Round High Fluctuating Flow Scenario

Gates of Lodore and the Jensen gage. The flow patterns at the Jensen gage differ from those at Gates of Lodore because of the inflow from the Yampa River.

Seasonally Adjusted High Fluctuating Flow Scenario. The daily maximum and minimum flows in the moderate hydrologic year (1987) under the seasonally adjusted high fluctuating flow scenario and the seasonal average inflow of the Yampa River are given in Appendix C, Table C.7. Under this operational scenario, the reservoir release fluctuation would be 2,010 to 3,900 cfs, except that no fluctuation would be allowed in February and March (the assumed ice cover period), October would have a steady release of 800 cfs (to compensate for high Yampa River flow), and June 1 through 21 would have a steady release as high as 4,700 cfs (as required by the Biological Opinion). The fluctuation at Gates of Lodore would be reduced to about 19 to 80% of that at the dam. Similar to the year-round high fluctuating flow scenario, further downstream reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 19 to 80% of that at the dam. At the Jensen gage, the fluctuation would be 17 to 78%.

Figure 4.5 shows the maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and Jensen gage. As discussed above, the flow fluctuation does not change much between the Gates of Lodore and Jensen gage.

Seasonally Adjusted Moderate Fluctuating Flow Scenario. The daily maximum and minimum flows in a moderate water year (1987) for the seasonally adjusted moderate fluctuating flow scenario are shown in Appendix C, Table C.8. Under this operational scenario, the reservoir release fluctuation would be 1,000 to 1,950 cfs, except that no fluctuation would be allowed in February and March because of ice cover, October would have a steady release of 800 cfs, and June 1 through 21 would have a steady release up to 4,700 cfs (as required by the Biological Opinion). The fluctuation at Gates of Lodore would be reduced to about 0 to 88% of that at the dam. As for the year-round and seasonally adjusted high fluctuating flow scenarios, further downstream reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 0 to 88% of that at the dam. At Jensen gage, the fluctuation would be 0 to 83%.

Figure 4.6 shows the maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and the Jensen gage. As discussed above, the flow fluctuation does not change much between the Gates of Lodore and Jensen gage.

Seasonally Adjusted Steady Flow Scenario. Under the seasonally adjusted steady flow scenario, the reservoir release in each season would be steady (Appendix C, Tables C.1 through C.3). Figure 4.7 shows the flows at the dam, Gates of Lodore, and the Jensen gage. The flows at Gates of Lodore would be the same as reservoir releases, and the flows at the Jensen gage would be the sums of reservoir releases and the Yampa River inflows.

FIGURE 4.5 Maximum and Minimum Flows under the Seasonally Adjusted High Fluctuating Flow Scenario

FIGURE 4.6 Maximum and Minimum Flows under the Seasonally Adjusted Moderate Fluctuating Flow Scenario

FIGURE 4.7 Flows under the Seasonally Adjusted Steady Flow Scenario

Stage

Maximum and minimum Green River stages resulting from reservoir releases under the four operational scenarios were estimated on the basis of the flows presented in Figures 4.4 to 4.7 and stage-flow relationships presented in Yin (1994a). The river stage at a particular location depends mainly on the river flow and channel geometry in the area. Daily maximum and minimum stages above that for a flow of 800 cfs at Flaming Gorge Dam, Gates of Lodore, and Jensen gage are shown for a moderate year (1987) in Figures 4.8, 4.9, and 4.10 for the year-round high fluctuating flow, seasonally adjusted high fluctuating flow, and seasonally adjusted moderate fluctuating flow scenarios, respectively. River stages for the seasonally adjusted steady flow scenario are shown in Figure 4.11.

Under the year-round high fluctuating flow scenario, the daily stage fluctuations would be about 4.8 ft year-round at Flaming Gorge Dam, about 2.4 to 4.9 ft at the Gates of Lodore, and about 0.6 to 2.0 ft at the Jensen gage. Under the seasonally adjusted high fluctuating flow scenario, the daily stage fluctuations would be about 0 to 4.8 ft at Flaming Gorge Dam, about 0 to 4.9 ft at Gates of Lodore, and about 0 to 2.2 ft at the Jensen gage. Under the seasonally adjusted moderate fluctuating flow scenario, the daily stage fluctuations would be about 0 to 2.2 ft at Flaming Gorge Dam, about 0 to 2.1 ft at Gates of Lodore, and about 0 to 0.9 ft at the Jensen gage. Under the seasonally adjusted steady flow scenario, no daily stage fluctuations would result from hydropower operations.

For historical operations, when power releases ranged from 800 to 4,200 cfs, the daily stage fluctuation was estimated to be up to 4.2 ft below Flaming Gorge Dam and at Gates of Lodore, and 1.7 ft at the Jensen Gage.

4.2.3.2.2 Sediment

The Green River from Flaming Gorge Dam to Browns Park has been armored by previous flows (Section 3.3.2.2). Because of this armoring, none of the operational scenarios would have a flow sufficiently high to alter this reach.

Net erosion currently occurs from Browns Park to the confluence of the Yampa River; sediment is leaving the reach, but very little is coming in because of the presence of the dam (Section 3.3.2.2). Rates of sediment removal were calculated for the four operational scenarios and for historical flows; the results are summarized in Table 4.15 (see Appendix C, Section C.1.4, for a description of the methodology used). Because the rate of erosion and river meandering in an alluvial stream is proportional to the sediment removed (Leopold et al. 1964), the ratio of the loads relative to year-round high fluctuating flows are also shown in the table.

For a moderate or wet year, year-round high fluctuating flows would have the largest sediment loads (about 3.6 and 1.2 million tons, respectively). For a wet year, all three seasonally adjusted scenarios would produce a comparable load (28% less). For a moderate

FIGURE 4.8 Maximum and Minimum River Stages under the Year-Round High Fluctuating Flow Scenario

FIGURE 4.9 Maximum and Minimum River Stages under the Seasonally Adjusted High Fluctuating Flow Scenario

FIGURE 4.10 Maximum and Minimum River Stages under the Seasonally Adjusted Moderate Fluctuating Flow Scenario

FIGURE 4.11 River Stages under the Seasonally Adjusted Steady Flow Scenario

TABLE 4.15 Summary of Sand Load in Browns Park for Different Hydropower Operational Scenarios

Water Year	Operational Scenario	Sand Load ^a (million tons)		
		Value	% Diff.	Erosion Rate
Moderate (1987)	Year-round high fluctuating flows	1.15	11	1.11
	Seasonally adjusted high fluctuating flows	1.10	6	1.06
	Seasonally adjusted moderate fluctuating flows	0.99	-5	0.95
	Seasonally adjusted steady flows	0.98	-6	0.94
Dry (1989)	Year-round high fluctuating flows	0.17	31	1.31
	Seasonally adjusted high fluctuating flows	0.29	123	2.23
	Seasonally adjusted moderate fluctuating flows	0.28	115	2.15
	Seasonally adjusted steady flows	0.27	108	2.08
Wet (1983)	Year-round high fluctuating flows	3.57	3	1.03
	Seasonally adjusted high fluctuating flows	2.60	-25	0.75
	Seasonally adjusted moderate fluctuating flows	2.58	-25	0.75
	Seasonally adjusted steady flows	2.58	-25	0.75

^a % Diff. is the percent difference from transport under historical release patterns; Erosion Rate is the rate of erosion or meandering relative to historical flows.

year, seasonally adjusted steady flows would have the smallest loads (0.98 million tons; 16% less than under historical flows). For a dry year, all loads would be small (Table 4.15) but would be higher than under historical release patterns. In a dry year, any of the seasonally adjusted operational scenarios would have higher loads than the year-round high fluctuating flows due to higher release rates in the spring.

For a moderate or dry year, impacts between the various operational scenarios cannot be differentiated because of uncertainties in the sediment transport model. In a wet year, the seasonally adjusted operational scenarios would transport less sediment than historical release patterns, whereas the year-round high fluctuating flow scenario would be similar to historical releases.

Downstream of the Yampa River, sediment load in the Green River is currently near equilibrium (Section 3.3.2.2). Because the seasonally adjusted operational scenarios would remove less sediment than year-round high fluctuating flows from the Browns Park reach, more sediment could be removed from Lodore Canyon and downstream of the Yampa River. During a dry year, this effect would be minimal because of the low total volumes of sediment involved (0.2 million tons from the Green River). For a moderate year, the effects of the scenarios would be relatively similar, and the net effect of erosion downstream of the Yampa River would be slight. For a wet year, about 1 million less tons of sediment would be delivered by the Green River upstream of the Yampa River. However, for wet conditions, the sediment load in the Yampa River is likely to be high (more than 2 million tons per year). Therefore, conditions below the confluence of the Green and Yampa rivers would not change appreciably, and impacts associated with hydropower operational scenarios for this reach would be slight.

4.2.3.2.3 Temperature

For year-round high fluctuating flows, temperatures would be the same as those measured historically. Hydropower operational scenarios for the Flaming Gorge Dam would not affect water temperatures appreciably. None of the operational scenarios would change the location of water withdrawal from the reservoir (Section 3.3.2.3). Also, changes in water-surface elevation of the reservoir would be small, and the Yampa River would continue to control water temperatures below its confluence. The travel times for water waves to go from the dam to Jensen, Utah, would be similar for all operational scenarios — between 30 and 36 hours (Section 3.3.2.1 and Appendix C) — and the travel time for water to go from the dam to the confluence of the Yampa River would also be similar (29 to 51 hours for releases of 1,000 to 4,000 cfs, respectively, as calculated with the HEC-2 flow model).

4.2.3.2.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios at Flaming Gorge Dam on the floodplain of the Green River. The approximate 100-year floodplain below Flaming Gorge Dam was assumed to correspond to the water level of a 12,200-cfs release (Section 3.3.2.4). Each of the four hydropower operational scenarios (Section 4.2.3.2.1) evaluated for this EIS would produce impacts to this floodplain. The maximum water release (Appendix C, Table C.1) for any of the operational scenarios (10,100 cfs in a wet year), however, would be about 80% of the postulated 100-year flood release. Impacts to the 100-year floodplain would be moderate to slight at low topographical elevations (up to a water surface elevation corresponding to a release of 10,100 cfs) and very slight to negligible at higher floodplain elevations (Sections 4.2.3.2.1 through 4.2.3.2.3).

4.2.3.3 Aspinall Unit

Potential impacts of the hydropower operational scenarios on water resources below the Aspinall Unit (i.e., Blue Mesa, Morrow Point, and Crystal reservoirs in downstream order) were assessed for moderate (1987), dry (1989), and wet (1983) years. Two operational scenarios were evaluated — seasonally adjusted high fluctuating flows and steady flows, both of which are based on USFWS research flows for the Aspinall Unit (Harris 1992). The first scenario permits seasonally adjusted high fluctuating flows, whereas the second scenario allows only seasonally adjusted steady flows (no hourly fluctuations within a day) from Blue Mesa and Morrow Point reservoirs. Crystal Reservoir would release a steady flow within each day under both operational scenarios.

4.2.3.3.1 Flow and Stage

The effects on river flow and stage below Crystal Dam would be the same for both operational scenarios because both would have seasonally adjusted steady releases from Crystal Reservoir. For this analysis, the potential effects of the operational scenarios on reservoir surface elevations were compared.

Reservoir Release Patterns

Reservoir release patterns for an average day in each month are summarized for the three Aspinall Unit reservoirs in Appendix C, Tables C.11, C.12, and C.13. The high fluctuating release pattern has a minimum release starting at midnight, ramps up to a maximum release in one hour, holds at the maximum for the on-peak duration, and then ramps down to the minimum release. The on-peak period was assumed to center around 4:00 p.m. The derivation of the release patterns is discussed in Appendix C.

Stage

Maximum daily fluctuations in reservoir surface elevation under the seasonally adjusted high fluctuating flow scenario in a moderate year are shown in Table 4.16. The fluctuations result from both the hourly reservoir release fluctuations and the monthly inflow-outflow imbalance. The maximum surface fluctuations in one day range from 0.1 to 0.5 ft for Blue Mesa and from 0.3 to 1.5 ft for Morrow Point. Because of its relatively small storage capacity, Crystal Reservoir elevations would have larger daily fluctuations, ranging from 2.1 ft in June to 8.4 ft in September. Under the seasonally adjusted steady flow scenario, daily reservoir surface fluctuations would range from 0 to 0.5 ft at Blue Mesa, 0 to 0.2 ft at Morrow Point, and 0 to 0.4 ft at Crystal (Appendix C). Weather-induced daily reservoir surface fluctuations at Blue Mesa and Morrow Point can be greater than those attributable to hydropower operations (shown in Table 4.16).

TABLE 4.16 Maximum Daily Surface Fluctuations for a Moderate Year at the Aspinall Unit Reservoirs under the Seasonally Adjusted High Fluctuating Flow Scenario

Month	Maximum Daily Surface Fluctuation (ft)		
	Blue Mesa Reservoir	Morrow Point Reservoir	Crystal Reservoir
Oct	0.3	1.1	8.0
Nov	0.2	0.8	6.9
Dec	0.2	0.8	6.4
Jan	0.1	0.3	4.0
Feb	0.1	0.3	3.8
Mar	0.1	0.4	4.3
Apr	0.2	1.5	3.2
May	0.5	1.3	2.4
Jun	0.3	0.4	2.1
Jul	0.3	0.9	3.4
Aug	0.3	1.3	8.1
Sep	0.3	1.3	8.4

Approximate water surface elevations below Morrow Point Dam are shown in Figure 4.12 for flows ranging from 100 to 5,300 cfs. The river stage just below the dam may fluctuate about 10 ft as the dam releases vary from 0 to 5,300 cfs. At 0.25 mi below the dam, the stage fluctuation would be reduced to about 5.5 ft due to the effect of Crystal Reservoir; at 0.5 mi below the dam, the stage would be largely controlled by Crystal Reservoir. The elevations in Figure 4.12 were estimated by assuming a Crystal Reservoir elevation of 6,750 ft. In a moderate year, Crystal Reservoir end-of-month elevations during the growing season (May through September) could range from about 6,747 to 6,751 ft (Appendix C). A lower Crystal elevation would tend to lower all water surface profiles in the figure, with lesser effects on the profiles for higher flows and lesser effects on locations farther upstream.

4.2.3.3.2 Sediment

Because the operational scenarios for Crystal Dam would not be controlled for the production of hydropower, evaluation of sediment transport in the Gunnison River below Crystal Dam is outside the scope of this Power Marketing EIS. Potential reaches for evaluating sediment transport include Blue Mesa Reservoir, Morrow Point Reservoir, Crystal Dam Reservoir, and short stretches of the Gunnison River that connect the separate hydropower facilities. For downstream reaches of the Gunnison River below and between Blue Mesa Dam, Morrow Point Dam, and Crystal Dam, impacts to sediment would be very slight because outflow from the dams would frequently enter directly into the headwaters of the downstream reservoir without traversing any sediment-bearing intermediate reach. In

FIGURE 4.12 Water Surface Elevations below Morrow Point Dam (Crystal Reservoir Elevation at 6,750 ft)

Blue Mesa and Morrow Point reservoirs, impacts to sediment caused by operational scenarios would be slight over the 15-year period of the power marketing program because of the large size of the reservoirs. In Crystal Dam Reservoir, impacts to sediment would also be slight because Blue Mesa and Morrow Point dams would remove most of the upstream sediment.

4.2.3.3.3 Temperature

Hydropower operational scenarios for the Aspinall Unit would not affect water temperatures in the affected environment. None of the operational scenarios would change the location of water withdrawal from the reservoirs, and, because changes in water-surface elevation of the reservoirs would be small, the resulting changes in water temperature in the reservoir itself would be very slight. Because distances between the dams and the downstream reservoirs are small, travel times would be short and the effects of solar heating would not be detectable.

4.2.3.3.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios at Flaming Gorge Dam on the floodplain of the Gunnison River. The approximate 100-year floodplain for the area below Crystal Dam was assumed to correspond to the water level of a 14,400-cfs release (Section 3.3.3.4). Neither of the two hydropower

operational scenarios evaluated for this EIS (Section 4.2.3.3.1) would produce impacts to this 100-year floodplain.

4.2.4 Ecological Resources

This section discusses impacts to ecological resources that would result from hydropower operational scenarios at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Resources include fish, vegetation, wildlife, and threatened and endangered species.

4.2.4.1 Glen Canyon Dam

4.2.4.1.1 Aquatic Ecology

This section addresses the potential impacts of the operational scenarios at Glen Canyon Dam to trout and native fish. These impacts are summarized in Table 4.17. Impacts to Federally listed endangered fish species are addressed in Section 4.2.4.1.3. Impacts to introduced fish species, the aquatic food base, and aquatic habitats below Glen Canyon Dam are also considered because impacts to these resources could directly or indirectly affect trout and native fish in the system. The potential impacts to these resources are presented within the discussions of impacts to trout and native fish when such impacts may result in either beneficial or adverse impacts to those species.

Trout

With continuation of historical operations, or with maximum power plant capacity operations, the status of the trout population below Glen Canyon Dam would not change from existing conditions. Reproduction between the dam and Lees Ferry would continue to be limited by the exposure and dewatering of trout redds. Trout reproduction and recruitment below Lees Ferry would be largely unaffected because these parameters are dependent on tributaries which are unaffected by hydropower operations. During the spawning season, trout would continue to become stranded under continued historical flows during downramping events and when flows fall below 3,000 cfs (Reclamation 1993). The impact of redd exposure and trout stranding on the trout population below Glen Canyon Dam may be unimportant because the current high-quality trout fishery below the dam became established under historical operations and because many trout are stocked (Maddux et al. 1987). Although the growth and condition of trout below the dam has declined since the early 1980s, this decline may not be a result of hydropower operations but instead may reflect changes in nutrient inputs from Lake Powell (which are affecting the aquatic food base) or other factors (e.g., parasites and disease) (Arizona Game and Fish Department 1993) that are not directly associated with hydropower operations.

TABLE 4.17 Summary of Impacts to Trout and Native Fish below Glen Canyon Dam under the Different Operational Scenarios

Operational Scenarios	Trout	Native Fish
Continuation of historical flows	No change from current conditions; daily flow fluctuations from hydro-power operations limit natural reproduction, via redd dewatering, and adult stranding, above Lees Ferry; population remains stocking-dependent.	No change from current conditions; populations stable to declining; population is limited by cold water temperatures, which are not affected by hydropower operations, and possibly by competition and predation from introduced species.
Maximum power plant capacity	Same as above.	Same as above.
Restricted high fluctuating flows	Slight benefit above Lees Ferry from a potential increase in spawning habitat, and a decrease in redd dewatering and adult stranding; population remains stocking-dependent.	Same as above except for a slight benefit due to an increase in the aquatic food base; may be offset by increase in abundance of introduced fish species.
Moderate fluctuating flows	Slight benefit above Lees Ferry from potential increase in spawning habitat and a potential decrease in stranding; benefit may be greater than for restricted high fluctuating flows; potential increase in growth rates; population remains stocking-dependent.	Same as above.
Modified low fluctuating flows	Slight to moderate benefit above Lees Ferry from potential increase in spawning habitat and a potential decrease in stranding; benefits may be greater than for moderate fluctuating flows; potential increase in growth rates; population remains stocking-dependent.	Slight benefit from potential increase in nursery habitat stability and increased food base; benefits may be offset by potential increase in numbers of introduced fish; benefits may be greater than for moderate fluctuating flows.
Interim low fluctuating flows	Same as above.	Slight benefit; similar to above except no habitat maintenance flow to potentially limit abundance of introduced fish and restore backwater habitats.
Existing monthly volume steady flows	Moderate benefit above Lees Ferry due to potential increase in spawning habitat and the elimination of most redd dewatering and reduction in stranding; potential increase in growth rates; population may become self-sustaining.	Slight to moderate benefit over all fluctuating flow scenarios due to increased nursery habitat stability and food base; benefits may be offset, or adverse impacts may occur from potential increase in numbers of introduced fish.

TABLE 4.17 (Cont.)

Operational Scenarios	Trout	Native Fish
Seasonally adjusted steady flows	Moderate benefit from an increase in potential spawning habitat and the elimination of most redd dewatering and stranding above Lees Ferry; benefit may be greater than for existing monthly volume steady flows; potential increase in growth rates; population may become self-sustaining.	Moderate benefit; same as above except for increased nursery habitat stability and habitat maintenance.
Year-round steady flows	Moderate benefit above Lees Ferry from increase in potential spawning habitat and the elimination of most redd dewatering and stranding; benefit may be greater than for seasonally adjusted steady flows; potential increase in growth rates; population may become self-sustaining.	Slight to moderate benefit; similar to seasonally adjusted steady flows, but may be more adversely affected by potential increases in numbers of introduced fish and the filling of some backwater habitat with sediment or vegetation.

Source: Reclamation (1993).

None of the other operational scenarios would cause adverse impacts to the trout fishery below the dam. The fluctuating flow scenarios would result in slight benefits from reduced redd exposure and stranding of spawning adults above Lees Ferry (Reclamation 1993). Any of the steady flow operational scenarios would result in moderate benefits to the trout. Steady flow scenarios would greatly reduce stranding of adults and would also eliminate most, if not all, of the exposure and desiccation of trout redds compared with the effects of historical or maximum power plant capacity operations (Reclamation 1993). Because of the reduced stranding and redd exposure, natural recruitment should increase under each of the steady flow scenarios, and the trout population may become self-sustaining.

As minimum flows increased from 1,000 cfs under historical operations to 8,000 cfs under existing monthly volume steady flows, so would the zone for aquatic food production and potential spawning habitat increase. As a result, trout might benefit slightly from the increased food production and increased spawning habitat. If the size of the trout population remains stable, the increase in the aquatic food base could increase growth rates of the trout. Food production and spawning habitat would be greatest under the steady flow scenarios, and little or no difference would occur among these scenarios in their effects on food production and spawning habitat (Reclamation 1993).

Native Fish

Cold water temperature is the most important factor limiting native fish in the Colorado River below the Glen Canyon Dam (Reclamation 1993). The water is cold because it is released from the depths of Lake Powell. Because of the cold water in the main channel, reproduction by native fish is confined primarily to the warmwater tributaries (Reclamation 1993). Conditions in the tributaries are unaffected by hydropower operations.

Under a continuation of historical flows, no change is expected in the status of native fish, some of which are exhibiting declines in abundance. Operational scenarios that maintain backwaters and shallow nearshore habitats may be beneficial to the native fish by promoting increased growth and survival of these species. Under historical and maximum power plant capacity flows, daily fluctuations in flow would maintain backwater areas but would periodically drain and inundate the backwater habitats with cold main channel waters, thereby reducing the value of the backwater areas to the native fish (Reclamation 1993).

Native fish could benefit slightly under the moderate, modified low, and interim low fluctuating flow operational scenarios. Nursery habitats would become more stable because of decreases in the allowable daily change in flow and reduced ramp rates. Nursery habitat stability would be greatest with the steady flow scenarios, however, and each of these scenarios could result in a moderate benefit to the native fish. Without occasional flood flows, backwater habitats eventually would fill with sediment and vegetation, thereby eliminating these stable backwater areas as nursery habitats and resulting in an adverse impact to native fish. The yearly habitat-maintenance flow that would occur under the moderate and modified low fluctuating flow and the seasonally adjusted steady flow operational scenarios may provide a slight to moderate benefit for native fish by reforming backwater channels (Reclamation 1993). Similar benefits to native fish could also occur with the beach/habitat-building flows that are common elements of all the restricted fluctuating and steady flow alternatives.

Native fish might also receive slight to moderate benefits from increases in the number of backwater habitats available for use by young fish. The abundance of backwaters has been reported to be lowest at flows below 5,000 cfs and may increase as flows increase (Maddux et al. 1987). Minimum flows below 5,000 cfs would occur under the historical, maximum power plant capacity, and restricted high fluctuating flow operational scenarios. Backwater abundance might increase (to the benefit of native fish) with moderate, modified low, and interim low fluctuating flow operational scenarios, each of which would have minimum flows of 5,000 cfs. Under the steady flow scenarios, minimum flows would be at 8,000 cfs or more, and abundance of backwaters could decrease (Reclamation 1993). However, the remaining backwaters would be very stable. Thus, native fish could receive a moderate benefit under the steady flow scenarios.

Potential benefits to native fish could, however, be offset by increased competition with and predation by some introduced species (Minckley 1991; Minckley et al. 1991) because any operational scenario that would benefit native fish populations could also benefit populations of some introduced species. Populations of introduced species may benefit,

especially from the reduced fluctuations characteristic of several operational scenarios. Any benefits to these populations could be offset by the proposed periodic habitat-maintenance flows that would occur under the moderate fluctuating flow, modified low fluctuating flow, and seasonally adjusted steady flow scenarios. The beach/habitat-building flows of the restricted fluctuating flow and the steady flow operational scenarios could also control populations of introduced fish. However, because the exact form and magnitude of interaction between native and introduced fish below the dam, as well as the exposure of introduced species to the habitat maintenance and beach/habitat-building flows, are not well known, the potential changes in the populations of introduced species cannot be quantified for the various operational scenarios.

4.2.4.1.2 Terrestrial Ecology

Vegetation

Assessments of impacts to riparian vegetation were based on the predicted changes in flow regime that would result from the nine operational scenarios under consideration in the Glen Canyon EIS (Reclamation 1993) (Section 4.2.3.1.1). Flow regime affects riparian vegetation by affecting the soil moisture levels and inundation frequencies to which plant species are adapted. Changes in these conditions could cause shifts in species composition within the riparian zone. Impacts of operational scenarios were assessed for woody riparian vegetation and marsh vegetation. Table 4.18 summarizes these impacts.

The operational scenarios differ considerably in the projected impacts to riparian vegetation. Most of these differences, which are further discussed below, are between the various fluctuating flow scenarios and the steady flow scenarios. A more detailed discussion of impacts to riparian vegetation is provided in Appendix D, Section D.3.1.

Continuation of historical operations would not result in impacts to any riparian vegetation type because the extent and nature of the vegetation in the river corridor is primarily a function of these historical operations. Since construction of the dam, riparian vegetation has increased in abundance due to the elimination or reduction in annual flooding that had occurred naturally (Section 3.4.1.2.1). With this reduction of flooding, riparian vegetation became established at lower elevations — those determined by the maximum flows (32,000 cfs) that have occurred during historical operations.

Except for a continuation of historical operations, operations at maximum power plant capacity, and high fluctuating flows, any of the operational scenarios under consideration would increase the area covered by woody riparian vegetation (Table 4.18). The greatest gain would be for year-round steady flows (94% increase in area); existing monthly volume steady flows, seasonally adjusted steady flows, low fluctuations, and moderate fluctuations would each produce increases of at least 23% in the area of woody vegetation. Operation at maximum power plant capacity would result in a slight decrease (up to 9%) in woody riparian vegetation.

TABLE 4.18 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Glen Canyon Dam

Operational Scenarios	Woody Riparian Vegetation	Marsh Vegetation ^a
Continuation of historical flows	No impact to existing vegetation.	No impact to existing vegetation.
Maximum power plant capacity	Slight adverse impact (0-9% decrease in area).	Slight benefit (5% increase in maximum stage).
Restricted high fluctuating flows	No impact to existing vegetation.	No impact to existing vegetation.
Moderate fluctuating flows	Moderate benefit (23-40% increase in area).	Moderate adverse impact (29% decrease in maximum stage).
Modified low fluctuating flows	Moderate benefit (30-47% increase in area).	Moderate adverse impact (37% decrease in maximum stage).
Interim low fluctuating flows	Same as above.	Same as above.
Existing monthly volume steady flows	Large benefit (45-65% increase in area).	Large adverse impact (48% decrease in maximum stage).
Seasonally adjusted steady flows	Large benefit (38-58% increase in area).	Large adverse impact (43% decrease in maximum stage).
Year-round steady flows	Large benefit (63-94% increase in area).	Large adverse impact (64% decrease in maximum stage).

^a Impacts are based on change in maximum stage. Area coverage cannot be predicted.

Source: Reclamation (1993).

Changes in marsh vegetation in response to different operational scenarios would be more complex (Table 4.18). No changes to existing marsh vegetation would be expected for continued historical or restricted high fluctuation operational scenarios because wetting of existing marshes would occur sufficiently often for them to persist. Because of the reduced frequency of inundation, the area of marsh vegetation could decrease under operational scenarios with reduced fluctuations. Thus, slight to moderate decreases in marsh vegetation could occur with moderate and low fluctuations, and large decreases (up to 64%) could occur with the steady-flow operational scenarios. Marsh vegetation could initially increase with the decreases in fluctuation associated with the low fluctuation and the steady-flow operational scenarios but eventually could be replaced by woody vegetation at higher elevations.

Shifts in flows between months or periods that are characteristic of seasonally adjusted steady flows and existing monthly steady flows would create unvegetated zones below the stage elevation for 11,000- to 13,000-cfs flows, respectively, because these areas would be inundated for extended periods, and vegetation would drown.

Wildlife

Table 4.19 summarizes impacts to nongame wildlife, waterfowl, and game mammals under the nine operational scenarios. Nongame wildlife could be affected by the changes in riparian vegetation expected with the altered flows of different operational scenarios. Most of the expected habitat changes would involve expansion of woody riparian vegetation as flow fluctuations were decreased (Section 4.2.4.1.2, *Vegetation*). Changes in marsh habitat would not be of major importance to wildlife because of the relatively small amount of such habitat present along the river. Many nongame species inhabiting the corridor would, however, benefit from the increase in woody riparian vegetation projected for most operational scenarios, and this increase in vegetation could greatly increase the carrying capacity of the corridor for these species by increasing food supply, nesting sites, or cover.

TABLE 4.19 Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Glen Canyon Dam

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Continuation of historical flows	No impact; riparian habitat unchanged.	No impact; habitat and food supply unaffected.	No impact; habitat unchanged.
Maximum power plant capacity	Slight adverse impact; 0-9% loss of woody riparian habitat.	Same as above.	No impact; slight change in habitat but area receives little use.
Restricted high fluctuating flows	No impact; riparian habitat unchanged.	Same as above.	No impact; habitat unchanged.
Moderate fluctuating flows	Moderate benefit; 23-40% gain in woody riparian habitat.	Slight benefit; potential increase in aquatic food base.	No impact; increase in riparian habitat unimportant because area receives limited use.
Modified low fluctuating flows	Moderate benefit; 30-47% gain in woody riparian habitat.	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Large benefit; 45-65% gain in woody riparian habitat.	Same as above.	Same as above.
Seasonally adjusted steady flows	Large benefit; 38-58% gain in woody riparian habitat.	Same as above.	Same as above.
Year-round steady flows	Large benefit; 63-94% gain in woody riparian habitat.	Same as above.	Same as above.

Existing monthly volume steady flows, seasonally adjusted steady flows, and year-round steady flows would all result in the loss of some currently vegetated areas as existing marsh vegetation was inundated for extended periods and died. For these operational scenarios, any existing vegetation would be lost between the elevations of the current 8,000-cfs minimum flow and 12,000- to 13,000-cfs flows (Section 4.2.4.1.2, *Vegetation*). This zone receives little use by most species because the vegetation is relatively sparse and the zone is frequently inundated. Species such as the side-blotched lizard and red-spotted toad that do use this habitat could be adversely affected, but the impact should be minor because those species do not depend exclusively on this habitat for survival. Any adverse impacts to these species resulting from the loss of marsh vegetation would be greatly offset by the benefits of an increase in woody riparian vegetation.

The current low level of use of the river by waterfowl reduces the potential impact of any of the operational scenarios on such species. Differences in the degree of flow fluctuation associated with different operational scenarios should have little effect on the suitability of open-water habitats but could affect the aquatic food base (Reclamation 1993). The changes in marsh habitat described above in the *Vegetation* subsection should not have important impacts to waterfowl because of the current limited availability and use of this habitat. The few species that prefer open shoreline (e.g., killdeer, spotted sandpiper) could be adversely affected by any reductions in this habitat that would occur with existing monthly volume steady flows or year-round steady flows.

The two game mammals that use riparian areas below Glen Canyon Dam — bighorn sheep and mule deer — use riparian habitats only occasionally. The increases in woody riparian vegetation expected under all operational scenarios except continuation of historical flows, maximum power plant capacity, and restricted high fluctuations would increase the availability of suitable habitat for these species. Given the current limited use of the river corridor by either of these species and the abundance of these habitats, however, it appears unlikely that either species would respond to any such changes.

4.2.4.1.3 Threatened and Endangered Species

Aquatic Species

Potential impacts to the Federally listed humpback chub, razorback sucker, and flannelmouth sucker under the various operational scenarios are summarized in Table 4.20. Impacts to the Federally listed endangered humpback chub and razorback sucker are discussed in greater detail in the remainder of the section. The assessment presented here is based on the assessment in the EIS for operation of Glen Canyon Dam (Reclamation 1993).

As discussed in Section 3.4.1.3.1, the most important factor adversely affecting the Federally listed fish in the system is water temperature, which is not affected by hydropower

TABLE 4.20 Summary of Potential Impacts to, and Overall Population Status of, the Humpback Chub, Razorback Sucker, and Flannelmouth Sucker below Glen Canyon Dam under Different Operational Scenarios^a

Operational Scenarios	Humpback Chub (F-E, AZ-E)	Razorback Sucker (F-E, AZ-E)	Flannelmouth Sucker (F-C2, AZ-NL)
Continuation of historical flows	Slight adverse impact; no change in adult population from current levels; population stable to declining; reproduction and recruitment in the Colorado River limited by cold water temperature, independent of hydropower operations; large daily flow fluctuations limit nursery habitat stability.	No impacts from hydropower operations; population stable to declining; no reproduction because of cold water.	No change from current conditions; population stable to declining; population is limited by cold water temperatures, which are not affected by hydropower operations, and possibly by competition and predation from introduced species.
Maximum power plant capacity	Same as above, except greater daily flow fluctuations would further limit nursery habitat stability.	Same as above.	Same as above, except greater daily flow fluctuation would further limit nursery habitat stability.
Restricted high fluctuating flows	Same as above.	Same as above.	Same as above.
Moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Modified low fluctuating flows	Slight benefit from increase in nursery habitat stability and possible increase in backwater abundance; benefits may be offset by increased populations of introduced species; habitat maintenance flows may limit abundance of introduced fish.	Same as above (because of absence of spawning, no benefits expected from increased nursery habitat stability and abundance).	Slight benefit from slight increase in nursery habitat stability and increased food base; benefits may be offset by potential increase in numbers of introduced fish; habitat maintenance flows may limit abundance of introduced fish; benefits may be greater than for moderate fluctuating flows.
Interim low fluctuating flows	Same as above, except no habitat maintenance flows to limit introduced fish.	Same as above.	Same as above, except no habitat maintenance flows to limit introduced fish.
Existing monthly volume steady flows	Slight benefit; stability of backwater habitats greater than moderate fluctuating flows; benefits may be offset or adverse impacts may occur from potential increase in numbers of introduced fish.	Same as above.	Slight benefit from increased nursery habitat stability and food base; benefits may be offset or adverse impacts may occur from potential increase in numbers of introduced fish.

TABLE 4.20 (Cont.)

Operational Scenarios	Humpback Chub (F-E, AZ-E)	Razorback Sucker (F-E, AZ-E)	Flannelmouth Sucker (F-C2, AZ-NL)
Seasonally adjusted steady flows	Slight to moderate benefit. Same as above except that habitat maintenance flows may limit abundance of introduced fish.	Same as above.	Slight to moderate benefit. Same as above except that habitat maintenance flows may limit abundance of introduced fish.
Year-round steady flows	Slight benefit; habitat stability greater than under other scenarios; potential filling of nursery areas and increased populations of introduced species may negate any benefits and may adversely impact the humpback chub.	Same as above.	Slight benefit; similar to seasonally adjusted steady flows, but may be more adversely affected by potential increases in numbers of introduced fish and potential filling of nursery areas.

^a Parenthetical coding for species indicates current status. These codes are defined in Table 3.8.

Source: Adapted from Reclamation (1993).

operations. The continual release of cold water from Lake Powell appears to be the main factor limiting or preventing successful reproduction, larval growth, survival, and recruitment in the main channel.

Humpback Chub (Endangered). Except for potential adverse impacts from introduced species, impacts of hydropower operations on the humpback chub would be relatively similar among the historical, maximum power plant capacity, restricted high fluctuating flow, and moderate fluctuating flow operational scenarios. Under historical flows, the humpback chub population below the dam (including that in the Little Colorado River) should remain at or very near current levels or slowly decline because of natural mortality of adults. The humpback chub would continue to depend almost exclusively on reproduction and recruitment in the Little Colorado River, which would be unaffected by any of the operational scenarios. Similarly, little or no change in the status of the humpback chub would be anticipated under the maximum power plant capacity and restricted high fluctuating flow operational scenarios. The high daily flow fluctuations that would occur under the historical, maximum power plant capacity, and restricted high fluctuating flow operational scenarios would reduce the stability of backwater and nursery habitats and thus could result in a slight adverse impact to the potential growth and survival of humpback chub larvae in the Colorado River (Reclamation 1993). Because the greatest flow fluctuations would occur under the maximum power plant operations, nursery habitats would be least stable under this scenario.

Growth and recruitment of humpback chubs in the Colorado River could be slightly improved with moderate, modified low, and interim low fluctuating flows, primarily because of slightly increased stability in backwater nursery habitats. Additional benefit could be realized under the seasonally adjusted, existing monthly, and year-round steady flows. Under these scenarios, slight increases could occur in survival, growth, and recruitment of humpback chubs in the Colorado River (Reclamation 1993). Because nursery habitats would be most stable under the year-round steady flow operational scenario, this scenario could result in the greatest benefit to the humpback chub. However, main channel water temperatures would remain cold, and the benefit gained by the humpback chub would probably be small (Reclamation 1993). In addition, under year-round steady flows and in the absence of occasional flood flows, backwater habitats eventually would fill with sediment and vegetation, thereby eliminating these stable backwater areas as nursery habitats and resulting in an adverse impact to the chub (Reclamation 1993). The beach/habitat-building flows, which are common to all the restricted fluctuating and steady flow scenarios, could remove accumulated sediment and vegetation from backwater habitat, thus restoring the capacity of these habitats to function as nursery areas.

Any potential benefits to the humpback chub population resulting from lower fluctuations in flow could be offset by a concurrent increase in the number of introduced fish. Introduced fish have been suggested as a major factor responsible for the decline of native fish below Glen Canyon Dam (Minckley 1991; Minckley et al. 1991; see also Section 3.4.1.1). The increased stability of nursery habitats that could occur under many of the operational scenarios could benefit not only endangered and native fish but also could increase survival,

growth, and recruitment of introduced fish (Reclamation 1993, see also Section 4.2.4.1.1). This condition could, in turn, result in increased competition with and predation on the endangered and native fish. The steady flow operational scenarios (particularly the year-round steady flow scenario) would have the greatest potential for increasing competition or predation from introduced fish. The beach/habitat building flows that are common elements of all the restricted fluctuation and steady flow scenarios may act to limit the abundance of introduced fish (Reclamation 1993). In addition, the yearly habitat-maintenance flows that would occur under the moderate and modified low fluctuation and the seasonally adjusted steady flow operational scenarios could act to further limit the abundance of introduced fish.

Razorback Sucker (Endangered). The razorback sucker population in the Colorado River between the dam and Lake Mead consists of only a few, very old (in excess of 25 years old) individuals. Little or no change would be expected in the status of the razorback sucker under any of the operational scenarios. Although some of the scenarios could increase the stability and abundance of nursery habitats that could be used by the razorback sucker larvae, this species does not reproduce in the river or its tributaries below the dam. Spawning is limited by cold water, which is not affected by variations in dam operations. In the absence of reproduction and recruitment, the razorback sucker population will continue to decline, and this species may become extirpated from the river between the Glen Canyon and Hoover dams.

Terrestrial Species

Expected impacts to Federally and state-listed species from hydropower operational scenarios at Glen Canyon Dam are summarized in Table 4.21. Impacts to Federally listed species are discussed in greater detail in the remainder of the section. In general, the various operational scenarios would have only minor (if any) impacts on these species.

Kanab Ambersnail (Endangered). None of the operational scenarios are expected to adversely affect the Grand Canyon population of the Kanab ambersnail, since it is located above maximum power plant capacity flows (Reclamation 1993). Operational scenarios with lower maximum flows would result in an expansion of riparian vegetation to lower elevations (Section 4.2.4.1.2, *Vegetation*). Some of this vegetation could provide suitable habitat for the ambersnail and thus could allow the population to expand to lower elevations.

Bald Eagle (Endangered). None of the operational scenarios under consideration are expected to have important impacts on the bald eagle (Reclamation 1993). Fluctuations in flow could strand trout in isolated pools, a condition that could benefit foraging eagles, but these same fluctuations could limit trout spawning activities and thus offset this benefit. Expected increases in the aquatic food base with moderate, modified low, and interim low fluctuating flows and the steady flow operational scenarios could be of slight benefit to this species.

TABLE 4.21 Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Glen Canyon Dam^a

Operational Scenarios	Grand Canyon Flaveria (F-C1)	Kanab Ambersnail (F-E)	Chuckwalla (F-C2)
Continuation of historical flows	No impact; species above riparian zone.	No impact; species above fluctuation zone.	No impact; no change to existing habitat.
Maximum power plant capacity	Same as above.	Same as above.	No impact; habitat changes unimportant because species not dependent on riparian habitat.
Restricted high fluctuating flows	Same as above.	Same as above.	No impact; no change to existing habitat.
Moderate fluctuating flows	Same as above.	Possible beneficial impact; expansion of habitat to lower elevations.	No impact; habitat changes unimportant because species not dependent on riparian habitat.
Modified low fluctuating flows	Same as above.	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Same as above.	Same as above.	Same as above.
Year-round steady flows	Same as above.	Same as above.	Same as above.
<hr/>			
Operational Scenarios	White-Faced Ibis (F-C2)	Osprey (AZ-T)	Bald Eagle (F-E, AZ-E)
Continuation of historical flows	No impact; no change to existing marsh habitat.	No impact; food supply (fish) unchanged.	No impact; food supply (fish) unchanged.
Maximum power plant capacity	No impact; marsh habitat may change but still suitable.	Same as above.	Same as above.
Restricted high fluctuating flows	No impact; no change to existing marsh habitat.	Slight benefit resulting from potential increase in fish population.	Same as above.
Moderate fluctuating flows	No impact; marsh habitat may change but still suitable.	Same as above.	Slight benefit; possible increase in food supply.
Modified low fluctuating flows	Same as above.	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Same as above.	Same as above.	Same as above.
Year-round steady flows	Same as above.	Same as above.	Same as above.

TABLE 4.21 (Cont.)

Operational Scenarios	Northern Goshawk (F-C2, AZ-C)	Peregrine Falcon (F-E, AZ-C)	Mexican Spotted Owl (F-T, AZ-T)
Continuation of historical flows	No impact; woodland habitat unaffected.	No impact; food supply (birds) would not change.	No impact; woodland habitat unaffected.
Maximum power plant capacity	Same as above.	Same as above.	Same as above.
Restricted high fluctuating flows	Same as above.	Same as above.	Same as above.
Moderate fluctuating flows	Same as above.	Slight benefit; potential increase in bird populations resulting from increases in woody riparian vegetation.	Same as above.
Modified low fluctuating flows	Same as above.	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Same as above.	Same as above.	Same as above.
Year-round steady flows	Same as above.	Same as above.	Same as above.
Operational Scenarios	Belted Kingfisher (AZ-C)	Southwestern Willow Flycatcher (F-PE, AZ-E)	Loggerhead Shrike (F-C2)
Continuation of historical flows	No impact; food supply (fish) unchanged.	No impact; riparian habitat unchanged.	No impact; riparian habitat unchanged.
Maximum power plant capacity	Same as above.	Slight adverse impact; slight decrease in woody riparian habitat.	Slight adverse impact; slight decrease in riparian habitat.
Restricted high fluctuating flows	Same as above.	No impact; riparian habitat unchanged.	No impact; riparian habitat unchanged.
Moderate fluctuating flows	Slight benefit from potential increase in fish population.	Slight benefit from increase in woody riparian habitat.	Moderate benefit from increase in woody riparian habitat.
Modified low fluctuating flows	Same as above.	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Moderate benefit due to increase in woody riparian habitat.	Same as above.
Seasonally adjusted steady flows	Same as above.	Same as above.	Same as above.
Year-round steady flows	Same as above.	Same as above.	Same as above.

TABLE 4.21 (Cont.)

Operational Scenarios	Spotted Bat (F-C2, AZ-C)	Southwestern River Otter (F-C2, AZ-E)
Continuation of historical flows	No impact; food supply (insects) unchanged.	No impact; no change in food supply (fish) or suitability of shoreline habitat.
Maximum power plant capacity	Same as above.	Same as above.
Restricted high fluctuating flows	Same as above.	Slight benefit from potential increase in fish population.
Moderate fluctuating flows	Slight benefit; potential increase in insect populations resulting from increases in woody riparian vegetation.	Same as above.
Modified low fluctuating flow	Same as above.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Same as above.
Seasonally adjusted steady flows	Same as above.	Same as above.
Year-round steady flows	Same as above.	Same as above.

^a Parenthetical coding for species indicates current status. These codes are defined in Table 3.9.

Peregrine Falcon (Endangered). It is thought that peregrine falcons have benefitted from the increases in aquatic and terrestrial productivity that have resulted from construction of Glen Canyon Dam. Most importantly, falcon prey (mostly birds) may have increased in abundance in response to (1) increases in the abundance of aquatic insects with less turbid water and (2) increases in terrestrial insects in response to the increase in riparian vegetation. However, a quantitative link between these factors has not been firmly established, and, thus, it is difficult to determine what effects (if any) changes in hydropower operations would have on peregrine falcons along the river (Reclamation 1993). It is possible that the expected increases in riparian vegetation associated with reduced fluctuations could result in slight increases in food supply under moderate fluctuation, low fluctuation, and steady flow operational scenarios, but this increase would probably not affect the peregrine falcon population.

Mexican Spotted Owl (Threatened). No impacts to the Mexican spotted owl are likely to occur along the Colorado River as a result of the operational scenarios being considered. The woodland habitats that could be used by the owl are above the level of

maximum flows and would not be affected by any of the hydropower operational scenarios. Projected increases in woody riparian vegetation under operational scenarios with reduced fluctuations (Section 4.2.4.1.2) would probably not benefit this species because most colonizing vegetation would consist of shrubs rather than trees.

Southwestern Willow Flycatcher (Proposed Endangered). Operational scenarios could affect the southwestern willow flycatcher through their effects on woody riparian vegetation, which has been proposed as critical habitat for this species (Reclamation 1993). Only the maximum power plant capacity operational scenario could have an adverse effect on the flycatcher because of the slightly higher maximum flows that would inundate some woody riparian vegetation. Moderate fluctuation, modified low fluctuation, and interim low fluctuation operational scenarios could result in slight benefits to this species as woody riparian vegetation increased in response to reductions in maximum flows. Further benefits could accrue with additional increases in woody riparian vegetation associated with the steady flow scenarios.

4.2.4.2 Flaming Gorge Dam

4.2.4.2.1 Aquatic Ecology

Potential impacts to trout and native fish are the focus of this discussion of the impacts of hydropower operational scenarios on the aquatic ecology of the Green River below Flaming Gorge Dam. These potential impacts are summarized in Table 4.22. Endangered fish are addressed separately in Section 4.2.4.2.3.

Although concerns may exist regarding impacts to specific aquatic habitats (e.g., backwater areas in the lower portion of the Green River), to the aquatic food base, and to introduced fish species, these concerns are related to potential indirect impacts to endangered fish, native fish, and trout. Therefore, these topics are addressed within the discussions of impacts to fish.

Trout

Important factors relative to trout in the Green River include growth rates, condition factors, overwinter survival of stocked trout, and natural reproduction. Impacts to trout are summarized in Table 4.22.

Under historical operations and current fishery management practices, the area of the Green River below Flaming Gorge Dam has become one of the premier trout fisheries of the western United States (Modde et al. 1991). Excellent growth rates and condition factors have been documented for this trout fishery (Modde et al. 1991; Johnson et al. 1987). However, the majority of the trout are stocked, and recruitment of naturally reproduced

TABLE 4.22 Summary of Impacts to Trout and Native Fish below Flaming Gorge Dam under Different Hydropower Operational Scenarios

Operational Scenarios	Trout	Native Fish
Year-round high fluctuating flows	Slight to moderate adverse impact to growth rates and overwinter survival of young; potential reduction in natural reproduction; slight potential decrease in condition.	Slight to moderate adverse impact; populations may be limited by low overwinter survival and recruitment from daily flow fluctuations and introduced fish; use of and reproduction in the Green River above the Yampa River is limited by cold water, independent of hydropower operations.
Seasonally adjusted high fluctuating flows	Slight to moderate adverse impact, same as above.	Slight to moderate benefit; recruitment may be enhanced; no change in overwinter survival; high spring flows may limit abundance of introduced species; potential slight increase in use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.
Seasonally adjusted moderate fluctuating flows	Slight benefit; slight improvement in condition and slight increase in overwinter survival; increase in number of wild-spawned trout.	Moderate benefit; recruitment and overwinter survival may be enhanced; high spring flows may limit abundance of introduced species; potential slight increase in the use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.
Seasonally adjusted steady flows	Slight benefit; highest level of overwinter survival; slight improvement in condition and slight increase in hatching success over seasonally adjusted moderate fluctuations.	Moderate to large benefit; highest potential recruitment and overwinter survival of all scenarios; high spring flows may limit abundance of introduced species; potential slight increase in use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.

young to the adult populations is typically low. This low recruitment may be due to the substantial daily fluctuations in dam releases that have occurred in the past during the spawning and egg development periods (see Appendix D, Section D.2.1.2 for additional discussion). Daily fluctuations can strand spawning adults, expose eggs, or reduce the quality of spawning sites. One of the trout species present below the dam, the brown trout, relies completely upon natural reproduction of wild stocks to maintain population levels, and reproduction occurs at low levels.

Under the year-round high and seasonally adjusted high fluctuating flow operational scenarios, maximum releases from the dam would be about 500 cfs greater than under historical operations, and the magnitude of daily flow fluctuations would also be greater. The increase in the magnitude of the daily flow fluctuations could result in slight to moderate adverse impacts to trout. The large daily fluctuations that would occur during spawning and the egg development periods could limit natural reproduction, particularly by the brown trout. The daily fluctuations of the year-round and seasonally adjusted high fluctuating flow scenarios could also reduce growth rates, condition, and overwinter survival of trout (see Appendix D).

Both the seasonally adjusted moderate fluctuating flow and seasonally adjusted steady flow operational scenarios would increase the amount of potential spawning substrate available for trout that spawn during the fall (brown trout and rainbow trout) or spring (rainbow trout and brook trout), and these areas would remain inundated throughout the period of egg development and hatching. In addition, the reduction or elimination of daily fluctuations could increase populations of aquatic insects such as mayflies, stoneflies, and caddisflies that serve as food for trout. Thus, under these two scenarios, the number of naturally reproduced brown, rainbow, and brook trout could increase. During other times of the year, however, the amount of feeding habitat and shelter available for trout would be similar under all operational scenarios. If trout population levels were maintained near present levels, reduced daily fluctuations in discharge could improve growth and condition of trout, because aquatic food resources could increase slightly. If trout population levels increased, however, growth rates and overall condition of the fish could decrease because of increased competition for food resources. Modde et al. (1991) reported that growth rates of trout in the Green River declined as population levels increased, suggesting that food or habitat is limited. Whether trout population levels increased or remained at current levels would, as in the past, depend primarily on trout stocking and management programs.

Overwinter survival of trout could be improved by the seasonally adjusted moderate fluctuation and seasonally adjusted steady flow operational scenarios because of reduced daily fluctuations in discharge during the winter, with the latter scenario expected to yield the highest overwinter survival.

Native Fish

The primary issues relative to native fish in the Green River include reproduction, growth, condition, overwinter survival, and recruitment of young fish to the adult populations. Impacts to native fish are summarized in Table 4.22.

Under historical operations, use of the Green River above the Yampa River by adult and juvenile native fish may have been limited by daily flow fluctuations and cold water, while reproduction in this portion of the Green River was limited by the cold water. Reproduction in the Green River above the confluence with the Yampa River would remain limited under all operational scenarios because of the cold water released from the reservoir regardless of the operational scenario implemented. Use of the Green River above the Yampa River confluence by adult and juvenile native fish would continue to be limited under the year-round and seasonally adjusted high fluctuating flow operational scenarios and might be further reduced in winter because the daily flow fluctuations under these scenarios would be greater than during past operations. Use by native fish of the Green River through the Canyon of Lodore in all seasons except winter could increase slightly under the seasonally adjusted moderate fluctuating flow and steady flow operational scenarios, primarily as a result of reduction or elimination of hydropower-generated daily flow fluctuations.

The Yampa River maintains flows in the lower portion of the Green River near pre-dam levels (USFWS 1992b). According to the Biological Opinion issued on the operation

of the dam (USFWS 1992b), continuation of historical operations at Flaming Gorge Dam would cause a decline of some native fish populations, primarily because of daily flow fluctuations. These fluctuations limit the abundance and quality of nursery habitats in the Green River below the Yampa River and thus reduce recruitment of young fish to adult populations (USFWS 1992b). Daily flow fluctuations in the Green River below the confluence of the Yampa River would be greater during the nursery period under the year-round high fluctuating flow scenario than under past operations and could reduce recruitment of some native fish. Thus, populations of some native fish species could continue to decline at rates equal to or greater than those occurring in the past. In addition, species with stable populations may begin to decline under year-round high fluctuating flows because of the greater magnitude of the daily fluctuations.

The seasonally adjusted high fluctuating flow operational scenario would control flow fluctuations within specified ranges during the nursery periods for most native and endangered fish species (USFWS 1992b). Under these conditions, growth and recruitment of young fish would be enhanced, and the populations of native fish could increase slightly (see Appendix D, Section D.2.1.2 for a discussion of backwater stability). Little or no change would be expected in overwinter survival.

The seasonally adjusted moderate fluctuating flow operational scenario would produce considerably smaller daily fluctuations in flows in the Green River below the Yampa River during all seasons of the year. The daily flow fluctuations that would occur under the seasonally adjusted moderate fluctuating flow operational scenario are within the range of daily fluctuations allowed under the Biological Opinion and considered protective of backwater nursery habitats for endangered (and native) fish species (USFWS 1992b). Under this scenario, flows at Jensen during the critical nursery habitat period would fluctuate by no more than 200 cfs per day, resulting in fluctuations of less than 2 in. per day in surface water elevations of backwaters. Seasonally adjusted steady flow operations would produce no hydropower-generated fluctuations. Under these two scenarios, moderate to high increases in the populations of native fish could occur. These increases could result from increased stability of nursery areas, increased production of the food base, improved growth rates, and improved survival of young and adults; reproduction levels in the Green River are not likely to change.

The ecological requirements of some of the introduced fish in the Green River below the Yampa River are similar to those of the native fish. Thus, operational scenarios that potentially increase growth and survival of native species could similarly benefit the introduced species. Furthermore, since predation by and competition with introduced species have been suggested as contributing to the decline of native fish (USFWS 1992b; Minckley 1991; Minckley et al. 1991; Tyus and Karp 1991), increased numbers of introduced species could at least partially offset any benefits gained by native species under a particular operational scenario.

High spring flows may reduce numbers of introduced fish in canyon-bound reaches of western rivers (Minckley and Meffe 1987; McAda and Kaeding 1989; Osmundson and

Kaeding 1991). Thus, the high spring flows of the seasonally adjusted operational scenarios could reduce predation and competition on native fish in reaches of the Green River such as the Canyon of Lodore, Whirlpool Canyon, and Split Mountain. Little or no decrease in the abundance or diversity of introduced species is expected in broad floodplain areas, such as Island Park and near Jensen. In these areas, introduced species could probably avoid downstream transport by fast currents. For this reason, the response of introduced fish to operational scenarios and their subsequent effect on native fish cannot be quantified at this time.

4.2.4.2.2 Terrestrial Ecology

Vegetation

Assessments of impacts to riparian vegetation along the Green River below Flaming Gorge Dam were based on the predicted changes in flow regime that would result from the four operational scenarios under consideration for this dam (Section 4.2.3.2.1). Impacts of hydropower operational scenarios were assessed for woody riparian vegetation and marsh vegetation, as described in Appendix D, Section D.2.1.3. Table 4.23 summarizes potential impacts to riparian vegetation under the four operational scenarios. A more detailed discussion of these impacts is provided in Appendix D, Section D.3.2.

All operational scenarios would result in some impacts to existing riparian vegetation. Woody riparian vegetation currently occurs in a band along the edge of the river above the historical maximum operating release of 4,200 cfs. Year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and seasonally adjusted moderate

TABLE 4.23 Summary of Impacts to Riparian Vegetation below Flaming Gorge Dam under Different Hydropower Operational Scenarios

Operational Scenarios	Woody Riparian Vegetation	Marsh Vegetation
Year-round high fluctuating flows	Slight adverse impact to existing vegetation; 7% decrease in area.	Slight benefit; 17% increase in area available for marsh vegetation.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Moderate adverse impact; area available for marsh vegetation decreases by about 24%.
Seasonally adjusted steady flows	Slight benefit; 12% increase in woody riparian vegetation as high water line lowered to around 3,400-cfs level.	Large adverse impact; area available for marsh vegetation decreases by about 69%.

fluctuating flows would all feature extended periods during the growing season when releases would reach 4,700 cfs on a daily basis. This increase in maximum flows represents a stage change of approximately 6 in. and would inundate some existing woody riparian vegetation (about 0.9 acre per mile, a 7% decrease). For the seasonally adjusted steady flow operational scenario, flows would be less than historical operational levels for most of the year and could allow an expansion of woody riparian vegetation to around the 3,400-cfs level. This expansion would represent an increase in the area of woody riparian vegetation of about 12% (1.6 acres per mile).

With year-round high fluctuating flows, existing marsh vegetation would be maintained. With daily maximum flows of 4,700 cfs, the area of the fluctuation zone (where most marsh vegetation occurs) would increase by about 17%. This increase is expected to produce an increase in the amount of marsh vegetation within the river corridor. A similar increase in marsh vegetation is expected with seasonally adjusted high fluctuating flows because this same daily fluctuation zone would be maintained during several months of the growing season.

Marsh vegetation could decline under both the seasonally adjusted moderate fluctuation and seasonally adjusted steady flow operational scenarios because of decreases in the size of the fluctuation zone. Based on the seasonal and daily patterns of releases, the area available for marsh vegetation is expected to decrease by about 24% under seasonally adjusted moderate fluctuations and by about 69% for seasonally adjusted steady flows. Under both operational scenarios, the area below the 2,400-cfs level would be largely unvegetated or support short-lived annual plants because of the extended period of inundation each year. This unvegetated area would occupy about 2.4 acres per mile of river corridor.

Wildlife

Table 4.24 summarizes impacts to nongame wildlife, waterfowl, and game mammals under the four operational scenarios for Flaming Gorge Dam. Most of the impacts would be attributable to changes in riparian vegetation that serves as wildlife habitat (Section 4.2.4.2.2, *Vegetation*). These impacts are discussed below.

Nongame wildlife could be adversely affected by the year-round high fluctuation, seasonally adjusted high fluctuation, or seasonally adjusted moderate fluctuation scenarios. These species are most dependent on the woody riparian habitat that dominates the Green River corridor, and the area occupied by this vegetation would be reduced by about 7% under these scenarios. Seasonally adjusted steady flows could, on the other hand, cause a 12% increase in woody riparian vegetation, thus providing a moderate benefit to most nongame species. Expected reductions in marsh habitat associated with seasonally adjusted moderate fluctuating flow and steady flow operational scenarios could adversely affect some nongame species, but these impacts should be relatively minor given the relative abundance of marsh vegetation in nearby Browns Park wildlife refuges.

TABLE 4.24 Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Flaming Gorge Dam

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Year-round high fluctuating flows	Slight adverse impact associated with 7% decrease in area of woody riparian vegetation.	Slight benefit; 17% increase in marsh habitat; open water maintained in winter.	Slight adverse impact associated with 7% decrease in woody riparian habitat.
Seasonally adjusted high fluctuating flows	Same as above.	Slight adverse impact; 17% increase in marsh habitat, but less ice-free water in winter.	Same as above.
Seasonally adjusted moderate fluctuating flows	Slight adverse impact; associated with 7% decrease in area of woody riparian vegetation and 24% decrease in marsh.	Moderate adverse impact; 24% reduction in marsh habitat and less ice-free water in winter.	Same as above.
Seasonally adjusted steady flows	Slight benefit from 12% increase in woody riparian habitat.	Moderate adverse impact; 69% decrease in marsh habitat and less ice-free water in winter.	Slight benefit; increase in woody riparian habitat of minor importance because other habitats also used.

Differences in the degree of flow fluctuation associated with different operational scenarios should have little effect on the open-water habitats or aquatic food supply used by waterfowl in the spring, summer, and autumn. In addition, nesting areas currently used by species such as Canada geese should not be adversely affected because the slight increase in maximum flows would result in only a 6-in. increase in stage. On the other hand, none of the operational scenarios would increase nesting habitat either. The reduced maximum flows of all the seasonally adjusted flow scenarios, which could increase the availability of nesting substrates, occur between July and September, after the nesting season.

Reductions in marsh vegetation under seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows should have only slight adverse effects on waterfowl because the amount of marsh available in riparian areas along the river is small compared with the thousands of acres of managed wet marsh in the nearby Browns Park wildlife refuges. The few species that prefer open shoreline habitats (e.g., killdeer, spotted sandpiper) could benefit from the increase in unvegetated shoreline that would occur with seasonally adjusted moderate fluctuations or steady flows.

Wintering waterfowl could be adversely affected by a reduction in the availability of open, ice-free water with any of the seasonally adjusted flow scenarios. These scenarios have been developed to discourage ice breakup once an ice cap has formed, thus fluctuations would be reduced after February 1 for each scenario. Open, ice-free water would be maintained for all operational scenarios, however, from the dam to the Gates of Lodore because of the relatively warm dam releases. Use of this river reach by waterfowl in the winter would likely increase.

Riparian habitats below Flaming Gorge Dam receive various levels of use from mule deer, elk, moose, pronghorn, and bighorn sheep. The 12% increase in woody riparian vegetation projected under the seasonally adjusted steady flow scenario could benefit these species by increasing the carrying capacity of the river corridor. All but moose use a variety of nonriparian habitats, and, therefore, the importance of an increase in riparian vegetation is probably minor. While moose would potentially benefit most from increases in riparian vegetation (especially willow, a preferred forage), their current low numbers in the area would limit the importance of this habitat increase.

4.2.4.2.3 Threatened and Endangered Species

Aquatic Species

Except for the year-round high fluctuating flow operational scenario, the scenarios evaluated for Flaming Gorge Dam were developed to comply with the Biological Opinion on the operation of Flaming Gorge Dam (USFWS 1992b), and each would be protective of the endangered fish (and presumably all native fish) in the Green River downstream of Jensen, Utah. Therefore, this analysis evaluates the effects of the operational scenarios on endangered fish only for that reach of the Green River between the dam and Jensen. The year-round high fluctuating flow operational scenario would not comply with the Biological Opinion and is discussed here only to provide a point of comparison between conditions under maximum power plant operations and those that would prevail under the operational scenarios that would comply with the opinion. Impacts to Federally and state-listed aquatic species between the dam and Jensen are summarized in the following subsections and in Table 4.25. Impacts to the Federally endangered fish are discussed in greater detail in the following sections.

It should be noted that competition with and predation by introduced fish species have been suggested as factors contributing to the decline of native fish, including threatened and endangered species (Minckley 1991; USFWS 1992b), and conditions that benefit native fish could also benefit introduced ones. Therefore, any benefits realized by threatened and endangered fish species under the various operational scenarios might be at least partially offset by concomitant benefits to introduced species. The high spring flows of the seasonally adjusted operational scenarios could reduce the distribution and abundance of some introduced fish species, particularly in the canyon-bound reaches of the Green River (Minckley and Meffe 1987). However, the increased stability of backwater and nursery habitats in summer and autumn under the seasonally adjusted operational scenarios might benefit not only endangered fish, but also introduced fish (Section 4.2.4.2.1, *Native Fish*), potentially offsetting any benefits to endangered fish (Kaeding and Osmundson 1988; Tyus and Beard 1990; Haines and Tyus 1990; Karp and Tyus 1990a; Reclamation 1993). The potential for increased production and growth of introduced fish during the summer and autumn would be greatest under seasonally adjusted steady flows because this scenario would provide the most stable conditions in backwaters and other nursery areas. It is not

TABLE 4.25 Summary of Impacts to Threatened, Endangered, Candidate, and Sensitive Fish Species below Flaming Gorge Dam under Different Operational Scenarios^a

Operational Scenarios	Humpback Chub (F-E, CO-E, UT-E)	Bonytail Chub (F-E, CO-E, UT-E)
Year-round high fluctuating flows	Slight to moderate adverse impact; population stable to declining; population may be limited by low overwinter survival and recruitment from daily flow fluctuations and introduced fish; use of and reproduction in the Green River above the Yampa River limited by cold water, independent of hydropower operations; use of this reach may also be limited by daily flow fluctuations.	Same as for the humpback chub.
Seasonally adjusted high fluctuating flows	Slight to moderate benefit; recruitment may be enhanced; no change in overwinter survival; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase in summer and autumn; benefits may be offset by increased populations of introduced fish species.	Same as for the humpback chub.
Seasonally adjusted moderate fluctuating flows	Moderate benefit; recruitment and overwinter survival may be enhanced; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase in summer and autumn; benefits may be offset by increased populations of introduced fish species.	Same as for the humpback chub.
Seasonally adjusted steady flows	Moderate to large benefit; highest potential recruitment and overwinter survival of all scenarios; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase in summer and autumn; benefits may be offset by increased populations of introduced fish species.	Same as for the humpback chub.

4 of 5

TABLE 4.25 (Cont).

Operational Scenarios	Colorado Squawfish (F-E, CO-E, UT-E)	Razorback Sucker (F-E, CO-E, UT-E)
Year-round high fluctuating flows	Same as for the humpback club.	Slight to moderate adverse impact; population declining; no recruitment, probably due to predation, daily flow fluctuations, and absence of suitable nursery habitats; fluctuating flows may reduce overwinter survival; reproduction in the Green River above the Yampa River limited by cold water temperatures; use of this reach may also be limited by daily flow fluctuations.
Seasonally adjusted high fluctuating flows	Same as for the humpback chub.	Slight benefit; recruitment may be enhanced; reproduction in the Green River above the Yampa River remains limited; use of the Green River above the Yampa River may increase in summer and autumn; benefits may be offset by increased populations of introduced fish.
Seasonally adjusted moderate fluctuating flows	Same as for the humpback chub.	Slight to moderate benefit; possible reduced stress from hydropower operations on overwintering fish; recruitment may be enhanced; reproduction in the Green River above the Yampa River remains limited by cold water; use of the Green River above the Yampa River may increase; benefits may be offset by increased abundance of introduced fish.
Seasonally adjusted steady flows	Same as for the humpback chub.	Same as above.

TABLE 4.25 (Cont).

Operational Scenarios	Flannelmouth Sucker (F-C2)	Roundtail Chub (F-C2)
Year-round high fluctuating flows	Slight to moderate adverse impact; population may be limited by low overwinter survival and reduced recruitment from daily flow fluctuations and introduced fish; reproduction in the Green River above the Yampa River limited by cold water, independent of hydropower operations; use of this reach may also be limited by daily flow fluctuations.	Same as for the humpback chub.
Seasonally adjusted high fluctuating flows	Slight to moderate benefit; recruitment may be enhanced; no change in overwinter survival; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase in summer and autumn; benefits may be offset by increased populations of introduced fish species.	Same as for the humpback chub.
Seasonally adjusted moderate fluctuating flows	Moderate benefit; recruitment and overwinter survival may be enhanced; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase; benefits may be offset by increased populations of introduced fish species.	Same as for the humpback chub.
Seasonally adjusted steady flows	Moderate to large benefit; highest potential recruitment and overwinter survival of all scenarios; no change in reproduction in the Green River above the Yampa River; use of the Green River above the Yampa River may increase; benefits may be offset by increased survival and production of introduced fish species.	Same as for the humpback chub.

^a Parenthetical coding for species indicates current status. These codes are defined in Table 3.10.

possible at this time to quantify the balance between negative and positive influences of the various operational scenarios to introduced fish species.

Humpback Chub (Endangered). Reproduction by humpback chub in the Green River above the confluence with the Yampa River would remain limited under all operational scenarios because of the cold water released from the reservoir. Because the humpback chub spawns in the Yampa River, which is not influenced by Flaming Gorge Dam, none of the operational scenarios would affect spawning. Impacts to the humpback chub are summarized in Table 4.25.

In the Green River, hydropower-induced fluctuations in flow and stage in spring and summer may stress adults and limit reproduction and recruitment (USFWS 1992b) by destabilizing adult, juvenile, and nursery habitats. Fluctuations in winter may stress adults and reduce condition and survival (Valdez and Masslich 1989). Under year-round high fluctuating flows, daily fluctuations in flow and stage would be greater than under past operations, resulting in greater adverse impacts to adult, juvenile, and nursery habitats than occurred in the past. Adult and juvenile growth, recruitment, and overwinter survival could be reduced, and the population could decline at a rate equal to or slightly greater than in the past.

The humpback chub might receive slight benefits under seasonally adjusted high fluctuating flows. Daily fluctuations in flow and stage in winter and early spring (April and May) would be the same as under year-round high fluctuating flows, and there would be no difference in stress to fish in winter or spring. However, daily fluctuations in nursery habitats in summer and autumn would be reduced, possibly increasing recruitment by increasing survival and growth of young fish.

The potential benefit to the humpback chub would be even greater under the seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows. Daily fluctuations in flow and stage in summer and autumn would be very small, and nursery habitat stability would be similar under the two scenarios. As a result, a moderate to high potential increase in recruitment could occur. The difference in habitat stability between these two scenarios would be small and within the range of natural fluctuations resulting from variations in Yampa River flow. Fluctuations in flow and stage in winter due to hydropower operations would be reduced or eliminated under seasonally adjusted moderate fluctuating or steady flows, and fluctuation-induced stress would be reduced or eliminated. Use of the Green River through the Canyon of Lodore by adult and juvenile humpback chub could increase slightly under the seasonally adjusted moderate fluctuation and steady flow operational scenarios, primarily as a result of reduced hydropower-generated daily flow fluctuations.

Bonytail Chub (Endangered). Without specific information on the status and ecology of the bonytail chub in the Green River between the dam and Jensen, it is difficult to assess impacts to this species. However, because of the similarity between the bonytail

and humpback chubs (Kaeding et al. 1986) and the general similarity in adult and juvenile habitats among other endangered and native Colorado River fish, it is assumed that conditions meeting the habitat and life history requirements of the humpback chub, Colorado squawfish, and razorback sucker would benefit the bonytail chub. Thus, the assessment prepared for the humpback chub is presumed to apply to the bonytail chub as well (Table 4.25).

Colorado Squawfish (Endangered). Impacts of each of the hydropower operational scenarios on the Colorado squawfish would be very similar to the impacts identified for the humpback chub (Table 4.25). None of the operational scenarios is expected to affect the two known spawning areas for this species located in the lower Yampa River and Desolation Canyon of the lower Green River. Under year-round high fluctuating flows, daily fluctuations in flow and stage would be greater than under past operations and thus could adversely affect adult, juvenile, and nursery habitats. Adult and juvenile growth, recruitment, and overwinter survival could be reduced, and the population could decline at a rate equal to or greater than in the past.

Increased backwater habitat stability under the seasonally adjusted and steady flow scenarios might increase growth, survival, and recruitment of this species. Habitat stability would be greatest under seasonally adjusted steady flows. Decreased fluctuations in winter under the seasonally adjusted moderate fluctuation and steady flow scenarios could enhance overwinter survival of Colorado squawfish. Use of the Green River through the Canyon of Lodore by adult and juvenile Colorado squawfish could increase slightly in response to the reduced daily flow fluctuations that would occur under the seasonally adjusted moderate fluctuation and steady flow scenarios.

Razorback Sucker (Endangered). Potential impacts of each of the operational scenarios to the razorback sucker would be similar to the impacts identified for the humpback chub and the Colorado squawfish (Table 4.25). None of the operational scenarios is expected to affect access to spawning areas in the Yampa River or in the Green River below Jensen. Flow fluctuations in winter may stress razorback suckers (USFWS 1992b), and thus could reduce survival.

The daily flow fluctuations to which the razorback sucker would be subject under the year-round and seasonally adjusted high fluctuating flow scenarios would be greater than the daily fluctuations that occurred under past operations. Thus, overwinter survival could be less than occurred in the past, and the population could decline more rapidly under these scenarios.

Fluctuations would be reduced or eliminated under seasonally adjusted moderate fluctuating or steady flows, respectively, and overwinter survival could be enhanced under either of these operational scenarios. Use of the Green River through the Canyon of Lodore by adult razorback suckers could increase slightly under the seasonally adjusted moderate

fluctuation and steady flow operational scenarios, primarily as a result of reduced or eliminated hydropower-generated flow fluctuations.

Flooded bottomland nursery habitats, because of their warmer temperatures and high production of food resources, are thought to play a critical role in the survival and recruitment of young razorback suckers into the adult population (USFWS 1992b). Under each of the seasonally adjusted operational scenarios, flow and daily fluctuations would fall within the target flows and fluctuations identified in the Biological Opinion that would produce and maintain nursery habitats for the razorback sucker and other native fish (USFWS 1992b). Thus, recruitment could be enhanced under each of the seasonally adjusted flow operational scenarios as a result of nursery habitats stability; nursery habitats would be most stable under the seasonally adjusted steady flow scenario.

Terrestrial Species

Impacts of hydropower operational scenarios on Federally and state-listed terrestrial plant and animal species below Flaming Gorge Dam are summarized in Table 4.26. Impacts to Federally listed species are discussed in greater detail in the following subsections.

Ute Ladies-Tresses (Threatened). Prolonged inundation or reduction in soil moisture during the growing season could affect Ute ladies-tresses. However, no operational scenario is expected to cause inundation of any individuals of this species because the plants are all located several feet above the height of maximum hydropower releases. Soil-moisture levels would be maintained under year-round high fluctuations, seasonally adjusted high fluctuations, and seasonally adjusted moderate fluctuations during most of the growing season. Seasonally adjusted steady flows, however, could result in lower soil-moisture levels during most of the summer and thus could adversely affect this population.

Whooping Crane (Endangered). Hydropower operations at Flaming Gorge Dam are not likely to impact the whooping crane because the probability that habitat along the river would be used by migrating cranes appears low. The expected reduction in the amount of marsh habitat under seasonally adjusted moderate fluctuations or seasonally adjusted steady flows could represent a slight adverse impact to this species if migrating birds began to use the river corridor regularly during migration. These marsh habitats could serve as potential foraging areas for the species.

Bald Eagle (Endangered). Operational scenarios at Flaming Gorge Dam would differ in the amount of open, ice-free water available during the winter for foraging eagles. All but the year-round high fluctuation scenario incorporate flows that are intended to maintain a solid ice cover during the winter to protect endangered fish. Thus, seasonally

TABLE 4.26 Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Flaming Gorge Dam^a

Operational Scenarios	Ute Ladies-Tresses (F-T)	Ownbey Thistle (F-C2, UT-S, CO-1)	Smooth Cliff-Brake (CO-3)	Giant Helleborine (CO-2)
Year-round high fluctuating flows	No impact; plants above maximum flows.	No impact; plants above maximum flows.	No impact; plants on cliff faces above maximum flows.	No impact; maximum flows would maintain soil moisture levels in riparian zone throughout year.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Potential slight adverse impact; soil moisture could be reduced in summer.	Potential slight adverse impact; soil moisture could be reduced in summer.	Same as above.	Potential slight adverse impact; soil moisture could be reduced in summer.
Seasonally adjusted steady flows	Potential moderate adverse impact; soil moisture could be reduced in summer.	Moderate adverse impact; soil moisture could be reduced in summer.	Same as above.	Potential moderate adverse impact; soil moisture could be reduced in summer.
Operational Scenarios	Alcove Bog-Orchid (UT-S, CO-2)	Narrow-Leaf Primrose (F-C2, UT-S, CO-2)	Alcove Death Camas (F-3C, UT-S, CO-2)	
Year-round high fluctuating flows	No impact; maximum flows would maintain soil moisture levels in riparian zone throughout year.	No impact; maximum flows would maintain soil moisture levels in riparian zone throughout year.	No impact; maximum flows would maintain soil moisture levels in riparian zone throughout year.	
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.	
Seasonally adjusted moderate fluctuating flows	Potential slight adverse impact; lower maximum flows in summer could reduce soil moisture levels.	Potential slight adverse impact; lower maximum flows in summer could reduce soil moisture levels.	Potential slight adverse impact; lower maximum flows in summer could reduce soil moisture levels.	
Seasonally adjusted steady flows	Potential moderate adverse impact; lower maximum flows in summer could reduce soil moisture levels.	Potential moderate adverse impact; lower maximum flows in summer could reduce soil moisture levels.	Potential moderate adverse impact; lower maximum flows in summer could reduce soil moisture levels.	

TABLE 4.26 (Cont.)

Operational Scenarios	Utah Milk Snake (UT-S)	Western Smooth Green Snake (UT-S)	Whooping Crane (F-E, UT-E, CO-E)
Year-round high fluctuating flows	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.	No impact; species does not currently use area.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Slight benefit; increase in woody riparian habitat.	Slight benefit; increase in woody riparian habitat.	Same as above.
Operational Scenarios	Greater Sandhill Crane (CO-E)	Western Snowy Plover (F-C2, UT-S, CO-SC)	Long-Billed Curlew (F-3C, UT-S, CO-SC)
Year-round high fluctuating flows	Slight benefit; marsh habitat increases.	No impact; unvegetated shoreline unchanged.	Slight benefit; marsh habitat increases.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Slight adverse impact; marsh habitat decreases.	Slight benefit; unvegetated shoreline increases.	Slight adverse impact; loss of some marsh habitat.
Seasonally adjusted steady flows	Slight adverse impact; marsh habitat decreases.	Same as above.	Same as above.
Operational Scenarios	Northern Goshawk (F-C2, UT-S)	Swainson's Hawk (UT-S)	Bald Eagle (F-E, UT-E, CO-E)
Year-round high fluctuating flows	No impact; riparian wood- lands not affected.	No impact; riparian wood- lands not affected.	No impact; roost trees and open-water foraging habitat unchanged.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Moderate adverse impact; reduced foraging habitat due to ice cover below Gates of Lodore.
Seasonally adjusted moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	No impact; increase in woody riparian vegetation (shrubs) would not benefit species.	No impact; increase in woody riparian vegetation (shrubs) would not benefit species.	Same as above.

TABLE 4.26 (Cont.)

Operational Scenarios	Osprey (UT-S)	Peregrine Falcon (F-E, UT-E, CO-E)	Mexican Spotted Owl (F-T, UT-S)
Year-round high fluctuating flows	No impact; food supply (fish) unchanged.	No impact; food supply (birds) would not change.	No impact; riparian woodlands not affected.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Slight benefit; fish populations could increase.	Same as above.	Same as above.
Seasonally adjusted steady flows	Same as above.	Slight benefit; increase in woody riparian vegetation could result in increased prey populations.	No impact; increase in woody riparian vegetation (shrubs) would not benefit species.
<hr/>			
Operational Scenarios	Western Yellow-Billed Cuckoo (UT-S)	Black-Chinned Hummingbird (UT-S)	Lewis's Woodpecker (UT-S)
Year-round high fluctuating flows	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Potential slight benefit; woody riparian vegetation increases.	Slight benefit; woody riparian vegetation increases.	Slight benefit; woody riparian vegetation increases.
<hr/>			
Operational Scenarios	Willow Flycatcher (UT-S)	Loggerhead Shrike (F-C2, UT-S)	American Redstart (UT-S)
Year-round high fluctuating flows	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Slight benefit; woody riparian habitat increases.	Slight benefit; woody riparian habitat increases.	Slight benefit; woody riparian vegetation increases.

TABLE 4.26 (Cont.)

Operational Scenarios	Wilson's Warbler (UT-S)	Yellow-Breasted Chat (UT-S)	Dwarf Shrew (UT-S)
Year-round high fluctuating flows	Slight adverse impact; woody riparian habitat decreases.	Slight adverse impact; woody riparian habitat decreases.	No impact; no change in suitability of habitat.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted steady flows	Slight benefit; woody riparian habitat increases.	Slight benefit; woody riparian habitat increases.	Same as above.
Operational Scenarios	Spotted Bat (F-C2, UT-S)	River Otter (UT-S)	Ringtail (UT-S)
Year-round high fluctuating flows	No impact; food supply (insects) unaffected.	No impact; food supply (fish) and suitability of shoreline habitat unaffected.	No impact; no change in suitability of habitat.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Slight benefit; fish population could increase.	Same as above
Seasonally adjusted steady flows	Slight benefit; insect population could increase in response to increase in woody riparian vegetation.	Same as above.	Same as above

^a Parenthetical coding for species indicates current status. These codes are defined in Table 3.11.

adjusted high fluctuation, moderate fluctuation, and steady flows would reduce the availability of open water in important foraging areas such as Island and Rainbow parks. Much of the river above the Gates of Lodore would remain open under all operational scenarios because the temperature of water released from the dam is sufficiently high to prevent freezing. Eagles would concentrate their use in this section of the river during the winter under seasonally adjusted flow scenarios. No other impacts to this species are anticipated.

Peregrine Falcon (Endangered). Given the expected magnitude of impacts to riparian vegetation and aquatic ecology along the Green River associated with various operational scenarios (Section 4.2.4.2.2, *Vegetation*), it is unlikely that the peregrine falcon population would be affected regardless of the operational scenario employed. A slight beneficial impact could occur if prey populations increased in response to the increase in woody riparian vegetation expected under seasonally adjusted steady flows.

Mexican Spotted Owl (Threatened). No impacts to the Mexican spotted owl are likely to occur along the Green River under any of the operational scenarios at Flaming Gorge Dam. Woodlands, all of which are above the level of maximum flows, would not be affected by any of the hydropower operational scenarios. The moderate increases in woody riparian vegetation expected with seasonally adjusted steady flows would probably not benefit this species. Such vegetation would consist primarily of shrubs rather than the trees used by the owl.

4.2.4.3 Aspinall Unit

4.2.4.3.1 Aquatic Ecology

Under the seasonally adjusted steady flows operational scenario, releases of water from the Aspinall Unit dams would not be controlled to produce hydropower. Daily changes in reservoir elevations would result solely from Bureau of Reclamation operations, and no adverse impacts would be expected from hydropower generation at any of the three dams. Under the seasonally adjusted high fluctuating flow scenario, the kokanee salmon would be the aquatic resource of principal concern. Potential impacts to this salmon could include increased mortality from entrainment and passage through the penstocks and hydropower turbines, reduced growth and condition as a result of a reduction in the aquatic food base, and loss of habitat. However, as discussed below, hydropower operations are not expected to produce any such impacts that would seriously affect the population.

Entrainment of kokanee salmon typically occurs in summer when adults seek cold temperatures in deep water. During this period, kokanee concentrate at depths of 50 to 100 ft below the surface of Blue Mesa Reservoir and from the surface to a depth of about 40 ft at Morrow Point Reservoir (Van Buren and Burkhard 1981). Under seasonally adjusted steady flows, these depths would be about 25-120 ft above the depths of the penstock intake structures. Thus, very little entrainment of kokanee salmon at the penstocks would be expected under this scenario.

Under seasonally adjusted high fluctuating flows, surface elevations in Blue Mesa Reservoir would vary by no more than 0.5 ft per day, and Morrow Point Reservoir would vary by no more than 1.5 ft per day. These variations are insufficient to bring the fish within the influence of the penstocks. Thus, no impacts to adult kokanee salmon are anticipated from entrainment in summer months. Entrainment is known to occur in Crystal Reservoir. Although releases from Crystal Dam would be identical under both operational scenarios, the surface water elevation in Crystal Reservoir may vary by more than 8 ft per day, depending on releases from Morrow Point Dam. At minimum reservoir elevations, the surface of Crystal Reservoir would be within about 40 ft of the intake structure. Nothing is known about the depth distribution of kokanee salmon in Crystal Reservoir, nor of the temperature profile of this reservoir (see Section 3.3.3.3). If adult kokanee salmon use Crystal Reservoir to depths of 40 ft below the surface as they do in Morrow Point Reservoir, the salmon could be entrained at minimum reservoir elevations. This would be a slight adverse impact, since the

kokanee salmon population in Crystal Reservoir is incidental to operations of upstream facilities and constitutes a very small portion of the kokanee salmon fishery in the Aspinall Unit reservoirs.

Kokanee salmon (as well as trout in the reservoirs) would not be affected by any daily fluctuations in surface water elevation and nearshore areas under the high fluctuating flows. Daily fluctuations along the shores of Blue Mesa and Morrow Point reservoirs would be comparable to the fluctuations produced by wind and watercraft. Although daily fluctuations in the surface elevation at Crystal Reservoir could exceed 8 ft, the nearshore habitats are of limited quality because of the very steep, vertical contours of the shoreline areas. Thus, fluctuations in this reservoir should not adversely affect kokanee salmon.

Little or no information is available on the aquatic food base in the Aspinall Unit reservoirs. Because these reservoirs are nutrient-poor, primary and secondary productivity is not high. The primary food base for kokanee salmon is plankton. Although the relationship between daily fluctuation in surface water elevation and plankton production is not known, the productivity of this resource would be limited by nutrient input to the reservoirs and unaffected by hydropower operations.

4.2.4.3.2 Terrestrial Ecology

Vegetation

The limited amount of riparian vegetation along any of the reservoirs of the Aspinall Unit greatly reduces the potential for impact from the two operational scenarios being considered. Table 4.27 and the following paragraphs summarize these potential impacts; additional details are presented in Appendix D.3.3.

No adverse impacts to existing woody riparian vegetation are expected to result from either hydropower operational scenario. Even under the seasonally adjusted high fluctuation scenario, daily fluctuations in Blue Mesa Reservoir water levels attributable to hydropower generation would be only about 0.5 ft and this would occur when reservoir levels would be more than 0.5 ft lower than historical levels (Section 4.2.3.3.1). Consequently, no impacts to the marsh in the upper reach of the reservoir are expected to result from hydropower operations. Although fluctuations in water levels due to hydropower operations would be greater in Morrow Point and Crystal reservoirs (up to about 1 ft or 8 ft, respectively), these fluctuations would be within the range of historical fluctuations and therefore should not affect woody riparian vegetation, which is established above this range.

For both operational scenarios, some expansion of woody riparian vegetation could occur in the half-mile riverine reach between Morrow Point Dam and the headwaters of Crystal Reservoir because of the seasonal adjustment in flows. Fluctuations in flow would be reduced from historical levels, and this reduction would lower the high-water line by about

TABLE 4.27 Summary of Impacts of Hydropower Operational Scenarios on Vegetation along the Aspinall Unit Reservoirs

Operational Scenarios	Woody Riparian Vegetation	Marsh Vegetation
Seasonally adjusted high fluctuating flows		
Blue Mesa Reservoir	No impact on existing vegetation because fluctuations would be within historical range.	No impact; existing marsh vegetation in upper reservoir maintained.
Morrow Point Reservoir	Same as above.	No impact; no marsh vegetation exists along reservoir.
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,800-cfs level represents increase of about 0.1 acre.	Slight adverse impact; about 0.4 acre of marsh vegetation lost.
Seasonally adjusted steady flows		
Blue Mesa Reservoir	No impact because fluctuations would be within historical range.	No impact; existing marsh vegetation maintained.
Morrow Point Reservoir	Same as above.	No impact; no marsh vegetation exists along reservoir.
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,325-cfs level represents increase of about 0.2 acre.	Slight adverse impact; about 0.6 acre of marsh vegetation lost.

1 ft during most of the growing season (1.0 ft lower for high fluctuations and 1.3 ft lower for steady releases). This increase would represent a slight benefit because of the very limited amount of vegetation involved (0.2 acre or less).

Reduction in the fluctuation zone in this half-mile reach below Morrow Point Dam under both operational scenarios would cause some reduction of the limited marsh vegetation that now occurs. Under the seasonally adjusted high fluctuating flow scenario, marsh vegetation would be limited to a vertical range of about 1.6 ft above the minimum flow level. This represents a loss of about 0.4 acre of marsh vegetation. Vegetation below the elevation of 1,800-cfs flows would be eliminated because of extended periods of inundation. Under seasonally adjusted steady flows, the fluctuation zone (and potentially all of the marsh vegetation) would be eliminated. Vegetation below the elevation of 3,325-cfs flows would be eliminated because of monthly changes in inundation and exposure. These impacts are considered slight because of the minimal amount of marsh vegetation present (about 0.6 acre).

Wildlife

Potential impacts to nongame wildlife, waterfowl, and game mammals that would result from the operational scenarios being considered for the Aspinall Unit are summarized in Table 4.28. Little potential exists for impacts to nongame wildlife along the Aspinall Unit

TABLE 4.28 Summary of Impacts of Hydropower Operational Scenarios on Wildlife at the Aspinall Unit Reservoirs

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; existing habitat unchanged.	No impact; existing habitat unchanged.	No impact; existing habitat unchanged.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; increase in woody riparian habitat along headwaters.	Same as above.	Slight benefit; increase in woody riparian habitat along headwaters.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; existing habitat unchanged.	Slight adverse impact; reservoir freezes earlier in winter.	No impact; existing habitat unchanged.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; increase in woody riparian habitat along headwaters.	Same as above.	Slight benefit; increase in woody riparian habitat along headwaters.

reservoirs. No change is expected to the limited amount of riparian vegetation that exists along either Blue Mesa or Morrow Point reservoirs. The increase in riparian vegetation (less than 0.2 acre) in the headwaters of Crystal Reservoir for both operational scenarios could result in a slight benefit to nongame species dependent on this half-mile section of habitat.

Waterfowl are not expected to be affected by either of the operational scenarios at the Aspinall Unit. These reservoirs receive little use by waterfowl, presumably because of the limited amount of suitable riparian habitat along the shorelines and the low productivity of the aquatic ecosystem (Section 4.2.4.3.1). Operational scenarios would have little effect on riparian vegetation or aquatic productivity. The 10-acre marsh at the upstream end of Blue Mesa Reservoir, which could be used by waterfowl, would not be affected by the small fluctuations in reservoir levels attributable to hydropower operations (Section 4.2.4.3.2, *Vegetation*).

Seasonally adjusted steady flows could increase the rate at which the Aspinall reservoirs freeze in the winter. Wintering waterfowl dependent on open, ice-free water would be forced to leave once the reservoirs froze. Since these reservoirs freeze over completely each year anyway, the increase in the rate of freezing should not be important.

Elk and mule deer, which occur along Blue Mesa and Morrow Point reservoirs, would not be affected by either operational scenario. No impact is expected to riparian habitat along these reservoirs, and these species utilize a wide variety of other habitats. The minor

increase in riparian vegetation expected along the half-mile section above Crystal Reservoir could provide some additional forage for the bighorn sheep that use this area, but any beneficial effect would be limited by the small size of the area affected.

4.2.4.3.3 Threatened and Endangered Species

Aquatic Species

No Federally listed threatened or endangered species are known to occur in the Aspinall Unit reservoirs. Thus, no impact to Federally listed species are anticipated from either of the two operational scenarios considered. The flannelmouth sucker, a Federal Category 2 species is present in Blue Mesa Reservoir, but its status in the other reservoirs is unknown. No impacts to this species in Blue Mesa Reservoir are anticipated under either of the operational scenarios. The flannelmouth sucker is a bottom-dwelling species and thus should not become entrained under either operational scenario or be affected by the small (less than 0.5 ft) daily changes in the elevation of Blue Mesa Reservoir.

Terrestrial Species

Expected impacts to Federally and state-listed species from the two hydropower operational scenarios considered for the Aspinall Unit are summarized in Table 4.29. Potential impacts to Federally listed species are discussed in greater detail below.

Whooping Crane (Endangered). The whooping crane would not be affected by operational scenarios at the Aspinall Unit. The 10-acre marsh at the upstream end of Blue Mesa Reservoir and the shallow open-water areas of the reservoir are the only habitats suitable for this species in the vicinity of the unit. No impacts to these habitats are anticipated because hydropower-induced changes in reservoir levels would be very small (Section 4.2.4.3.2, *Vegetation*).

Bald Eagle (Endangered). Operational scenarios at the Aspinall Unit could differ in the amount of available open, ice-free water, which serves as foraging areas for the bald eagle during the winter. The steady flows under the seasonally adjusted steady flow operational scenario would tend to increase the rate of ice formation and result in a more rapid reduction in area available for foraging eagles. However, even with fluctuating releases, the reservoirs freeze over completely each year, so any impacts from hydropower operations would be negligible. For both operational scenarios, ice-free foraging areas would be available in the waters immediately downstream of each dam throughout the winter.

TABLE 4.29 Summary of Impacts of Hydropower Operational Scenarios on Threatened, Endangered, Candidate, and Sensitive Terrestrial Species at the Aspinall Unit Reservoirs^a

Operational Scenarios	Gunnison Milkvetch (CO-3)	Skiff Milkvetch (F-C2, CO-1)	Rocky Mountain Thistle (CO-2)
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	No impact; above maximum water level of reservoir.	Not present.
Morrow Point Reservoir	Not present.	Not present.	Not present.
Crystal Reservoir	Not present.	Not present.	No impact; above maximum water level of reservoir.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	No impact; above maximum water level of reservoir.	Not present.
Morrow Point Reservoir	Not present.	Not present.	Not present.
Crystal Reservoir	Not present.	Not present.	No impact; above maximum water level of reservoir.
<hr/>			
Operational Scenarios	Sierra Corydalis (CO-3)	Black Canyon Gilia (F-3C, CO-1)	Colorado Desert-Parsley (F-C2, CO-1)
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	No impact; above maximum water level of reservoir.	Not present.
Morrow Point Reservoir	Not present.	Same as above.	Not present.
Crystal Reservoir	Not present.	Same as above.	No impact; above maximum water level of reservoir.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	No impact; above maximum water level of reservoir.	Not present.
Morrow Point Reservoir	Not present.	Same as above.	Not present.
Crystal Reservoir	Not present.	Same as above.	No impact; above maximum water level of reservoir.

TABLE 4.29 (Cont.)

Operational Scenarios	Hanging Garden Sullivantia (F-3C, CO-4)	Peregrine Falcon (F-E, CO-E)	Bald Eagle (F-E, CO-E)
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	No impact; food supply (birds) unchanged.	No impact; open-water foraging habitat unchanged.
Morrow Point Reservoir	Not present.	Same as above.	Same as above.
Crystal Reservoir	Not present.	Same as above.	Same as above.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; above maximum water level of reservoir.	Same as above.	Slight adverse impact; reservoir freezes earlier in winter.
Morrow Point Reservoir	Not present.	Same as above.	Same as above.
Crystal Reservoir	Not present.	Same as above.	Same as above.
<hr/>			
Operational Scenarios	Whooping Crane (F-E, CO-E)	White-Faced Ibis (F-C2)	Northern Goshawk (F-C2)
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; open water and marsh habitat unchanged.	No impact; open water and marsh habitat unchanged.	No impact; woodland habitat unchanged.
Morrow Point Reservoir	No impact; suitable habitat not present.	No impact; suitable habitat not present.	Same as above.
Crystal Reservoir	Same as above.	Same as above.	No impact; increase in woody riparian vegetation (shrubs) would not benefit this species.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; open water and marsh habitat unchanged.	No impact; open water and marsh habitat unchanged.	No impact; woodland habitat unchanged.
Morrow Point Reservoir	No impact; suitable habitat not present.	No impact; suitable habitat not present.	Same as above.
Crystal Reservoir	Same as above.	Same as above.	No impact; increase in woody riparian vegetation (shrubs) would not benefit this species.

TABLE 4.29 (Cont.)

Operational Scenarios	Greater Sandhill Crane (CO-E)	Loggerhead Shrike (F-C2)	Spotted Bat (F-C2)
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; open water and marsh habitat unchanged.	No impact; woody riparian habitat unchanged.	No impact; food supply (insects) unchanged.
Morrow Point Reservoir	No impact; suitable habitat not present.	Same as above.	Same as above.
Crystal Reservoir	Same as above.	Slight beneficial impact; woody riparian habitat increased.	Same as above.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; open water and marsh habitat unchanged.	No impact; woody riparian habitat unchanged.	Same as above.
Morrow Point Reservoir	No impact; suitable habitat not present.	Same as above.	Same as above.
Crystal Reservoir	Same as above.	Slight beneficial impact; woody riparian habitat increased.	Same as above.

Operational Scenarios	Southwestern River Otter (F-C2)		
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	Not present.		
Morrow Point Reservoir	Not present.		
Crystal Reservoir	No impact; food supply (fish) and suitable shoreline habitat unaffected.		
Seasonally adjusted steady flows			
Blue Mesa Reservoir	Not present.		
Morrow Point Reservoir	Not present.		
Crystal Reservoir	No impact; food supply and suitable shoreline habitat unaffected.		

^a Parenthetical coding for species indicates current status. These codes are defined in Table 3.12.

Peregrine Falcon (Endangered). No adverse impacts to the peregrine falcon would occur at the Aspinall Unit as a result of either operational scenario considered here. The area receives limited use by this species and the negligible habitat changes expected to occur only with seasonally adjusted steady flows should not affect bird populations on which the falcon feeds. Earlier freezing of the reservoirs in winter also should not affect this species. Although waterfowl, which serve as prey, may leave sooner under steady flows, eventual freezing would force them to leave anyway. Overwintering peregrines would switch to alternate prey sources (e.g., songbirds) once waterfowl left the area.

4.2.5 Cultural Resources

4.2.5.1 Glen Canyon Dam

4.2.5.1.1 Archaeological Sites and Historic Structures

All of the hydropower operational scenarios under consideration in this EIS could have adverse effects on archaeological sites (Reclamation 1993). A Class III survey determined that a total of 336 archaeological sites either have already been adversely affected or exhibit the potential to be adversely affected (directly or indirectly) by the river; 313 of these sites have been determined eligible for the *National Register of Historic Places* (NRHP) (Fairley et al. 1991). Some sites reflect effects or potential effects from more than one agent of impact. Fairley et al. (1991) observed direct impacts from inundation or bank erosion at 33 sites (10%); indirect effects from bank failure or slope movement at 101 sites (30%); and indirect effects from accelerated arroyo cutting at 123 sites (37%). Potential impacts were identified at 238 sites (71%) on the basis of their geomorphic setting (riverine deposits), and potential impacts were identified at an additional 73 sites (22%) on the basis of their location below the 300,000-cfs level (Fairley et al. 1991).

Currently, no adverse effects to specific sites have been explicitly linked to hydropower operations (all operational scenarios), although some sites were affected by the 1983 flood flows. Other factors likely to cause or to contribute to impacts to archaeological sites include (1) long-term downcutting action of the Colorado River in Glen Canyon; (2) effect of Glen Canyon Dam as a sediment trap, resulting in a reduction in sediment replenishment; (3) erosion due to wind and surface water runoff; and (4) regulated flows unrelated to hydropower operations at Glen Canyon Dam. The effects of these factors must be accounted for in order to assess the impacts of the hydropower operational scenarios.

Although not all impacts to specific archaeological sites can be linked to the hydropower operational scenarios, levels of potential impacts of the scenarios can be compared in general terms. The historical, maximum power plant capacity, and possibly the restricted high fluctuating flow scenarios would probably adversely affect more archaeological sites than would the other scenarios. These operational scenarios would probably accelerate

sediment loss and bank erosion relative to the moderate fluctuation, low fluctuation, and the steady flow scenarios (Reclamation 1993).

4.2.5.1.2 Native American Cultural Resources

The hydropower operational scenarios could adversely affect Native American cultural resources, including archaeological sites of traditional or religious significance, sacred locations or areas (e.g., Honga Springs), and biotic and abiotic resources of cultural significance (e.g., riparian plants, birds with yellow feathers) (Reclamation 1993). Currently, the effects of each hydropower operational scenario on specific archaeological sites have not been determined, although, in general, the historical, maximum power plant capacity, and possibly restricted high fluctuating flow scenarios would probably adversely affect more archaeological sites than would the other scenarios. The historical, maximum power plant capacity, and possibly the restricted high fluctuating flow scenarios would also probably have greater adverse effects on locations, areas, and resources of cultural significance because of accelerated erosion of sediment and greater impact to plants and animals. However, some types of Native American cultural resources (e.g., springs, side-valley canyons) will likely be unaffected by any of the operational scenarios. As in the case of archaeological sites, sufficient information is not now available to project the impact of the operational scenarios on specific cultural resources.

4.2.5.2 Flaming Gorge Dam

4.2.5.2.1 Archaeological Sites and Historic Structures

Six archaeological sites and two historic structures downstream of Flaming Gorge Dam would be exposed to erosion by the Green River during the next 15 years (the time span of the power marketing program). These sites and structures are located on or near the margins of the first or second terrace in Browns Park (Table 4.30). Although all of these sites would eventually be eroded in the course of the natural evolution of the river (augmented by the presence of the dam), rates of erosion would vary among the four hydropower operational scenarios. The year-round high fluctuating flows and seasonally adjusted high fluctuating flows would generate the highest erosion rates. The seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows scenarios would generate lower erosion rates (14-15% less than the year-round high fluctuating flows scenario) (Table 4.31).

Potential impacts to archaeological sites and historic structures were assessed by applying the projected erosion rates of the various hydropower operational scenarios (Section 4.2.3.2) to the geomorphic context of individual sites. Information on individual sites was collected during a field study undertaken for this EIS. Variables examined included relationship to active channels (distance and elevation), sedimentary context, slope,

TABLE 4.30 Archaeological Sites and Historic Structures Downstream of Flaming Gorge Dam that Could Be Affected by Hydropower Operational Scenarios

Site Description	Location	Erosion Potential
Jarvie Ranch; historic structure listed on the NRHP; riprap present.	First terrace; extends to the river.	High, but protected.
Former historic bridge.	Floodplain and second terrace on outer meander of river; 5 ft above mean water level; 50-100 ft from channel.	High, actively eroding, but may not be eligible for NRHP.
Prehistoric lithic scatter with hearths.	Second terrace on vertical bank; 15-20 ft above mean water level.	Very high, actively eroding.
Prehistoric lithic scatter.	First terrace; 10 ft above mean water level; 3 ft from channel.	High.
Fort Davy Crockett; historic site; listed on the NRHP; has been excavated.	First terrace; extends to cutbank.	High, actively eroding, but mitigated.
Protohistoric campsite; potentially eligible for NRHP.	First terrace; 100 ft from channel; may extend to cutbank at edge of terrace.	High, if site extends to cutbank; more data needed.
James Warren Cabin; historic log cabin; potentially eligible for the NRHP.	First terrace; may extend to edge of terrace.	High, more data needed.
Historic scatter; eligible for the NRHP.	First terrace; 10 ft above mean water level; extends to cutbank.	Very high, actively eroding.

vegetation, and others (Moeller et al. 1993b). Some information on current erosion rates is available for the first terrace, which has been subject to measurable attrition at historic site Fort Davy Crockett in lower Browns Park since 1980 (Eddy et al. 1982).

No sites upstream of Browns Park (Red Canyon, Little Hole, and Devil's Hole) would be affected by river erosion during the next 15 years. No sites are recorded in areas of Red Canyon that would be affected by dam flows. At least 20 archaeological sites have been recorded within the boundaries of the river corridor in Little Hole and Devil's Hole (Section 3.5.2.2). However, these sites are located in areas that would not be subject to river erosion during the next 15 years, such as on bedrock surfaces or the second (about 20-ft) terrace (composed of cobbles and gravels in a sandy matrix) (Moeller et al. 1993a,b).

One prehistoric archaeological site and two historic structures in upper Browns Park (between Red Canyon and Swallow Canyon) would be exposed to potential river erosion

TABLE 4.31 Summary of Impacts of Hydropower Operational Scenarios on Cultural Resources below Flaming Gorge Dam

Operational Scenario	Archaeological Sites	Historic Structures
Year-round high fluctuating flows	Six sites potentially impacted by erosion.	Two structures potentially impacted by erosion.
Seasonally adjusted high fluctuating flows	Six sites potentially impacted by erosion at a rate of 4% less than year-round high fluctuations. ^a	Two structures potentially impacted by erosion at a rate of 4% less than year-round high fluctuations.
Seasonally adjusted moderate fluctuating flows	Six sites potentially impacted by erosion at a rate of 14% less than year-round high fluctuations.	Two structures potentially impacted by erosion at a rate of 14% less than year-round high fluctuations.
Seasonally adjusted steady flows	Six sites potentially impacted by erosion at a rate of 15% less than year-round high fluctuations.	Two structures potentially impacted by erosion at a rate of 15% less than year-round high fluctuations.

^a The erosion rate for a moderate water year is used (Table 4.15); little difference is noted between the erosion rates for the seasonally adjusted operational scenarios for wet and dry years.

(Table 4.30). Although 26 sites and structures have been recorded within the boundaries of the river corridor (Section 3.5.2.2), most sites are located in geomorphic settings that would not be affected by dam flows during the next 15 years (e.g., alluvial fans overlying the first terrace, bedrock outcrops). The potentially affected sites include John Jarvie Ranch, a historic structure complex listed on the NRHP. The ranch occupies an area extending to the margin of the first terrace. A riprap barrier has been constructed by the BLM to protect the site from erosion. The other potentially affected sites include the remains of a historic bridge and a prehistoric lithic scatter. These sites are located on concave meander banks near active channels. Both sites occupy sparsely vegetated sand and gravel surfaces on the second terrace (15-20 ft), the historic site extending onto the floodplain. With respect to NRHP status, the integrity of the historic bridge has been compromised by past disturbance, and it appears unlikely to meet eligibility criteria. The prehistoric site, which contains several former hearths, may be eligible, but requires further field study.

Four prehistoric and historic archaeological sites and one historic structure in lower Browns Park (between Swallow Canyon and Gates of Lodore) would be potentially exposed to river erosion (Table 4.30). As in the case of upper Browns Park, many sites and structures (a total of 29) occur within the boundaries of the river corridor, but most occupy geomorphic settings that would not be subject to river erosion within the next 15 years. The potentially affected sites include two prehistoric lithic scatters, two historic archaeological sites (Fort Davy Crockett and another unnamed site), and one historic structure (James Warren Cabin). These sites are located on or near the margin of the first terrace (10 ft), which is composed

of sand (Moeller et al. 1993b). Although they are not situated on concave meander banks, these sites are adjacent to vertical cut banks, and recent erosion has occurred at Fort Davy Crockett, and two unnamed sites (Moeller et al. 1993b). The effects of erosion at Fort Davy Crockett, which is listed on the NRHP, have been mitigated by data recovery (excavation) undertaken by the USFWS (Eddy et al. 1982). The two remaining historic sites and at least one of the prehistoric sites appear to be potentially eligible for the NRHP (Norman and Merrill 1981) but require additional field study.

Adverse effects to sites or structures that are eligible for the NRHP require mitigative measures developed in consultation with the appropriate SHPO (36 CFR 800). This EIS addresses the impacts of power marketing and hydropower operations, which must be considered separately from the effects of natural river action and the presence of the dam (which increases the erosive power of the river by reducing sediment load). The higher rates of erosion generated by the high fluctuation scenarios could have adverse effects (in addition to erosion caused by natural river action and the presence of the dam) to sites and structures that are listed on, eligible for, or potentially eligible for the NRHP. Additional studies must be undertaken to complete the inventory and evaluation of affected sites and structures. Protection, where feasible, is the preferred mitigation and could entail construction of protective features (e.g., riprap) to reduce erosion rates. Alternatively, impacts to sites could be mitigated through data recovery, entailing collection, mapping, and (if appropriate) excavation within the framework of a problem-oriented research design.

4.2.5.2.2 Native American Cultural Resources

No sites, areas, or resources of Native American religious or cultural significance have been identified to date in areas that would be affected by the hydropower operational scenarios considered in this EIS. Consultation with potentially affected Native Americans is in progress.

4.2.5.3 Aspinnall Unit

4.2.5.3.1 Archaeological Sites and Historic Structures

None of the hydropower operational scenarios considered in this EIS would affect archaeological sites or historic structures in the vicinity of the Aspinnall Unit. Many archaeological sites are located along the margins of Blue Mesa Reservoir (Section 3.5.3.2), and some of these have been subject to erosion damage from shifting reservoir levels (Jones 1986, 1992). However, the maximum contribution of hydropower operations to changes in reservoir level would not exceed 0.1 ft and would have no significant effect on these archaeological sites. One archaeological site and one historic structure complex are located near the margins of Morrow Point Reservoir, but they are situated at elevations (in excess of 7,200 ft above sea level) that would not be affected by reservoir-level changes caused by hydropower operations. (These operations-related reservoir changes would not exceed 1.3 ft).

No sites or structures are recorded in the remaining areas that would be affected by the hydropower operational scenarios (Section 3.5.3.2).

4.2.5.3.2 Native American Cultural Resources

To date, no sites, areas, or resources of Native American religious or cultural significance have been identified in areas that would be affected by the hydropower operational scenarios considered in this EIS. Consultation with potentially affected Native Americans is in progress.

4.2.6 Land Use

Impacts to land use were evaluated against standard assessment criteria. Factors examined included conversion, development potential, legal conflict, and disruption. Conversion refers to the potential of an action to result in the conversion of land from one type of use to another. Development potential refers to the likelihood that an action will change a parcel's potential for future development. Legal conflict refers to the potential of an action to cause conflicts with zoning or other legal controls. Finally, disruption refers to the potential for an action to disrupt activities associated with a particular land use.

Each criterion was applied to the affected areas associated with hydroelectric facilities for the stream flow changes under each operational scenario. Stream flow changes were found to have no influence on the conversion potential, development potential, or zoning designation of any of the affected areas for any of the operational scenarios. Changes in stream flow could, however, disrupt recreational activities on or along the Colorado and Green rivers and on the reservoirs of the Aspinall Unit. Impacts to recreational activities and facilities resulting from operational scenarios are discussed in Section 4.2.7.

4.2.6.1 Glen Canyon Dam

Hydropower operational scenarios would not affect land use below Glen Canyon Dam. Virtually the entire river corridor consists of public lands under the jurisdiction of the NPS, and little or no potential exists for private acquisition, conversion, or development of the land. Operational scenarios would neither conflict with the NPS zoning designation (natural) that governs the affected area nor result in the removal or modification of existing facilities.

4.2.6.2 Flaming Gorge Dam

Hydropower operational scenarios would not affect land use below Flaming Gorge Dam. With the exception of a few privately owned ranches, the entire affected area consists of public lands under the jurisdiction of the state of Utah and several Federal agencies. Consequently, little or no potential exists for private acquisition, conversion, or development

of the land. Operational scenarios would not result in any conflicts with existing land use regulations or controls. Special land uses, as identified in Section 3.6.2, would remain unaffected. No existing facilities in the affected area would be removed or altered. Private lands within the affected area would not be impacted.

4.2.6.3 Aspinall Unit

Land use would not be affected by either operational scenario for the Aspinall Unit. The affected environment consists of public lands under the jurisdiction of the NPS, and little or no potential exists for private acquisition, conversion, or development of the land. Operational scenarios would not alter the NPS zoning designation (natural) that governs Curecanti National Recreation Area. Modification of existing facilities would not be necessary under either scenario.

4.2.7 Recreation

A variety of recreational activities and resources occur in the areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. To assess the impacts of the hydropower operational scenarios on these recreational activities, it was assumed that boating (angling and nonangling), fishing, and riverside camping would be the most likely to be affected by stream flows. Activities such as hiking and hunting should not be affected by changing stream flows.

A number of studies have examined the relationship between flow and the quality of recreational experiences (Shelby et al. 1992), including a study by Bishop et al. (1987) of the effects of Glen Canyon Dam releases on recreation in the Grand Canyon. In general, anglers in the Grand Canyon (both boating and nonboating) tend to prefer constant flows over fluctuating flows, as do nonangling boaters (e.g., rafters, canoeists, and kayakers). However, nonangling boaters prefer high flows (up to a threshold where safety becomes a factor) to low flows. Anglers, especially those who fish from shore, tend to prefer lower steady flows (for wading into the river). Thus, the levels of stream flow considered best for angling are lower than the levels associated with high-quality rafting experiences, so a change in stream flow that constitutes an improvement for anglers may adversely affect rafters, and vice versa (Walsh et al. 1980; Bishop et al. 1987; Reclamation 1990b).

The assessment in this EIS assumed that both anglers and white-water boaters prefer constant flows to fluctuating flows. Anglers prefer constant flows because they believe sudden fluctuations in stream flow can cause fish to scatter, making them more difficult to locate and catch. White-water boaters prefer constant flows because they believe that fluctuations in stream flow result in a setting that is unnatural. In contrast, Bishop et al. (1987) concluded that day floaters (i.e., those who float downstream for all or part of a single day only) are indifferent to flow regimes, so changes in stream flow resulting from hydropower operations were assumed to have no impact on day floaters.

4.2.7.1 Glen Canyon Dam

The analysis of potential impacts to recreation at Glen Canyon Dam is based on the preliminary draft Glen Canyon Dam EIS (Reclamation 1993), which focused on the principal recreational users, including boat and shore anglers and white-water boaters. The impacts to beaches along the Colorado River are included in the discussion of impacts to white-water boaters because they are the primary users of riverside beaches. A moderate water year was assumed. Table 4.32 summarizes the assessment of impacts to recreation below Glen Canyon Dam under the nine operational scenarios presented in the Glen Canyon Dam EIS (Reclamation 1993).

4.2.7.1.1 Angling

Shore anglers, most of whom cluster around Lees Ferry, prefer moderate, constant flows. Operational scenarios with unrestricted, rapid upramping can result in a river stage increase that can potentially endanger a wading angler (Reclamation 1993). During summer, upramping episodes typically begin at 7 a.m. Angling boaters between Glen Canyon Dam and Lees Ferry prefer minimum flows of 5,000 cfs. At lower flows, most boats have difficulty navigating past 3-Mile Bar and can sustain damage from hitting rocks (Reclamation 1993). Motorized rafts that are used primarily for day floating can navigate upstream from Lees Ferry in low flows (below 3,000 cfs) that restrict other boats. Flows above 8,000 cfs appear to mitigate the majority of navigational problems. Because most boaters using this segment of the river do so to fish, it was assumed that they would prefer moderate, constant flows.

Current use levels for angling below Glen Canyon Dam have developed under flow conditions similar to those for the continued historical flow scenario. Thus, this operational scenario should result in no impacts to current use levels or values. Under the maximum power plant capacity scenario, slight adverse impacts from larger fluctuations and higher maximum flows could occur to anglers using the river between Glen Canyon Dam and Lees Ferry. For the restricted high fluctuating flow scenario, minimum flows between Labor Day and Easter would be set at 3,000 cfs and increased to 5,000 cfs after Labor Day. These minimum flows would be higher than the minimum flows under the continued historical flow scenario. Slight beneficial impacts to fishing would occur because higher minimum flows would provide some relief to those fishing from boats between the dam and Lees Ferry.

The year-round minimum flow of 5,000 cfs under the moderate fluctuating flow scenario would be slightly beneficial to angling boaters between the dam and Lees Ferry. The lower upramping rate under this scenario (4,000 cfs/h) would be more attractive to shore anglers than the unrestricted rates under scenarios of continued historical flows, maximum power plant capacity, and restricted high fluctuating flows.

The modified low fluctuating flow and interim low fluctuating flow operational scenarios would result in slight benefits to boat or shore anglers relative to continued historical flows and scenarios with larger fluctuations. Higher minimum flows (8,000 cfs

TABLE 4.32 Summary of Impacts to Recreational Activities below Glen Canyon Dam under Nine Hydropower Operational Scenarios

Operational Scenario	Angling	Day Floating	White-Water Boating	Beaches
Continuation of historical flows	No impact; no change from current conditions.	None	No impact; no change from current conditions.	No impact; no change from current conditions.
Maximum power plant capacity	Slight adverse impact to shore and boat anglers because of larger fluctuations and higher maximum flows.	None	Slight adverse impact due to larger fluctuations.	Slight adverse impact; smallest area, lowest number, and poorest mooring quality.
Restricted high fluctuating flows	Slight benefit to anglers because of increase in minimum flows.	None	Slight benefit from reduced fluctuations.	No impact; no change from current conditions.
Moderate fluctuating flows	Slight benefit to boat anglers from higher minimum flows in fall; slight benefit to shore anglers from restricted upramping.	None	Slight benefit from reduced fluctuations.	Slight benefit; greater area and improved mooring quality.
Modified low fluctuating flows	Slight benefit to boat anglers from higher minimum flows; slight benefit to shore anglers from reduced fluctuations and ramp rates.	None	Moderate benefit; sustained minimum flows of 8,000 cfs and moderate reduction in fluctuations and ramping.	Slight benefit; increase in area over moderate fluctuating flows.
Interim low fluctuating flows	Same as above.	None	Same as above.	Same as above.
Existing monthly volume steady flows	Large benefit; flows closest to those preferred by anglers.	None	Large benefit; flows close to those preferred by river guides and passengers.	Large benefit; improved mooring and increase in number and area over continued historical flows and all fluctuating flow scenarios.
Seasonally adjusted steady flows	Moderate benefit; minimum releases during spring peak higher than preferred flows.	None	Same as above.	Same as above.
Year-round steady flows	Large benefit; flows close to those preferred by anglers.	None	Same as above.	Same as above.

Source: Reclamation (1993).

between 7 a.m. and 7 p.m.), moderate maximum releases (20,000 cfs), and relatively low daily fluctuations (5,000-8,000 cfs) would be available during the summer.

Beneficial impacts to angling activities would be expected under the steady flow operational scenarios. Relatively high minimum flows (8,000 cfs year-round), low upramping rates (2,000 cfs/d), and limited daily fluctuations would create conditions close to those that most anglers prefer.

4.2.7.1.2 White-Water Boating

White-water boaters running the Colorado River from Lees Ferry prefer constant flows with moderate fluctuations, ramping restrictions, and minimum flows of 5,000 cfs (Reclamation 1993). Under such conditions, trip schedules are not threatened, the character of most rapids remains dynamic, and most beach campsites are accessible and provide good mooring for boats and rafts.

Current use levels for white-water boating developed under flow conditions similar to those for the continued historical flow scenario. Thus, a continuation of that scenario should result in no impacts to current use levels or values. The larger fluctuations that would occur under the maximum power plant capacity scenario would result in slight adverse impacts relative to continued historical flows. Under the restricted high fluctuating flow scenario, minimum flows would be 5,000 cfs during the peak season. This flow level would result in a slight benefit to white-water boaters relative to continued historical flows and maximum power plant capacity because these scenarios would have peak season minimum flows of only 3,000 cfs.

Daily releases exceeding 25,000 cfs would submerge certain beaches and result in a decrease in size and number of beach campsites and diminished mooring quality. Such releases would occur most often under scenarios of continued historical flows, maximum power plant capacity, and restricted high fluctuating flows. Usable beach areas would be smallest and mooring quality poorest under the maximum power plant capacity scenario.

Conditions under the moderate fluctuating flow scenario would be slightly improved over scenarios of continued historical flows, maximum power plant capacity, and high fluctuating flows. Mooring quality, as well as area and number of beach campsites, would increase only slightly compared with higher fluctuating flow scenarios. Under the modified low fluctuating flow and interim low fluctuating flow scenarios, conditions for white-water boating would be close to those preferred by river guides and would represent an improvement compared with scenarios of continued historical flows, maximum power plant capacity, and restricted high and moderate fluctuating flows. Beach campsite area would increase slightly compared with the moderate fluctuating flow scenario.

All three steady flow operational scenarios would result in conditions most preferred by white-water boaters. Beach campsite area and number and mooring quality are highest under the steady flow scenarios. However, reduced fluctuations would also result in an

increase in the amount of vegetation on these beaches (see Section 4.2.4.1.3) and a concurrent decrease in their quality as campsites.

4.2.7.2 Flaming Gorge Dam

In the reach immediately below Flaming Gorge Dam, shore anglers tend to prefer flows ranging from 800 to 1,100 cfs (Section 3.7.2.1), and boat anglers tend to prefer flows ranging from 800 to 1,500 cfs, with the upper end of this range considered ideal. The relatively low flows preferred by shore anglers allow them to wade into the river to cast and gives them greater overall access to the river. For boat anglers, low flows mean slower currents and more time to hit "holes" containing fish. Because motorized boats are prohibited between the dam and Browns Park, lower flows give anglers optimal control of their boats.

According to Bishop et al. (1987), anglers prefer constant flows over fluctuating flows. White-water boaters in Dinosaur National Monument were also assumed to prefer constant flows over fluctuating flows. However, they prefer higher flows and can safely operate in flows well above maximum power plant capacity.

The assessment in this EIS focused on flow conditions between dawn and dusk when boat angling, shore angling, and white-water boating would occur. For anglers, flows that were within 100 cfs of preferred flows were considered beneficial, whereas flows that exceeded the upper limit of angler preferences by more than a factor of two were considered adverse. For white-water boaters in Dinosaur National Monument, flows were considered constant as long as fluctuations did not occur between 7 a.m. and 3 p.m. at the Gates of Lodore. A moderate water year was assumed. The assessment of impacts on recreation below Flaming Gorge Dam is summarized in Table 4.33.

4.2.7.2.1 Angling

Current use levels for angling below Flaming Gorge Dam developed under flow conditions in which actual fluctuations were smaller than would occur under the year-round high fluctuating flow scenario. Thus, year-round high fluctuating flows could have some adverse impacts on angling. Seasonal adjustments in flow (e.g., the spring peak in flows from June 1 through 21 and low summer flows) are required by the Biological Opinion to meet the needs of endangered fish species in the lower Green River (USFWS 1992b). Such flow patterns would occur under the seasonally adjusted high fluctuating flow, moderate fluctuating flow, and steady flow scenarios but not under the year-round high fluctuating flow scenario.

Overall, adverse impacts to angling would be greater under the seasonally adjusted high fluctuating flow scenario than under the year-round high fluctuating flow scenario. From April 1 to July 9, the seasonally adjusted high fluctuating flow scenario would result in conditions more adverse for shore and boat anglers. This scenario would have extended

TABLE 4.33 Summary of Impacts to Recreational Activities on the Green River below Flaming Gorge Dam under Moderate Hydrological Conditions

Operational Scenario	Shore Angling	Boat Angling	White-Water Boating	Day Floating
Year-round high fluctuating flows	Slight adverse impact due to larger daily fluctuations.	Slight adverse impact due to larger daily fluctuations.	No impact; current use rates continue.	No impacts attributable to hydropower operations.
Seasonally adjusted high fluctuating flows	Large adverse impact due to high flows from April 1 through July 9; large benefit after July 9. More periods of adverse flows from April 1 to July 9 than under year-round high fluctuating flows.	Large adverse impact due to high flows from April 1 through July 9; moderate benefit in September. More periods of adverse flows from April 1 to July 9 than under year-round high fluctuating flows.	Moderate benefit from high flows in May and June. Minimum flows higher than those under year-round high fluctuating flows.	No impacts attributable to hydropower operations.
Seasonally adjusted moderate fluctuating flows	Slight adverse impact from high minimum flows in April; moderate adverse impact in May; large adverse impact from high flows in June; and moderate benefit after July 9. Overall conditions approximately the same as seasonally adjusted high fluctuating flows.	Large adverse impact from high flows in May and June; moderate benefit in August and September. Overall conditions approximately the same as seasonally adjusted high fluctuating flows.	Moderate benefit; conditions improved because of less fluctuation and higher minimum flows.	No impacts attributable to hydropower operations.
Seasonally adjusted steady flows	Moderate adverse impact from high flows in May and June; moderate benefit from July 10 through October. With no daily fluctuations, conditions moderately improved over seasonally adjusted moderate fluctuating flows.	Moderate adverse impact in May, large adverse impact from high flows in June; moderate benefit from July 10 through September. With no daily fluctuations, conditions moderately improved over seasonally adjusted moderate fluctuating flows.	Moderate benefit; sustained steady flows and high flows during May and June and minimum flows slightly higher than those under seasonally adjusted moderate fluctuating flows. No daily fluctuations.	No impacts attributable to hydropower operations.

periods of constant flows from April 1 to July 9, but most of these flows would be held at 4,700 cfs between dawn and dusk to meet requirements of the Biological Opinion. The 4,700-cfs threshold is far higher than the flows preferred by shore and boat anglers. Consequently, even though constant flows are preferred by anglers, constant flows of 4,700 cfs would be largely adverse rather than beneficial. Before July 9, the only times that anglers would experience flows below 4,700 cfs would be from dawn until 10 a.m. in April and from dawn until 12 p.m. from July 1 through 9.

After July 9, seasonally adjusted high fluctuating flows would result in improved conditions for anglers compared with year-round high fluctuating flows because fluctuations from July 10 to October 31 would be smaller (2,900 to 3,100 cfs) and of shorter duration (two hours). However, more anglers fish between April 1 and June 15 than after July 10. Therefore, the potential benefits to anglers after July 9 might not offset the adverse effects present between April 1 and June 15.

Under the seasonally adjusted moderate fluctuating flow scenario, impacts to angling would be mixed. Overall, impacts would be similar to those associated with the seasonally adjusted high fluctuating flow scenario. Except for June 1 through 21, the moderate fluctuating flow scenario would have fewer sustained flows of 4,700 cfs and a lower range of fluctuations than the high fluctuating flow scenario. However, moderate fluctuations would be achieved by increasing the minimum flows over those occurring under the high fluctuating flow scenarios (from 800 cfs in April and May to 2,400 in April and 2,700 in May). These minimum flows would generate slight to moderate adverse impacts for shore anglers from April through May because they could severely restrict wading and would be well above the upper limit of flows that shore anglers prefer.

Boat anglers would experience better conditions in April and May under the seasonally adjusted moderate fluctuating flow scenario. Although the minimum flows would be above the upper range considered ideal by boating anglers, they would not be high enough to be considered adverse. After July 9, flows associated with the moderate fluctuating flow scenario would be beneficial to all anglers from dawn until 2 p.m. and from 5 p.m. until dusk. Minimum flows after July 9 would slightly improve conditions for boat anglers.

The seasonally adjusted steady flow scenario would also result in mixed impacts compared with year-round high fluctuations. Like the moderate and high fluctuating flow scenarios, the steady flow scenario would generate large adverse impacts for shore anglers during the sustained spring peak in June (4,700 cfs). However, in months before and after this peak, flows would also be relatively high (3,400 cfs in May and 3,700 cfs for the rest of June). Any beneficial aspect of constant flows would be overridden by these high flows, which far exceed those preferred by anglers, particularly shore anglers. Any benefits derived by constant flows for boat anglers would also be canceled out by relatively high flows in May and June. The constant flows of April (2,600 cfs) would create conditions more stable for all anglers than would exist under the seasonally adjusted moderate or high fluctuating flows. Although flows after July 9 would be similar in impact (beneficial for all anglers) to the fluctuating flow scenarios, the steady flow scenario would not result in the daily fluctuations

that would occur under all the fluctuating flow scenarios. Consequently, it would have more beneficial impacts on angling during this period than any of the other scenarios.

4.2.7.2.2 White-Water Boating

The impacts of hydropower operations on white-water boating in Dinosaur National Monument depend on the degree of attenuation affecting daily maximum releases and the timing of their arrival in the monument. Maximum releases of relatively short (two hours) or long (17 hours) duration tend to attenuate more quickly (Section 4.2.3.2.1) than releases of medium duration (e.g., 10 hours). The minimum and maximum flows expected at Gates of Lodore under each scenario are presented in Appendix C. The average travel time for water released from the dam has been estimated at approximately 3 mph for releases of 4,000 cfs and 2.6 mph for releases of 1,000 cfs (Section 3.3.2.1). Thus, it would take a change (i.e., increase or decrease) in flow at the dam approximately 15 to 17 hours to be detectable at the Gates of Lodore. Because dam releases spread out as they travel downstream, the effects of a dam release episode would be detectable at Gates of Lodore for a longer period of time than the duration of the release itself.

The impacts of hydropower operations on flows below the confluence of the Green and Yampa rivers are greatly reduced by flows of the Yampa River, particularly in spring (Appendix C, Table C.8). Current use levels for white-water boating in Dinosaur National Monument developed under flow conditions similar to those that would occur under the year-round high fluctuating flow scenario. Although large fluctuations would occur under this scenario, the timing of fluctuations at Flaming Gorge Dam would result in constant flows through Dinosaur National Monument during daylight hours. Therefore, year-round high fluctuating flows should have no impact on current levels of use.

The seasonally adjusted high fluctuating flow scenario would result in moderately improved conditions for white-water boating compared with year-round high fluctuating flows because it would have longer periods of high sustained flows, higher minimum and maximum flows at Gates of Lodore (Table C.7), and daily fluctuations of less magnitude and shorter duration after July 9. On the basis of travel time estimates, relatively high steady flows would occur from dawn until approximately mid-afternoon in April and May, for the entire day from June 1 through 21 (as required by the Biological Opinion), and from dawn until 5 p.m. for the rest of June. Even though a large fluctuation (4,700 cfs down to 800 cfs at the dam) would occur after 1 p.m. in April, few white-water boaters would be using the river at this time, so no adverse impact would result.

Flows occurring from July 1 through 9 would be similar for both the seasonally adjusted high and the year-round high fluctuating flow scenarios. After July 9, relatively high flows would not occur under the seasonally adjusted high fluctuating flow scenario, and fluctuations at Gates of Lodore would occur at about 6 a.m. and after 9 a.m. However, the magnitude of these fluctuations would be relatively small, usually around 400 cfs (Table C.7). Even though white-water boaters prefer constant flows, these fluctuations would not be considered adverse because their duration is short and their magnitude low. Minimum flows

before and after each daily fluctuation from July 10 through September would be slightly higher compared with year-round high fluctuations.

Conditions for white-water boating would improve slightly under the seasonally adjusted moderate fluctuating flow scenario. Although there would be fewer periods of relatively high flows than under the high fluctuating flow scenarios, minimum flows would be higher under the moderate fluctuating flow scenario, and fluctuations would be less severe than under either high fluctuating flow scenario (Table C.8). After July 9, maximum flows would be lower at Gates of Lodore than under the high fluctuating flow scenarios. Minimum flows at Gates of Lodore would be slightly higher throughout the season under the moderate fluctuating flow scenario. The high constant flows required by the Biological Opinion would provide beneficial impacts during the spring peak (June 1 through 21).

The seasonally adjusted steady flow scenario has the constant flows preferred by white-water boaters. It also has high flows in May and June and the highest minimum flows of any operational scenario. Compared with the other scenarios, the steady flow scenario would appear to result in improved conditions for white-water boating during most months. However, during May and the last nine days of June, there is a trade-off between the benefits of higher flows associated with the seasonally adjusted high and moderate fluctuating flow scenarios and the beneficial effect of constant flows under the seasonally adjusted steady flows scenario.¹²

4.2.7.3 Aspinall Unit

The range of daily fluctuations under the seasonally adjusted high fluctuating flow scenario is slightly larger than under the steady flow scenario, but virtually no adverse impacts to recreational resources or use rates are expected. Daily fluctuations on Blue Mesa Reservoir resulting from hydropower operations would be less than 0.1 ft throughout a moderate water year. Morrow Point Reservoir would experience hydropower-induced daily fluctuations of between 0.3 and 1.5 ft, with the highest daily fluctuations occurring during April, May, August, and September (Table 4.16). Impacts to recreational facilities or use rates would be negligible. Morrow Point has no boat ramps (all boats must be carried in), but none of its potential boaters or shore anglers would be affected by such a slight fluctuation in daily water level. Adequate space would be available for those fishing from shore. The reservoir's campgrounds (Pioneer Point and Hermits Rest) are located above full pool level (elevation 7,160 ft) and would not be affected.

Under the seasonally adjusted high fluctuating flow scenario, water levels would drop below the minimum threshold (elevation 7,147 ft) required for the reservoir's floating dock and pontoon tour boat for part of the day during the month of August. However, overall impacts to users of the tour boat should be negligible. No impacts to recreation would occur

¹² This trade-off accounts for the drop in use values between the seasonally adjusted moderate fluctuating flow and the seasonally adjusted steady flow scenarios, as shown in Table 4.11.

on or along Crystal Reservoir. Like Morrow Point, Crystal Reservoir has no boat ramps, and all boats must be carried in. Although daily fluctuations in water levels could be more extreme (over 8 ft in August and September) at Crystal than at Morrow Point, boaters would not be affected. The reservoir's single campground (Crystal Creek) is located high enough above the full pool threshold to remain unaffected by changing water levels.

Hydropower operations under the seasonally adjusted steady flow operational scenario would result in no adverse impacts to recreational users or facilities on the Aspinall Unit's reservoirs. Steady flows would result in minimum water levels that would not adversely affect the boat dock or tour boat on Morrow Point Reservoir.

4.2.8 Visual Resources

In riverine environments, the relationship between scenic value and stream flow is not well understood. In general, a river and its environs has the least scenic value at both flood tide and lowest flows. At flood stage, features such as riffles, small rapids, beaches, bars, and islands are submerged. At very low flows, certain unattractive visual elements — such as debris, mud flats, rotting vegetation, and the "bathtub ring"¹³ that stains rock surfaces — can be exposed. Brown and Daniel (1991) recently examined the relationship between scenic value and flow and concluded that perception of the scenic value of a river increases with increased flow to a point but then decreases with further increases in flows; also, frequent visitors to a particular river corridor prefer a variety of flows across successive visits. Landform and vegetation are two of the visual elements most likely to be affected by releases from the dams examined in this EIS.

The impact analysis for visual resources in the affected areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Section 3.8) relied on subjective criteria. The conclusions were not empirically based. The analysis included several assumptions concerning viewers, viewing times, and viewing zones. Because a vast majority of viewers (recreationists) are present between March 15 and October 31, winter months were not included in the discussion of impacts. Viewing times were assumed to be from 7 a.m. to 7 p.m. daily.¹⁴ Only foreground and middle-ground viewing zones were included in the analysis. Dam operations are not expected to impact views from points beyond the outer edge of the middle-ground viewing zone. The foreground zone contains the beaches and shore vegetation and would contain most of the viewers. Middle-ground viewing zones contain many of the road and trail viewpoints.

¹³ Although a "bathtub ring" effect can be visible at most sustained flows, it is most pronounced at the lowest flows.

¹⁴ Although complete darkness does not set in until close to 10 p.m. during early summer, most users of the rivers and reservoirs examined in this EIS typically leave the environs of the water by 7 p.m.

4.2.8.1 Glen Canyon Dam

The Colorado River provides high-quality landscapes at any flow and from all viewing proximity zones. Each operational scenario has the potential to change the visual character of the river, but such changes have positive aspects that balance out potentially negative impacts. For example, under steady flow operational scenarios, the areal extent and number of white-water effects could decrease and a bathtub ring would be visible, but the size of the areas supporting riparian vegetation would be expected to increase (Section 4.2.4.1). A positive visual impact could result because increased amounts of vegetation would add color and contrast to existing inner-canyon landscapes. Under fluctuating flow operational scenarios, a wider range of river effects (rapids) and shoreline landscapes would be available for viewers, and any effects that would diminish visual quality (e.g., inundated beaches, bathtub ring, submerged geologic features) would be temporary.

Views of the river from the mesas above Glen Canyon Dam or from the rims of the Grand Canyon would not be affected by flows associated with any of the operational scenarios. Distances from the viewer to the river are too great, and the surrounding landscapes offer high visual diversity.

4.2.8.2 Flaming Gorge Dam

Under the year-round high fluctuating flow operational scenario, low flows (less than 1,100 cfs) that result in exposed debris and a prominent bathtub ring would occur for most of the viewing day during spring and summer. However, these low flows would also result in visually diverse views that include numerous beach areas, islands, bars, and riffles. Existing riparian vegetation would not be adversely affected. No change in status would occur on the stretches of the Green River that are classified under the USFS and BLM visual resource management systems (Section 3.8.2). Overall, impacts are expected to be negligible.

The seasonally adjusted high fluctuating flow operational scenario would generate flows below 1,100 cfs less often than the year-round high fluctuating flow scenario. High flows (4,700 cfs) would be maintained continuously for several days during June. The seasonally adjusted high fluctuating flow scenario would also have longer daily periods of sustained high flows between March and early July than the year-round high fluctuating flow operational scenario. These higher sustained flows would result in conflicting visual impacts; although the visible debris and bathtub ring effects would be reduced, the high flows would also tend to submerge some of the beach areas, riffles, and small rapids for most of the viewing day between April 1 and July 1. The seasonally adjusted high fluctuating flow operational scenario would result in some changes in riparian vegetation but in no net loss (Section 4.2.4.2). Overall, impacts are expected to be negligible.

The relatively high minimum releases of the seasonally adjusted moderate fluctuating flow operational scenario would result in impacts to riparian vegetation and in less bathtub ring effects than the year-round high fluctuating flow scenario. Between March 1 and July 10, unattractive visual effects associated with the lowest flows would be

absent because minimum flows would never fall below 1,100 cfs. No vegetation would grow in the zone between flows of 2,700 and 800 cfs (Section 4.2.4.2). This barren strip would be most visible from July 10 through 31 and throughout October, when minimum flows would be 1,000 and 800 cfs, respectively. However, because this strip would add more visual diversity than either of the high fluctuation scenarios, it would not be considered an adverse impact. No adverse impacts are anticipated under this operational scenario.

The seasonally adjusted steady flow scenario would result in more consistent daily viewing than any of the fluctuating flow scenarios. Views would change from month to month during the season and during June and July. The greatest visual diversity would occur from the spring peak (June 1 through 21) to the middle of July. During this period, flows would drop from 4,700 cfs on June 21 to 3,700 cfs on June 22 to 2,100 cfs on July 1 and 1,100 cfs on July 10. The steady flow operational scenario would have the highest minimum flows of any scenario, and higher minimum flows would reduce unattractive debris effects. Overall, no adverse impacts are anticipated.

4.2.8.3 Aspinall Unit

The aesthetic values of the Aspinall reservoirs vary with lake levels. Because the Morrow Point and Crystal reservoirs are deep, narrow, and long, they are less susceptible to changes in visual quality resulting from rising or dropping water levels than are larger and wider lakes such as Blue Mesa Reservoir.

No adverse impacts to visual resources on Blue Mesa Reservoir would occur under either operational scenario. Although water levels on the reservoir could vary considerably, little of the change would be attributable to operational scenarios. The resulting barren shoreline would be relatively small in area and would blend in with the existing landscape. A bathtub ring would be visible when the reservoir level dropped below full pool, but it would not be a prominent visual element. Consequently, views in the foreground and middle-ground proximity zones would not be adversely affected.

No impacts to visual resources on Morrow Point or Crystal reservoirs would be expected under either operational scenario. Although daily fluctuations attributable to hydropower operations could reach 1.5 ft on Morrow Point Reservoir and more than 8 ft on Crystal Reservoir, the surrounding area's uniform topography (canyon walls) and relatively sparse vegetation limit visual diversity for those standing in the foreground viewing zone. Although a bathtub ring would be visible in the foreground zone of both reservoirs, it would not drastically detract from the overall view because most of the surrounding rock and canyon walls are dark and provide little visual contrast. The impacts to views from the middle-ground zone would be negligible.

4.3 SUMMARY OF IMPACTS OF COMMITMENT-LEVEL ALTERNATIVES AND HYDROPOWER OPERATIONAL SCENARIOS

This section summarizes the potential impacts of the commitment-level alternatives and hydropower operational scenarios addressed in this EIS.

4.3.1 Commitment-Level Alternatives

Table 4.34 presents a detailed summary of the estimated impacts that each of the commitment-level alternatives would have on various socioeconomic variables, air resources, and other natural and cultural resources. Impacts are further disaggregated on the basis of the various supply options that were assumed as part of the analysis. These supply options were defined as follows:

- *Supply Option A:* Continuation of historical operations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit;
- *Supply Option B:* Low fluctuations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit;
- *Supply Option C:* Seasonally adjusted steady flows at Glen Canyon, Flaming Gorge, and the Aspinall Unit.

Table 4.34 indicates that the largest economic impacts would be on retail rates paid by the end-users served by Western's utility customers. The financial condition of some of Western's customers might also be impacted. Under the combination of commitment-level alternative 4 and supply option C, less than 12% of the utilities included in the financial analysis would experience a decrease in financial viability. All of the other alternatives and operational scenarios would result in smaller impacts on financial viability. As indicated in Table 4.34, the predicted impacts on regional socioeconomic variables — population, employment, disposable income, and gross regional product — are not statistically different from zero. Consequently, those factors are not considered further here. For similar reasons, impacts on air resources, noise, conservation and renewable energy programs (consumption efficiency and load management), and agricultural production are not considered further.

The no-action alternative combined with supply options B and C illustrates the effects that restrictions on hydropower operations would have on the costs of electricity in the affected regions. Moving from supply option A to supply option C, rates tend to increase. This result reflects, in part, the fact that under supply option C, Western would be unable to take advantage of the rate differential that arises in the case of spot market sales. As such, the rates Western charged its long-term firm customers would have to be increased to ensure that Western could meet its repayment obligation. Under supply option C and the

TABLE 4.34 Relative Impacts of the Commitment-Level Alternatives

Commitment-Level Alternative/Supply Option	Financial Viability	Retail Rates	Regional Impacts/ Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
No action					
A	No impacts on financial viability.	No impacts on retail rates.	No impacts on regional economic variables or agricultural production.	No impacts on local or regional air quality or noise.	Dependent on specific operational scenarios corresponding to this supply option; see Tables 4.35 through 4.37 and accompanying text.
B	Two additional utilities (one low reliance and one high reliance) with CR < 1.1.	Weighted average increase of 1%; changes ranging from 0% in all states to 6% in New Mexico.	No statistically significant impacts on regional economic variables; minimal impacts on agricultural production.	Same as above.	Same as above.
C	Four additional utilities (one low reliance and three high reliance) with CR < 1.1.	Weighted average increase of 8%; changes ranging from 0% in New Mexico to 13% in New Mexico.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 1					
A	No impacts on financial viability.	Weighted average increase of 1%; changes ranging from -12% in Utah to 1% in Arizona.	Same as above.	Same as above.	Same as above.
B	No impacts on financial viability.	Weighted average increase of 3%; changes ranging from -11% in Utah to 6% in New Mexico.	Same as above.	Same as above.	Same as above.
C	No impacts on financial viability.	Weighted average increase of 5%; changes ranging from -7% in Utah to 11% in Arizona.	Same as above.	Same as above.	Same as above.

TABLE 4.34 (Cont.)

Commitment-Level Alternative/Supply Option	Financial Viability	Retail Rates	Regional Impacts/ Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
Commitment-level alternative 2					
A	Three additional utilities (two low reliance and one high reliance) with CR < 1.1.	Weighted average increase of 1%; changes ranging from -8% in Wyoming to 12% in Utah.	Same as above.	Same as above.	Same as above.
B	Same as supply option A.	Weighted average increase of 3%; changes ranging from -2% in Nevada and Utah to 15% in Utah.	Same as above.	Same as above.	Same as above.
C	Four additional utilities (two low reliance and two high reliance) with CR < 1.1.	Weighted average increase of 6%; changes ranging from -6% in Wyoming to 18% in Utah.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 3					
A	Two additional utilities (one low reliance and one high reliance) with CR < 1.1.	Weighted average increase of 3%; changes ranging from -5% in Wyoming to 12% in Utah.	Same as above.	Same as above.	Same as above.
B	Same as supply option A.	Weighted average increase of 5%; changes ranging from -1% in Colorado to 14% in Utah.	Same as above.	Same as above.	Same as above.
C	Three additional utilities (one low reliance and two high reliance) with CR < 1.1.	Weighted average increase of 8%; changes ranging from -3% in Wyoming to 19% in Utah.	Same as above.	Same as above.	Same as above.

TABLE 4.34 (Cont.)

Commitment-Level Alternative/Supply Option	Financial Viability	Retail Rates	Regional Impacts/ Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
Commitment-level alternative 4					
A	Five additional utilities (two low reliance and three high reliance) with CR < 1.1.	Weighted average increase of 13%; changes ranging from -2% in Wyoming to 30% in Utah.	Same as above.	Same as above.	Same as above.
B	Same as supply option A.	Weighted average increase of 14%; changes ranging from -3% in Wyoming to 32% in Utah.	Same as above.	Same as above.	Same as above.
C	Same as supply option A.	Weighted average increase of 15%; changes ranging from 0% in Arizona, New Mexico, and Wyoming to 41% in Utah.	Same as above.	Same as above.	Same as above.
Commitment-level alternative 5					
A	Three additional utilities (one low reliance and two high reliance) with CR < 1.1.	Weighted average increase of 10%; changes ranging from -5% in Wyoming to 26% in Utah.	Same as above.	Same as above.	Same as above.
B	Four additional utilities (one low reliance and three high reliance) with CR < 1.1.	Weighted average increase of 12%; changes ranging from -8% in Wyoming to 28% in Utah.	Same as above.	Same as above.	Same as above.
C	Five additional utilities (two low reliance and three high reliance) with CR < 1.1.	Weighted average increase of 15%; changes ranging from -1% in Arizona to 31% in Utah.	Same as above.	Same as above.	Same as above.

TABLE 4.34 (Cont.)

Commitment-Level Alternative/Supply Option	Financial Viability	Retail Rates	Regional Impacts/ Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
Commitment-level alternative 6					
A	Two additional utilities (one low reliance and one high reliance) with CR < 1.1.	Weighted average increase of 4%; changes ranging from -3% in Wyoming to 13% in New Mexico.	Same as above.	Same as above.	Same as above.
B	Same as supply option A.	Weighted average increase of 5%; changes ranging from -3% in Wyoming to 16% in New Mexico.	Same as above.	Same as above.	Same as above.
C	Three additional utilities (one low reliance and two high reliance) with CR < 1.1.	Weighted average increase of 10%; changes ranging from -2% in Wyoming to 19% in New Mexico.	Same as above.	Same as above.	Same as above.

no-action alternative, the average rate charged by Western's utility customers would increase 8%. In addition, supply option C would result in a moderate increase in the number of utilities with a coverage ratio of less than 1.1. However, the number of utilities with a coverage ratio of at least 2.0 would remain unchanged under both supply options B and C.

The combination of commitment-level alternative 1 and supply option A would leave retail rates relatively unchanged. In some cases, such as for high-reliance municipal utilities in Utah, rates are predicted to decline by a moderate amount. In other cases, rates would decrease slightly, remain unchanged, or increase by a very slight amount. Under supply option B, rates would decrease slightly or increase by a small amount. However, as in the case of supply option A, the overall impact would be slight. Supply option C would result in the largest impacts, as illustrated in Table 4.4. The financial viability of Western's utility customers would be unaffected by the combination of commitment-level alternative 1 and any of the three supply options.

All of the other alternative/supply option combinations would result in retail rate and financial viability impacts of varying amounts. Overall, rate increases would be largest under commitment-level alternative 4 combined with supply option C. In this case, customers of high-reliance municipals in Utah would see their rates increase by an estimated 41%, while customers of high-reliance cooperatives in Utah would see their rates rise by 32%. These changes represent significant increases in the amount paid for electrical energy by these customers. Customers of high-reliance cooperatives in New Mexico would also experience a significant increase in rates relative to the baseline; it is predicted that rates would increase by 28%. This alternative would also result in the largest number of firms (five) experiencing a decline in financial viability. Alternative 5 would result in similar impacts on rates and financial viability. The largest rate increases would occur in Utah and New Mexico, where rates would be expected to increase by 31% and 23% under supply option C. Financial viability impacts under alternative/option combination 5C would be comparable to those under combinations 4A, 4B, and 4C, while impacts associated with combinations 5A and 5B would be somewhat smaller.

Commitment-level alternatives 2 and 3 would have comparable impacts on retail rates and the financial viability of affected utilities. Impacts are predicted to be slightly larger under alternative 3, but the distribution of impacts across states and utility categories would be generally similar to the largest rate impacts occurring in Utah under both alternatives. Rate and financial impacts associated with alternative 6 would be generally comparable to those occurring under alternatives 2 and 3. Once again, the largest impacts would occur under supply option C. However, the largest rate impacts would occur in New Mexico.

Overall, high-reliance utilities in Utah and New Mexico would experience the largest rate impacts under each of the commitment-level alternatives. This result reflects the fact that a large share of the power these utilities sell comes from Western. As such, changes in the rate Western charged for its power would have a larger absolute impact on the rates charged by these utilities to their end-users.

The impacts of commitment-level alternatives to water resources, ecological resources, cultural resources, land use, recreation, and visual resources are dependent on the operational scenarios implemented at the hydropower facilities under consideration in this EIS. In addition to the direct impacts of hydropower operations, indirect impacts could result from fulfilling the need for additional generating capacity under each commitment-level alternative. This need for additional capacity could be met by building new power plants, expanding existing ones, or by other methods. Construction and operation of power plants to meet additional capacity needs could result in additional impacts to natural and cultural resources in the vicinities of any new or expanded facilities. A detailed assessment of specific impacts is not presented here because the significance and nature of any such impacts would depend on the specific plans and locations for the new expanded facilities — information that is not available at this time.

4.3.2 Hydropower Operational Scenarios

This section summarizes the impacts to natural and cultural resources that would occur under the various hydropower operational scenarios considered for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Each facility is considered separately to emphasize the differences among operational scenarios at the individual facilities.

To determine the impacts to socioeconomics and air resources associated with a specific operational scenario, it is necessary to specify both an operational scenario and a commitment-level alternative (Section 4.1). In the assessment of socioeconomic and air resource impacts, commitment-level alternatives were paired with specific supply options that consisted of combinations of operational scenarios at each of the three hydropower facilities.

On the basis of an analysis conducted by Palmer and Ancrile (1993), the socio-economic and air resource impacts projected for the supply options capture the full range of impacts that could occur for any possible combination of operational scenarios. The impacts of any combination of operational scenarios that included a continuation of historical operations, maximum power plant capacity, or restricted high fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts identified for supply option A. The impacts of any combination that included moderate fluctuations or low fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts of supply option B. Finally, the impacts of any combination consisting of seasonally adjusted steady flows, existing monthly steady flows, or year-round steady flows at Glen Canyon Dam; any one of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts of supply option C. The impacts of these supply options on socioeconomics and air resources are summarized in Section 4.3.1.

4.3.2.1 Glen Canyon Dam

Table 4.35 summarizes impacts to natural and cultural resources in and along the Colorado River downstream of Glen Canyon Dam.

Continuation of historical operations and maximum power plant capacity operational scenarios would have impacts on most natural resources similar to those that have occurred since the dam was completed in 1963 and that have determined existing conditions for water resources, ecological resources, and recreational activities (as described in Sections 3.3.1, 3.4.1, and 3.7.1). Impacts identified for these scenarios include impacts to cultural resources, riparian vegetation, humpback chub, and recreation.

Restricted high fluctuations could result in moderate reductions in erosion rates and slight benefits to most ecological resources and to recreation. For this scenario, slight adverse impacts were identified for the humpback chub. Adverse impacts could also occur to cultural resources because of erosion.

Moderate and low fluctuation operational scenarios could produce benefits for water resources (substantially reduced erosion rates), terrestrial ecology (moderate increases in woody riparian vegetation), cultural resources, and white-water boating. These operational scenarios could result in slight benefits for aquatic ecology (trout and native fish), some endangered species (bald eagle, peregrine falcon, and southwestern willow flycatcher), and angling. Slight adverse impacts could occur to the humpback chub.

Although steady flow scenarios could result in benefits to a number of resources, any benefits would require the proposed occasional high flows to build beaches and maintain fish habitats. Benefits could occur for water resources (reduced erosion rates), aquatic ecology (trout and native fish), terrestrial ecology (large increase in woody riparian vegetation), endangered species (humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher), cultural resources, and recreation (angling and white-water boating).

4.3.2.2 Flaming Gorge Dam

Table 4.36 summarizes impacts to natural and cultural resources in and along the Green River downstream of Flaming Gorge Dam.

The year-round high fluctuation operational scenario features maximum flows and daily flow fluctuations that are slightly higher than historical operations. Consequently, this scenario could result in adverse impacts to native and endangered fish, trout, woody riparian vegetation, and cultural resources.

The remaining three operational scenarios are seasonally adjusted; that is, they feature shifts in monthly volumes to meet requirements of the USFWS Biological Opinion (USFWS 1992b). All of these scenarios exhibit a high sustained flow in May or June, reduced fluctuations and lower flows in summer and autumn, and steady flows when an ice cover is

TABLE 4.35 Summary of Impacts of Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam

Operational Scenario	Water Resources		Ecological Resources	
	Flow and Stage	Sediment	Aquatic Ecology	Terrestrial Ecology
Continuation of historical flows	No change from current conditions; large daily changes in flow and stage.	No change from current conditions.	No change from current conditions.	No impact to existing vegetation.
Maximum power plant capacity	Slight impact; slightly larger daily changes in flow and stage.	Same as above.	Same as above.	Slight adverse impact; slight decrease in woody riparian vegetation; slight increase in marsh vegetation.
Restricted high fluctuating flows	Moderate impact; large (but reduced from historical) daily changes in flow and stage.	Moderate benefit; decreased sediment load and erosion rate.	Slight benefit; improved spawning conditions for trout; improved nursery habitat for native fish; larger food base.	No impact to existing vegetation.
Moderate fluctuating flows	Large impact; moderate daily changes in flow and stage.	Large benefit; decreased sediment load and erosion rate.	Slight benefit; spawning and nursery conditions and food base improved slightly over restricted high fluctuating flows.	Moderate benefit; moderate increase in woody riparian vegetation; decrease in marsh vegetation.
Modified low fluctuating flows	Large impact; daily fluctuations in flow and stage less than under moderate fluctuation.	Same as above.	Slight to moderate benefit; spawning and nursery conditions and food base improved over moderate fluctuations.	Same as above.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.	Same as above.
Existing monthly steady flows	Large impact; monthly volumes the same as current, but no daily fluctuations in flow or stage.	Same as above.	Moderate benefit; spawning and nursery conditions and food base better than for any of the fluctuating flow scenarios.	Large benefit; large increase in woody riparian vegetation; decrease in marsh vegetation.

TABLE 4.35 (Cont.)

Operational Scenario	Water Resources		Ecological Resources	
	Flow and Stage	Sediment	Aquatic Ecology	Terrestrial Ecology
Seasonally adjusted steady flows	Large impact; monthly volumes shifted seasonally; no daily fluctuations in flow or stage.	Same as above.	Moderate benefit; improvements in spawning and nursery conditions and food base may be greater than for existing monthly steady flows.	Same as above.
Year-round steady flows	Large impact; no monthly or daily fluctuations in flow or stage.	Same as above.	Moderate benefit; improvements in spawning and nursery conditions and food base may be greater than seasonally adjusted steady flows.	Same as above.
<hr/>				
Operational Scenario	Ecological Resources (Cont.)			
	Federally Listed Threatened and Endangered Species	Cultural Resources ^a	Recreation ^b	Land Use and Visual Resources
Continuation of historical flows	Slight adverse impact to humpback chub.	Adverse impact because of high erosion rate.	No impact.	No impact.
Maximum power plant capacity	Slight adverse impact to humpback chub and southwestern willow flycatcher.	Same as above.	Slight adverse impact to angling and white-water boating.	No impact.
Restricted high fluctuating flows	Slight adverse impact to humpback chub.	Same as above.	Slight benefit to angling and white-water boating.	No impact.
Moderate fluctuating flows	Slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; slight adverse impact to humpback chub.	Benefit because of lower erosion rates.	Same as above.	No impact.

TABLE 4.35 (Cont.)

Operational Scenario	Ecological Resources (Cont.)			
	Federally Listed Threatened and Endangered Species	Cultural Resources ^a	Recreation ^b	Land Use and Visual Resources
Modified low fluctuating flows	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher.	Same as above.	Moderate benefit to white-water boating; slight benefit to angling.	No impact.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.	No impact.
Existing monthly steady flows	Same as above.	Same as above.	Large benefit to angling and white-water boating.	No impact.
Seasonally adjusted steady flows	Slight to moderate benefit to humpback chub; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher.	Same as above.	Large benefit to white-water boating; moderate benefit to angling.	No impact.
Year-round steady flows	Slight benefit to humpback chub; slight benefit to peregrine falcon and bald eagle; moderate benefit to southwestern willow flycatcher.	Same as above.	Large benefit to angling and white-water boating.	No impact.

^a Archaeological, historical, and Native American resources.

^b Angling and white-water boating.

TABLE 4.36 Summary of Impacts of Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam

Operational Scenario	Water Resources		Ecological Resources	
	Flow and Stage	Sediment	Aquatic Ecology	Terrestrial Ecology
Year-round high fluctuating flows	Slight impact; seasonal patterns of release unchanged; maximum daily release would be increased to 4,700 cfs from 4,200 cfs; minor increase in stage fluctuation.	Slight impact; increased erosion rate.	Slight to moderate adverse impact to trout and native fish; lower quality backwaters; reduced growth rate, condition, and overwinter survival for trout.	Slight adverse impact; decrease in woody riparian vegetation; increase in marsh vegetation.
Seasonally adjusted high fluctuating flows	Moderate impact; seasonal patterns of release changed; large daily fluctuations in flow and stage during some portions of year.	Same as above.	Slight to moderate benefit to native fish due to improved nursery conditions; slight to moderate adverse impact to trout as stated above.	Slight adverse impact; decrease in woody riparian vegetation; increase in marsh vegetation; waterfowl foraging areas freeze earlier in winter.
Seasonally adjusted moderate fluctuating flows	Moderate impact; seasonal patterns of release changed; moderate daily fluctuations in flow and stage during some portions of the year.	Slight benefit; reduced erosion.	Moderate benefit to native fish due to improved nursery conditions; slight benefit to trout due to improved food supply and spawning conditions.	Slight adverse impact; decrease in woody riparian vegetation and marsh vegetation; waterfowl foraging areas freeze earlier in winter.
Seasonally adjusted steady flows	Large impact; seasonal patterns of release changed; no within-season daily fluctuation in flow or stage.	Same as above.	Moderate to large benefit to native fish due to improved nursery conditions; slight benefit to trout.	Slight benefit; moderate increase in woody riparian vegetation; decrease in marsh vegetation; waterfowl foraging areas freeze earlier in winter.

TABLE 4.36 (Cont.)

Operational Scenario	Ecological Resources (Cont.)			
	Federally Listed Threatened and Endangered Species	Cultural Resources ^a	Recreation	Land Use and Visual Resources
Year-round high fluctuating flows	Slight to moderate adverse impacts to humpback chub, bonytail chub, Colorado squawfish, and razorback sucker; reduction in backwater quality.	Adverse impact because of high erosion rate.	Slight adverse impact on angling; no impact on white-water boating.	No impact.
Seasonally adjusted high fluctuating flows	Slight to moderate benefit to humpback chub, bonytail chub, Colorado squawfish, and razorback sucker; moderate adverse impact to bald eagle.	Same as above.	Large adverse impact to angling in spring and early summer; large benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.	No impact.
Seasonally adjusted moderate fluctuating flows	Slight to moderate benefit to humpback chub, bonytail chub, Colorado squawfish, and razorback sucker; slight adverse impact to Ute ladies-tresses; moderate adverse impact to bald eagle.	Moderate benefit because of reduced erosion rate.	Moderate to large adverse impact to angling in spring and early summer; moderate benefit to angling from mid-summer to fall; moderate benefit to white-water boating in spring and early summer.	No impact.
Seasonally adjusted steady flows	Moderate to large benefit to humpback chub, bonytail chub, and Colorado squawfish; slight to moderate benefit to razorback sucker; slight benefit to peregrine falcon; moderate adverse impact to Ute ladies-tresses and bald eagle.	Same as above.	Same as above.	No impact.

^a Archaeological, historical, and Native American resources.

present on the river (February and March). These flow patterns are intended to be protective of endangered fish in the system and could result in benefits to these species, as well as other resources. Some adverse impacts could result from this seasonal adjustment, however. The spring peak in flows would result in large adverse impacts to anglers. In addition, the bald eagle and waterfowl could be adversely affected by steady flows in February and March. With steady flows, less open ice-free water would be available for these species.

Seasonally adjusted high fluctuations would have moderate effects on flow and stage, but would have erosion rates similar to year-round high fluctuations. Slight to moderate benefits are expected to native fish (including the endangered humpback chub, bonytail chub, razorback sucker, and Colorado squawfish) because of improved nursery habitat conditions, but fluctuations could adversely affect trout. This scenario would result in large benefits to angling from mid-summer through autumn (when lower flows are maintained) and moderate benefits to white-water boating during the spring peak. Slight adverse impacts are expected to terrestrial ecology because of the inundation of some woody riparian vegetation. Because erosion rates would be similar to the year-round high fluctuation scenario, cultural resources could be adversely affected by this operational scenario.

Seasonally adjusted moderate and steady flows are relatively similar in their projected impacts to most natural and cultural resources. Both scenarios would have moderately reduced erosion rates and thus would benefit water and cultural resources. Slight benefits to trout and moderate to large benefits to native and endangered fish, angling, and white-water boating are also expected under these scenarios because of reduced daily fluctuations. Slight to moderate adverse impacts to the threatened Ute ladies-tresses could occur if these scenarios resulted in lower soil moisture levels in the alluvial meadows where the plant species occurs.

Slight adverse impacts under seasonally adjusted moderate fluctuations are expected to terrestrial resources because decreases in woody riparian and marsh vegetation could occur. The steady flow scenario would result in benefits to terrestrial resources by allowing a moderate increase in woody riparian vegetation.

4.3.2.3 Aspinall Unit

Table 4.37 summarizes impacts to natural and cultural resources in the vicinity of the Aspinall Unit. Because Crystal Dam reregulates flows from the Aspinall Unit, flows in the Gunnison River below the unit and the resources dependent on those flows would not be affected by hydropower operations.

Slight to moderate impacts to flow and stage in Blue Mesa and Morrow Point reservoirs would occur because of seasonal adjustments in releases and daily fluctuations. Despite this, neither operational scenario is expected to result in impacts to sediment, most ecological resources (aquatic ecology, threatened and endangered species), cultural resources, recreation, land use, or visual resources. Both scenarios could result in slight benefits to

TABLE 4.37 Summary of Impacts of Operational Scenarios on Natural and Cultural Resources in the Vicinity of the Aspinall Unit

Operational Scenario	Water Resources		Ecological Resources	
	Flow and Stage	Sediment	Aquatic Ecology	Terrestrial Ecology
Seasonally adjusted high fluctuating flows				
Blue Mesa Reservoir	Slight impact; daily fluctuations similar to historical but monthly release volumes changed.	No impact.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	No impact.	No impact.	No impact.
Crystal Reservoir	Same as above.	No impact.	No impact.	Slight benefit; slight increase in woody riparian vegetation; slight decrease in marsh vegetation.
Seasonally adjusted steady flows				
Blue Mesa Reservoir	Large impact; daily fluctuations eliminated; monthly release volumes changed.	No impact.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	No impact.	No impact.	No impact.
Crystal Reservoir	Same as above.	No impact.	No impact.	Slight benefit; slight increase in woody riparian vegetation; slight decrease in marsh vegetation; changes slightly greater than for high fluctuations.

TABLE 4.37 (Cont.)

Operational Scenario	Ecological Resources (Cont.)			
	Federally Listed Threatened and Endangered Species	Cultural Resources ^a	Recreation ^b	Land Use and Visual Resources
Seasonally adjusted high fluctuating flows				
Blue Mesa Reservoir	No impact.	No impact.	No impact.	No impact.
Morrow Point Reservoir	No impact.	No impact.	No impact.	No impact.
Crystal Reservoir	No impact.	No impact.	No impact.	No impact.
Seasonally adjusted steady flows				
Blue Mesa Reservoir	Slight adverse impact to bald eagle because reservoir freezes earlier in winter.	No impact.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	No impact.	No impact.	No impact.
Crystal Reservoir	Same as above.	No impact.	No impact.	No impact.

^a Archaeological, historical, and Native American resources.

^b Angling and boating.

terrestrial resources in the headwaters of Crystal Reservoir because of an increase in woody riparian vegetation. Slight adverse impacts to the bald eagle are expected under the seasonally adjusted steady flow scenario because the reservoirs would freeze earlier in the winter with reduced fluctuations.

4.4 MITIGATION AND MONITORING

A number of potential mitigation and monitoring activities have been identified that could be implemented in conjunction with any of the commitment-level alternatives or hydropower operational scenarios considered in this EIS. The following is a brief description and explanation of each of these activities.

4.4.1 Potential Mitigation for Commitment-Level Alternatives

Potential mitigation for the commitment-level alternatives includes:

- *Phase in commitment-level changes:* Implementation of this mitigation depends on the extent to which Western could phase in a commitment-level change over time. A change could consist of either a decrease or an increase in long-term firm capacity. In the case of an increase, Western would add allocations of power as it acquired new resources through uprates, new construction of generating facilities, purchases, and other means.
- *Establish financial exception criteria for the operations of Glen Canyon and Flaming Gorge:* Emergency exception criteria, which allow normal operating parameters to be exceeded under emergency conditions, are part of both the Glen Canyon Dam EIS alternatives and the Flaming Gorge operational scenarios. At times, spot-market prices for electrical energy purchased by Western are exorbitantly high. If normal operating parameters were allowed to be exceeded during these temporary conditions, Western would be able to avoid a large portion of its purchased power expenses. Adding operational exception criteria for financial reasons would not change the operation of these facilities significantly, but could mitigate the loss of marketable capacity for any restrictions in power plant operation.
- *Possible use of the Collbran, Seedskedee, and the Rio Grande Projects to meet peak load requirements.* As previously stated (Chapter 2), Western currently has no material influence on the operation of the hydropower facilities at the Collbran Project (Upper and Lower Molina dams), the Seedskedee Project (Fontenelle Dam), and the Rio Grande Project (Elephant Butte Dam). Western, in evaluating options to meet alternative electrical power peaking requirements of the SLCA/IP system,

would investigate modified use of these facilities. Anticipated use of these facilities for this purpose would be within current operating limits and operational constraints. Western and Reclamation are currently conducting feasibility testing of potential modifications to the generating resource at the Collbran Project. Western may also explore the potential peaking resource at the Rio Grande and Seedskedee projects. In so doing, it will comply with NEPA pursuant to 10 CFR Part 1021.

4.4.2 Potential Mitigation for Hydropower Operational Scenarios

Potential mitigation for hydropower operational scenarios includes:

- *Protect cultural and historic resource sites determined eligible for the NRHP that are at risk of accelerated erosion or perform data recovery where protection is not practical.*
- *Continue studies that could lead to further changes in the operations of SLCA/IP hydropower facilities:* Adaptive management has been built into each of the Glen Canyon Dam EIS alternatives. Five years of additional studies related to endangered fish species are planned for Flaming Gorge. Those studies are conceptually similar to adaptive management practices. Operations would be modified to reduce impacts on the basis of these studies or to restore flexibility at hydropower facilities where such changes do not affect the environment.
- *Implement beach/habitat building flows at Glen Canyon and Flaming Gorge:* Beach/habitat building flows are part of the Glen Canyon Dam EIS alternatives. Spring peak flows at Flaming Gorge Dam under the Biological Opinion are similar to the beach/habitat building flows at Glen Canyon Dam and serve the purpose of preparing backwater habitats for endangered fish species and depositing sediments at higher elevations.
- *Add a new population of humpback chub in the Grand Canyon and continue actions to recover endangered fish species in the Upper Colorado River Basin:* Participation in activities to establish a new humpback chub population is part of the Glen Canyon Dam EIS alternatives. Moreover, Western and Reclamation are participants in the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River. The goal of this program is to fully recover endangered fish species in the upper basin.

- *Continue the study of a selective withdrawal apparatus for the Glen Canyon Dam:* Increased temperatures in the main stem of the Colorado River in the Grand Canyon may improve habitat for endangered and threatened fish. This continued study is part of the Glen Canyon Dam EIS alternatives.

4.4.3 Potential Monitoring

Potential monitoring activities include:

- Annual surveys of backwaters to determine the abundance of introduced fish in these habitats below Glen Canyon and Flaming Gorge dams and the influence of dam operations on population levels,
- Annual monitoring of cultural resource sites at risk of erosion below Glen Canyon dam, and
- Annual surveys of Ute ladies-tresses populations in riparian areas along the Green River below Flaming Gorge Dam to determine the influence of operations on the soil moisture levels needed to sustain the population.

5 CUMULATIVE IMPACTS OF COMMITMENT-LEVEL ALTERNATIVES AND OPERATIONAL SCENARIOS

Cumulative impact, as defined by the Council on Environmental Quality (40 CFR 1508.7), is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." This section discusses potential cumulative impacts of the commitment-level alternatives for the SLCA/IP and the hydropower operational scenarios for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit.

As discussed below, commitment-level alternatives have the potential to contribute directly to cumulative impacts on regional socioeconomics and air quality, as well as indirectly (through required capacity expansion) on water, ecological, cultural, land use, recreation, and visual resources. Hydropower operations also have the potential to contribute to cumulative impacts to this latter group of resources. The fact that the three hydropower facilities under consideration are all within the Colorado River Basin increases the potential for cumulative impacts to resources that are affected by hydropower operations. In addition, other SLCA/IP hydropower facilities within the basin could contribute to cumulative impacts by altering the hydrology of the basin and affecting the resources dependent on this hydrology.

Past actions relevant to the cumulative impacts of commitment-level alternatives and hydropower operations include the construction and operation of existing hydropower facilities and thermal power plants, as well as development activities (e.g., housing, agriculture, mining, forestry) within the region that could affect the hydrology of the basin. These past impacts are discussed implicitly or explicitly as part of the description of the affected environment (Chapter 3). For example, the discussion of water resources in Section 3.3 presents flows and sediment balance within the Colorado River before completion of Glen Canyon Dam and the changes in these parameters that have occurred since then. The description of current flows and sediment balance integrates all factors, including ongoing activities, that affect existing (baseline) conditions. Because these past and ongoing activities are incorporated into baseline conditions, the assessment of impacts of commitment-level alternatives and hydropower operational scenarios presented in Sections 4.1 and 4.2 already considers these aspects of cumulative impacts.

Similarly, reasonably foreseeable future actions have been considered in the impact assessment wherever possible. Thus, the EIS for continued operation of Glen Canyon Dam (Reclamation 1993) is considered here by examining, as operational scenarios, all eight of the alternatives being considered in that EIS. Flow regimes stipulated in the Biological Opinion for Flaming Gorge Dam, recently issued by the USFWS (1992b), were incorporated into the development of operational scenarios for this facility. The impacts of possible future changes in release patterns from the Aspinall Unit are also considered here by assessment of the impacts of hydropower operations with the seasonally adjusted releases that are being

considered by Reclamation. No other future Federal, state, local, or private actions that could contribute to cumulative impacts are known at this time.

5.1 SOCIOECONOMICS

Most of the cumulative economic effects that could be attributed to a change in Western's commitment levels have already been addressed. The economic analysis of a change in Western's commitment levels was designed to provide estimates of both the short- and long-term impacts of each alternative. In particular, the analysis considered how changes in commitment levels and supply options would affect each utility's capacity expansion path. The results of this part of the analysis, combined with estimates of the effects of each alternative on the rates charged by Western (as well as other factors), were used to estimate the short- and long-term effects on the rates charged by each utility and the financial condition of each utility. The changes in rates were then used to estimate the short- and long-term effects on such regional economic variables as employment, income, and output.

Other factors that could influence cumulative impacts include the implementation of the Final Biological Opinion at Flaming Gorge Dam and changes in the operations at the Aspinall Unit and the Glen Canyon Dam. However, the selection of operational scenarios and corresponding supply options for this analysis was designed to capture the range of effects that any such changes could have on the economic analysis of the commitment-level alternatives (Section 4.1.1).

5.2 AIR RESOURCES

No significant variations in regional emissions of criteria air pollutants or CO₂ (used as the surrogate for all types of greenhouse gases emitted from fossil-fuel combustion) are expected under Western's commitment-level alternatives or operational scenarios (Sections 4.1.2.1.2 and 4.2.2.1.2). Therefore, no significant variations in cumulative impacts are expected.

5.3 WATER RESOURCES

Cumulative impacts for the hydropower operational scenarios include potential impacts for each of the individual hydropower facilities considered in this Power Marketing EIS, as well as for the overall system of power plants considered (Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit). Under the assumption that hydropower generation is an independent process from power plant to power plant (e.g., water releases at Flaming Gorge Dam are independent of power generation at Glen Canyon Dam and the Aspinall Unit, and vice versa), cumulative hydrological impacts for operational scenarios at any of the hydroelectric power plants considered in this EIS would range from slight to moderate (Section 4.2.3). This conclusion is based on a number of findings. First, impacts of the

operational scenarios would range from slight to moderate for each of the individual power plants considered in this EIS (Section 4.2.3). Next, incremental increases in impacts to the hydrological environment from such external activities as new construction, increased agricultural usage, or other activities in the associated basins would also be small relative to current environmental conditions. Finally, impacts due to other operational constraints on the dams (e.g., the Glen Canyon Dam EIS [Reclamation 1993], a Glen Canyon Dam Biological Opinion, and changes in the operation of the Aspinall Unit) would fall within the bounds of the analyses reported in this EIS.

In addition to slight to moderate cumulative impacts for each of the facilities, the cumulative impact of the hydropower operational scenarios considered in this EIS on operations of other SLCA/IP power plants would be small. This conclusion is based primarily on the large physical distances separating the power plants and the independence of the operational scenarios from annual and monthly water releases, which would remain under the control of Reclamation.

Flaming Gorge Dam is the most northern of the power plants considered. It is located on the Green River, a major tributary that joins the Colorado River about 35 mi southwest of Moab, Utah. The next most northern power plant is the Aspinall Unit, which is located on the Gunnison River about 100 mi upstream of the confluence with the Colorado River near Grand Junction, Colorado (approximately 125 mi northeast of the confluence of the Green and Colorado rivers). The southernmost power plant is Glen Canyon Dam, which is located on the Colorado River near Page, Arizona, about 70 mi southwest of Grand Junction, Colorado. Water release patterns from Flaming Gorge Dam or the Aspinall Unit would be indistinguishable by the time the released water reached the vicinity of Lake Powell because of physical attenuation and mixing with numerous tributaries that join the main stem of the Colorado River between Lake Powell and the upstream power plants. Upstream of Flaming Gorge Dam and the Aspinall Unit, Flaming Gorge Reservoir and Blue Mesa Reservoir would effectively buffer Fontenelle Dam and any units upstream of Blue Mesa Dam from impacts of hydropower operations.

As with flow, cumulative sediment impacts for the system of dams would be small because of the large distances between the units and the large number of tributaries and alluvial stretches of river that supply sediment to the main stem of the Colorado River. In addition, because the time frame of the Power Marketing EIS is 15 years, cumulative impacts on downstream reservoirs (e.g., Lake Mead) would be slight, considering their life expectancy (more than 500 years for Lake Mead).

5.4 ECOLOGICAL RESOURCES

In Section 4.2.4, the assessment of ecological impacts of each operational scenario at the Glen Canyon, Flaming Gorge, and Aspinall Unit dams incorporated impacts to the ecological resources that resulted from construction and historical operations of the dams (as summarized in Section 3.4) as part of the affected environment at each facility. Therefore, the impacts identified represent the cumulative impacts of each operational scenario

combined with the impacts of dam construction and operation activities in the Colorado, Green, and Gunnison rivers.

No additional cumulative impacts are anticipated to the ecological resources below Glen Canyon Dam beyond those impacts already identified in Section 4.2.4.1. The only major Federal action currently being planned for the area is modification of Glen Canyon Dam operations. An EIS for that action is being prepared by Reclamation, and the operational scenarios evaluated in Section 4.2.4.1 of this EIS are the same as the operational alternatives being evaluated by Reclamation. The operational scenario ultimately implemented at Glen Canyon Dam would be the operational alternative selected as part of Reclamation's NEPA process.

The river corridor below Flaming Gorge Dam is almost exclusively under the control of Federal agencies, such as the USFS and the NPS. As a result, few (if any) private or state actions are expected in or along the river between the dam and Jensen, Utah. The only known action currently planned in the river corridor below the dam is the modification of Flaming Gorge Dam operations by Reclamation to comply with the Biological Opinion issued by the USFWS for that facility (USFWS 1992b). With the exception of the year-round high fluctuating flow operational scenario, which was evaluated only for comparison with the other operational scenarios, all of the operational scenarios for Flaming Gorge Dam evaluated in this EIS would be in compliance with the Biological Opinion. The potential impacts of these scenarios on the ecological resources below the dam would be the same impacts that would occur under compliance with the opinion, and no additional impacts would be anticipated under any of the seasonally adjusted flow scenarios.

The reservoirs of the Aspinall Unit are all under the control of Federal agencies. Thus, no private or state actions would be expected to occur at the reservoirs. Water releases from Crystal Reservoir are currently being changed by Reclamation to provide flows downstream of Crystal Dam requested by the USFWS and the NPS. This change in releases from Crystal Dam will affect the storage and release patterns for the other reservoirs in the Aspinall Unit. The operational scenarios evaluated in this EIS were developed to provide the requested releases from Crystal Dam. Because the impacts of hydropower operations at the Aspinall Unit would be limited to the reservoirs themselves and not extend below Crystal Dam, no cumulative impacts would be expected to the ecological resources in the Gunnison River below that dam.

The location of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit within the Colorado River Basin increases the potential for interactive effects that could contribute to cumulative impacts to ecological resources. Such interactions could occur if (1) a facility affected downstream areas that were also affected by another facility or (2) a resource (e.g., a population of endangered fish) occurred in a sufficiently large area that this resource incurred impacts from several facilities. Impacts of Fontenelle Dam (60 mi upstream of the headwaters of Flaming Gorge Dam Reservoir) would not contribute to impacts on ecological resources below Flaming Gorge Dam because Flaming Gorge Reservoir serves as a buffer to any water resource impacts (e.g., flow, sediment, water temperature) of Fontenelle Dam.

Similarly, hydropower operations at Flaming Gorge Dam would not contribute to ecological impacts below Glen Canyon Dam because of the moderating effects of Lake Powell and the influence of tributaries on water quality between the two facilities (Section 5.3). The impacts of hydropower operations at the Aspinall Unit would be limited to the area of the reservoirs themselves (Section 4.2.4), thus precluding the potential for interactions between either Flaming Gorge Dam or Glen Canyon Dam.

The dams and reservoirs of the facilities effectively isolate most downstream aquatic resources. Thus, the population of humpback chubs below Glen Canyon Dam is separate from that below Flaming Gorge Dam, and impacts on one population cannot have interactive effects with any impacts on the other population. Only those aquatic resources below Flaming Gorge Dam and the Aspinall Unit could possibly be affected by more than one facility because no intervening facilities or natural features occur within the Green, Colorado, or Gunnison rivers that would prevent interaction. However, the fact that no hydropower operational scenario impacts are anticipated below the Aspinall Unit precludes any interactive effects on these resources.

The great distances between facilities limits the potential for cumulative impacts to terrestrial resources.

5.5 CULTURAL RESOURCES

No cumulative impacts to cultural resources have been identified to date for either the commitment-level alternatives or the hydropower operational scenarios. Cumulative effects for commitment-level alternatives cannot be identified because of the lack of information regarding possible capacity expansion. Cumulative impacts for the hydropower operational scenarios could occur in the Colorado River Basin if operational scenarios with projected impacts are implemented at both Flaming Gorge and Glen Canyon dams. Although Flaming Gorge and Aspinall lie within the same culture area, no adverse effects have been identified at the latter.

5.6 LAND USE

Adoption of certain commitment-level alternatives might require the construction of new power-generating facilities to meet requirements for firm capacity and energy. However, the location, size, and type of any new facilities are unknown at this time. The range and magnitude of impacts to land use resulting from construction and operation of such facilities cannot be determined without site-specific information. Because such information is not available, the potential cumulative impacts to land use associated with the various commitment-level alternatives cannot be thoroughly analyzed at this time.

No cumulative impacts to land use in the Colorado River Basin would result from any of the operational scenarios. No land use interactions would occur among the three facilities examined in this EIS.

5.7 RECREATION

The commitment-level alternatives may require construction of new power-generating facilities to compensate for the loss of hydropower resources; however, the location, size, and type of potential facilities are unknown at this time. The range and magnitude of impacts (including cumulative impacts) to recreational facilities and activities resulting from the construction and operation of such facilities would vary and cannot be analyzed until site-specific information is available.

In Section 4.2.7, the assessment of recreational impacts of each operational scenario at Glen Canyon and Flaming Gorge dams incorporated impacts to recreation that resulted from construction and historical operations of the dams (summarized in Section 3.7) as part of the affected environment at each facility. Therefore, the impacts identified represent the cumulative impacts of each operational scenario combined with the impacts of dam construction and operational activities in the Colorado and Green rivers. No additional cumulative impacts to recreation are anticipated under the operational scenarios beyond those identified in Section 4.2.7. Although Reclamation is preparing an EIS examining operations at Glen Canyon Dam, the alternatives assessed by Reclamation are the same as the operational scenarios examined in this EIS. On the Green River, Reclamation is operating Flaming Gorge Dam to comply with the USFWS Biological Opinion. Impacts from the operational scenarios examined in this EIS would not exceed those resulting from compliance with the Biological Opinion. Except for a few parcels of privately owned land, the segment of the Green River examined in this EIS is under Federal jurisdiction. No other action by any of the participating agencies is expected. The reservoirs of the Aspinall Unit are completely under the jurisdiction of the Federal Government, and no cumulative impacts with other actions are anticipated.

No interaction of recreational activities would occur among the three facilities examined in this EIS. No facility is located within the sphere of influence of another. Consequently, action at one facility would not cause a shift of use rates to any of the other two. No cumulative impacts are expected to recreational activities or resources in the Colorado River Basin.

5.8 VISUAL RESOURCES

Although commitment-level alternatives may require construction of new power-generating facilities to compensate for the loss of hydropower resources, the location, size, and type of potential facilities are unknown at this time. Site-specific information would be needed to determine the range and magnitude of impacts to visual resources associated with the construction and operation of such facilities. Because that information is not available, a thorough analysis of the cumulative impacts generated by commitment-level alternatives cannot be presented at this time. No cumulative impacts to visual resources would be generated under the operational scenarios. No relationship exists between the visual resources of the three hydropower facilities examined in this EIS. Visual resources in the Colorado River Basin would not be affected by flows from Glen Canyon Dam, Flaming Gorge Dam, or the Aspinall Unit dams.

6 UNAVOIDABLE ADVERSE IMPACTS

The impacts of commitment-level alternatives are presented in Section 4.1, and the impacts of hydropower operations at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are presented in Section 4.2. This chapter summarizes the impacts of commitment-level alternatives and hydropower operations that cannot be avoided.

Unavoidable adverse impacts to socioeconomics from implementation of any of the commitment-level alternatives would be relatively limited. Compared with the no-action alternative, commitment-level alternatives 2, 3, 4, 5, and 6 would in most cases result in increased costs for Western's customers and a corresponding increase in the retail rates charged by those customers. As was discussed in Section 4.1, the magnitude of these increases would vary across the affected utilities. Some utilities, especially small, high-reliance cooperatives, could see their financial condition worsen. In addition, some end-users, especially those in Utah, could see the rates they pay for electricity increase by as much as 41%. Over the forecast period, each of the alternatives could result in a short-term decrease in output, employment, income, and agricultural output in the majority of the affected subregions. However, any impacts that might occur are predicted to be extremely small and would gradually diminish over time. Nonetheless, the initial decrease for all but the no-action alternative does represent a potential unavoidable adverse impact to the levels of output, employment, and income.

Because of the small change in variables affecting air quality and noise, there would be no unavoidable adverse impacts to these attributes of the environment.

The need for new or replacement capacity (and therefore new power plants) associated with commitment-level alternatives could affect water resources, ecological resources, cultural resources, land use, recreation, and visual resources. Because the impacts of constructing and operating new power plants depend on plant characteristics and location (which are not known at this time), these impacts are assessed in a qualitative sense in this EIS (Section 4.1.3). Unavoidable adverse impacts associated with new power plants cannot be determined at this time, but any such impacts would be assessed in the environmental review that would be required for any proposed new facility.

Commitment levels could also affect natural and cultural resources through the hydropower operations employed to produce marketed power. Since the relationship between commitment levels and specific operational modes is dependent on many factors, the assessment in the EIS directly examined the effects of hydropower operations to bound the possible impacts (Section 4.2). Because the hydropower facilities examined in the EIS have been operating for the past 30 years, the existing condition of the natural environment associated with these facilities is a product of the presence of the dams and past operations. For the most part, hydropower operations similar to historical operations would not produce further changes in environmental conditions downstream of facilities. Thus, impacts associated with those scenarios similar to historical operations (continued historical operations, maximum power plant capacity, and restricted high fluctuation scenarios at Glen

Canyon Dam; year-round high fluctuations at Flaming Gorge Dam; and seasonally adjusted high fluctuations at the Aspinall Unit) would be limited. The high fluctuations characteristic of these operational scenarios at Glen Canyon and Flaming Gorge dams would result in higher erosion rates than other operational scenarios and could erode cultural resource sites near the river. These adverse impacts to cultural resources could be avoided with mitigation (e.g., protecting sites with riprap, or data recovery). Potential unavoidable adverse impacts to other resources for these operational scenarios would be slight but could include impacts to the humpback chub, riparian vegetation, and terrestrial wildlife.

Operational scenarios with fluctuations lower than historical levels would benefit most resources, including water resources (sediment), ecological resources (trout, native fish, woody riparian vegetation, most wildlife, and most threatened and endangered species), cultural resources, and recreation (all activities). Exceptions to this general trend include slight to moderate adverse impacts under operational scenarios with reduced fluctuations to (1) marsh vegetation at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit, (2) waterfowl at Flaming Gorge Dam and the Aspinall Unit, (3) bald eagles at Flaming Gorge Dam and the Aspinall Unit, and (4) Ute ladies-tresses at Flaming Gorge Dam. For the most part, these impacts would be unavoidable.

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

The commitment-level alternatives examined in this EIS consist of potential changes in the way hydroelectric capacity and energy produced at SLCA/IP facilities are marketed. In particular, Western is proposing to change the amount of firm capacity and energy that it would commit to for a specified period of time. In contrast, the total amount of capacity and energy produced on an annual basis would be unaffected by any of the commitment-level alternatives or hydropower operational scenarios. Thus, short-term uses are limited to the manner in which power is marketed and hydropower facilities are operated (especially with regard to the amount of daily flow fluctuation), not the total capacity and amount of energy produced.

With respect to socioeconomic impacts, the analysis indicates any impacts that might occur in the short-term would gradually disappear. Long-term productivity, as measured by economic variables such as employment, output, income, and agricultural production, would be unaffected by any of the commitment-level alternatives considered.

The amount that river flow fluctuates within a day affects the amount of sediment transported downstream, the amount of erosion, and ultimately the area available for riparian vegetation, wildlife populations, and shoreline recreational use (e.g., beaches). Thus, any operational scenario that features high flow fluctuations affecting sediment transport would also affect the long-term productivity of the area. These operational scenarios are continued historical operations, maximum power plant capacity, and restricted high fluctuations at Glen Canyon Dam and year-round high fluctuations and seasonally adjusted high fluctuations at Flaming Gorge Dam. Neither of the operational scenarios at the Aspinall Unit would influence the long-term productivity of the affected area. It is important to note that for long-term productivity to be affected, high fluctuating flow operational scenarios would have to be in place for a long, as yet undetermined, period of time. Switching to a reduced fluctuation operational mode could slow or halt declines in long-term productivity.

Although reduced fluctuations would generally have positive effects on long-term productivity (especially of terrestrial resources), backwater areas that are important to the long-term productivity of the aquatic ecosystem could eventually fill in without occasional high flows. However, all of the reduced fluctuation operational scenarios at Glen Canyon Dam (moderate fluctuation, low fluctuation, and the steady flow scenarios) and at Flaming Gorge Dam (seasonally adjusted moderate fluctuation and seasonally adjusted steady flows) feature annual or periodic high flows intended to flush accumulated sediments. Thus, none of the restricted fluctuation scenarios are expected to adversely affect long-term productivity.

8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Neither the capacity and energy produced from water stored behind each of the dams nor the natural resources associated with each facility would be irreversibly or irretrievably committed by implementation of any commitment-level alternative or hydropower operational scenario. This conclusion is based on the capability of facility operators and/or Western to modify hydropower operations or aspects of the power marketing program such as energy purchases and exchanges. Thus, changes in operations or elements of the marketing program could be made at any time to reverse or reduce impacts to resources.

The USFWS issued a Biological Opinion that concluded that continued operations of Flaming Gorge Dam would jeopardize the continued existence of endangered fish in the Green River. Consequently, the USFWS proposed, as a reasonable and prudent alternative, reoperation of the dam to provide flows protective of these fish (see Section 4.2.4.2.3). Of the operational scenarios for Flaming Gorge Dam considered in this EIS, only the year-round high fluctuating flows scenario would not comply with the Biological Opinion and thus, according to this opinion, could result in the irreversible loss of these species.

Similarly, a Biological Opinion is being developed for operation of Glen Canyon Dam, and that opinion could identify reoperation of the dam as a reasonable and prudent alternative for preventing a jeopardy condition for species in the Colorado River. A draft Biological Opinion has been prepared by the USFWS that identifies such a reasonable and prudent alternative. According to this draft opinion, a number of actions should be taken, including a change in operation, in order to avoid the irreversible loss of those species.

9 ENVIRONMENTAL STATUTES, REGULATIONS, EXECUTIVE ORDERS, AND PERMIT REQUIREMENTS

This chapter identifies the major laws, regulations, Executive Orders, U.S. Department of Energy (DOE) orders, and other instruments that impose environmental protection and compliance requirements upon Western's activities in the affected areas. Also addressed are applicable measures for which Federal law delegates enforcement or implementation authority to state or local agencies.

The Energy Reorganization Act of 1977 authorized the creation of Western as a separate and distinct entity within the DOE [42 USC § 7152(a)(3)]. The act transferred the power marketing and transmission functions from the Secretary of the Interior (Bureau of Reclamation) to the Secretary of Energy, acting through Western. Therefore, Western, as an administration within the DOE, is governed as a Federal agency and must comply with all Federal facility requirements and DOE regulations and orders.

Executive Order 12088, Federal Compliance with Pollution Control Standards, requires Federal agencies, including Western, to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act (Section 9.1), the Noise Control Act (Section 9.2), the Clean Water Act (Section 9.3.1), the Safe Drinking Water Act (Section 9.3.3), the Toxic Substances Control Act, and the Resource Conservation and Recovery Act (RCRA) (Section 9.6).

9.1 CLEAN AIR ACT (42 USC §§ 7401 *et seq.*)

Development and implementation of power marketing criteria by Western will not directly result in the release of air pollutants to the atmosphere. The hydroelectric power generating units are not major stationary sources as defined under the Clean Air Act¹ and, therefore, hold no permits and need no approvals from the U.S. Environmental Protection Agency (EPA) or the equivalent state agency.

Sections 4.2 and 5.2 discuss estimated potential effects of various operational scenarios of changes in Western's hydroelectric generation on local and regional air quality. These sections assume air pollutant emissions from local and regional public utility generating facilities are tied to the amount of peak power generated by the hydroelectric generating units included in this EIS. Therefore, air pollutant emissions eliminated by hydroelectric energy would increase as the operational scenarios under the various alternatives change from high to low flexibility.

¹ A major stationary source means any of a number of listed stationary sources of air pollutants that emit, or have the potential to emit, 100 tons per year or more of any pollutant subject to regulation or any stationary source that emits or has the potential to emit 250 tons per year or more of any air pollutant subject to regulation.

Increases in power generation from local or regional public utility generating units may result in additional regulatory compliance burdens on these utilities if air pollutant emissions also increase, either through modification of existing fossil-fuel-fired facilities, or construction of a new major source of air pollutants. Such modification or construction would require the utility to obtain approval and a permit to operate from either the EPA or the appropriate state agency. All such modifications and construction must meet the requirements of the Clean Air Act. However, examination of the regulatory compliance of other than Western is beyond the scope of this section.

9.2 NOISE CONTROL ACT OF 1972 (42 USC §§ 4901 *et seq.*)

Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies to conduct their programs in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health or welfare. Noise impacts of commitment-level alternatives and hydropower operational scenarios are analyzed in Sections 4.1.2 and 4.2.2.

The Noise Control Act leaves regulation of environmental noise to the states (42 USC § 4913). However, of the six states within the affected region, only Colorado has quantitative noise-limit regulations. The Colorado Noise Abatement Law (Colorado Revised Statutes 1973, Title 25, Article 12) establishes noise level limits (see Appendix B, Table B.6). Noise above those limits is deemed to constitute a public nuisance.

Analyses indicate that hydropower facilities make little contribution to the environmental noise levels beyond their immediate environs. In Colorado, the acoustic emissions from the Curecanti substation do not raise the residual background environmental noise levels above the Colorado limits at the nearest residential area, and hydropower facilities at Glen Canyon do not increase ambient noise levels beyond the rim of the canyon.

The acoustic emissions from Federal hydropower plants in Utah and Arizona do not increase residual background environmental noise levels in residential areas above the Federal guideline of 55 dBA (EPA 1974).

9.3 WATER QUALITY AND WATER RESOURCE REQUIREMENTS

Water quality and water resource requirements to which Federal hydropower generating facilities and activities would be subject are discussed in this section.

9.3.1 Clean Water Act (33 USC §§ 1251 *et seq.*)

The Clean Water Act (CWA) makes it illegal to discharge pollutants from a point source into navigable waters of the United States except in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. Section 402 of the CWA

(33 USC § 1342), provides for the issuance of a permit for the discharge of any pollutant or combination of pollutants within the applicable requirements of the act.

The EPA, however, does not consider dam-induced water quality changes to constitute the discharge of a pollutant under Section 401 of the CWA, and therefore no permit is necessary. This interpretation was upheld by the court in *National Wildlife Federation, et al v. Anne Gorsuch*, 693 F.2d 156 (D.C. Cir. 1982). In addition, in *United States of America ex rel. Tennessee Valley Authority v. Tennessee Water Quality Control Board*, 717 F.2d 992 (6th Cir. 1983), the court found that a state may not subject a Federal agency to a state-enacted permit program when, under the CWA, the pollutant at issue is not considered a discharge from a point source requiring a permit under Section 402. These rulings do not, however, mean that operations at a dam never require an NPDES permit. Permits may be required for operational wastewater discharges, as distinguishable from turbine generating water discharges. The wastewater discharges contain pollutants from outside the hydroelectric power generation system (e.g., noncontact cooling water, oil/water separator discharge, or turbine pit dewatering discharge) that would have to meet the limits of an NPDES permit.

9.3.1.1 Clean Water Act Requirements for Arizona

Arizona has not received full authority under the CWA to implement an NPDES permitting program for Federal facilities. Although the Arizona Department of Environmental Quality, Office of Waste and Water Quality Management, performs processing and monitoring functions, the Federal EPA (Region IX) retains responsibility for issuing permits and conducting enforcement functions within the state. The surface water segment of the Colorado River from Lake Powell to Topock is designated as protected for aquatic and wildlife (including coldwater fishery), domestic water source, full-body contact, agricultural irrigation, and livestock watering. Specific parameters have been set for each designation.

Reclamation holds a permit issued by EPA Region IX for discharge of domestic wastewater to the Colorado River from the treatment plant serving the Glen Canyon Dam and power plant. Western does not hold any permits for these facilities. Implementation of the proposed action, any alternative, or any of the hydropower operational scenarios under consideration would not result in changes in domestic wastewater discharges from the treatment plant because wastewater production at the facility is independent of dam operations.

9.3.1.2 Clean Water Act Requirements for Colorado

Colorado has full authority to implement an NPDES permitting program in the state under its Water Quality Control Act (Colorado Revised Statutes, Title 25, Article 8). However, under Section 25-8-503 of the act, activities in exercise of water rights, such as diversion, storage, or release of water, shall not be considered to be point-source discharges of pollution, provided such discharge does not generate wastewater effluent. No permits have

been issued by the Colorado Department of Health for the Aspinall Unit. Therefore, only if changes in hydropower operations would result in wastewater effluent being introduced into the Gunnison River would a permit application be necessary. The classifications and numeric standards applicable to the Gunnison River Basin are specified in the Code of Colorado Regulations, Title 5, Chapter 1002, Article 8, Section 3.5.0.

9.3.1.3 Clean Water Act Requirements for Utah

In Utah, the state does not have authority to administer the Federal NPDES permit program or pretreatment programs. Therefore, all NPDES permits issued in Utah under the CWA are issued by the EPA, Region IX. Utah may, however, issue a discharge permit under state-enacted water quality laws and regulations (Utah Water Quality Act, Title 19, Chapter 5, Section 19-5-104). The Green River is designated as protected for domestic drinking water purposes (Class 1C); for in-stream boating, water skiing, and similar uses, excluding recreational bathing (swimming) (2B); for warmwater species of game fish and other warmwater aquatic life (3B); and for agricultural uses, including watering stock and irrigating crops (4).

Reclamation holds a state permit to discharge domestic wastewater to the Green River downstream of Flaming Gorge Dam. Western does not hold any permits for these facilities. It is unlikely that implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would result in changes in domestic wastewater discharges from the treatment plant.

9.3.2 Rivers and Harbors Appropriations Act of 1899 (33 USC §§ 401 *et seq.*)

Section 10 of the Rivers and Harbors Appropriations Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable water of the United States. The construction of any structure in or over navigable water; the excavation from or depositing of material in such waters; or the accomplishment of any such work affecting the course, location, condition or capacity of such waters is unlawful unless the work has been recommended by the Corps of Engineers and authorized by the Secretary of the Army. The implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would not result in the construction of any structure or the excavation or deposit of any material into such waters, so no approval under the act would be necessary.

9.3.3 Safe Drinking Water Act (42 USC §§ 300(f) *et seq.*)

The primary objective of the Safe Drinking Water Act is to protect the quality of public water supplies, water supply and distribution systems, and all sources of drinking water. Sections of the act address public water systems, protection of underground sources of drinking water, and requirements to regulate underground injection wells. The National

Primary Drinking Water Regulations (40 CFR Part 141), administered by the EPA, establish standards applicable to public water systems. The implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would not affect drinking water supplies or systems at or near SLCA/IP facilities, so no provisions of this act will be applicable.

9.3.4 Wild and Scenic Rivers Act (16 USC §§ 1274 *et seq.*)

The Wild and Scenic Rivers Act provides for protection of the outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values of rivers designated as components or potential components of the National Wild and Scenic Rivers System. No license, permit, or other authorization can be issued for a Federally assisted water resources project that could have a direct or adverse impact on the values for which a river was designated as a wild and scenic river or a study river. Within the affected area, the entire segment of the Green River within Colorado and the segment of the Gunnison River from the upstream southern boundary of the Black Canyon of the Gunnison National Monument to its confluence with the North Fork were listed as rivers designated for potential addition to the National Wild and Scenic Rivers Systems [16 USC §§ 1276(a)(38) and (39)].

The Department of the Interior published a final environmental impact statement finding that the Secretary of the Interior would submit recommendations to the President for transmittal to Congress for inclusion in the National Wild and Scenic Rivers System of a 91-mi segment of the Green River from Flaming Gorge Dam downstream to the southern boundary of Dinosaur National Monument (48 Fed. Reg. 56,449, December 21, 1983). This recommendation, however, was conditioned upon completion of a number of interrelated activities, including the quantification and litigation of the Federal reserved water rights for Dinosaur National Monument and completion of studies to determine the minimum water requirements to preserve the habitat for endangered species of fish in the Green River. Pursuant to An Act of October 30, 1986 (P.L. 99-590, 100 Stat. 3330) studies of the Green River were to be completed and reports transmitted to Congress not later than January 1, 1987.

The Bureau of Land Management's Gunnison Resource Management Plan analyzed the Gunnison River pursuant to the Wild and Scenic Rivers Act. Only one segment of the Lake Fork of the Gunnison River (13.3 mi) met eligibility criteria for a potential classification as "recreational" and was carried further into the process. The plan, however, determined that segment was not suitable for inclusion in the National Wild and Scenic Rivers System (57 Fed. Reg. 11,727, April 7, 1992).

The Green River is under continuing consideration for potential additions to the National Wild and Scenic Rivers System. Therefore, Western must consider the status of the river in all planning for the use and development of water and related land resources. Any Federal agency having jurisdiction over any lands that include, border upon, or are adjacent to any river included in the National Wild and Scenic Rivers System, or under consideration

for such inclusion, shall take such action as necessary to protect such rivers in accordance with the act (16 USC § 1283). In addition, any Federal agency shall inform the Secretary of the Interior and, where national forest lands are involved, the Secretary of Agriculture of any proceedings, studies, or other activities within their jurisdiction that affect or may affect any of the rivers designated as potential additions to the National Wild and Scenic Rivers System. The Bureau of Land Management, the state of Utah, and the U.S. Forest Service jointly manage the land along the section of the Green River under consideration. These agencies should be consulted if the implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would result in any change in the status of the river.

9.3.5 Executive Order 11988 — Floodplain Management; Executive Order 11990 — Protection of Wetlands

Executive Order 11988 (May 21, 1977) requires Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain, and that floodplain impacts be avoided to the extent practicable. Executive Order 11990 (May 24, 1977) requires all Federal agencies to consider protection of wetlands in decision making for a proposed action.

The DOE has established procedures (10 CFR Part 1022 — Compliance with Floodplain/Wetlands Environmental Review Requirements) for compliance with these Executive Orders. These procedures require Western to assess the effects of a proposed action on the survival, quality, and natural or beneficial values of wetlands and to avoid impacts to floodplains to the extent practicable. Pursuant to the regulations, concurrent with Western's review of a proposed action, Western must prepare a floodplain/wetlands assessment. If the implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would result in changes or effects on floodplains or wetlands, Western must assess the positive, negative, direct and indirect, and long- and short-term effects of these actions and, if necessary, assess alternatives that may avoid adverse effects in the floodplain or wetlands area (10 CFR 1022.12). Such assessments are included in Section 4.2.3 for floodplains and in Appendix D (Section D.4) for wetlands.

In addition, for impacts on a floodplain, Western must publish a finding of facts either in the FEIS or separately (10 CFR 1022.15). The finding of facts must include a brief description of the proposed action, an explanation indicating why the action is proposed to be located in the floodplain, a list of alternatives considered, a statement that the action conforms to applicable state and local floodplain protection standards, and a brief description of steps to be taken to minimize potential harm to or within the floodplain. Such a finding of facts will be included in the FEIS.

9.4 ECOLOGICAL RESOURCES

9.4.1 Endangered Species Act of 1973 (16 USC §§ 1531 *et seq.*)

The Endangered Species Act is intended to prevent the further decline of endangered and threatened species of animals and plants and to restore these species and their habitats. The act is jointly administered by the U.S. Department of the Interior (all nonmarine plant and animal species and their habitats) and the U.S. Department of Commerce (marine plant and animal species and their habitats). Under terms of Section 7 of the act (16 USC § 1536), Western is required to consult with the Department of the Interior, Fish and Wildlife Service (USFWS), to ensure that any action carried out by Western is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of critical habitat of such species. Section 7(b) of the act requires the USFWS to issue a written statement setting forth its opinion detailing how the agency action affects listed species or critical habitat. Biological assessments are required under Section 7(c) of the act if listed species or critical habitat may be present in an area affected by any "major construction activity." No construction is contemplated under the proposed action, any alternatives, or any hydropower operational scenario; therefore, Western is not required to ask for a species list or prepare a biological assessment. However, since hydropower operations affect the timing and release of flows from existing dams and thus might impact downstream aquatic and terrestrial environments, the USFWS recommended that Western prepare a biological assessment (Harris 1991).

Western has consulted the USFWS, and biological assessments concerning potential impacts on endangered and threatened species or their critical habitats in the vicinity of the hydropower facilities are included in Sections 3.4 and 4.2.4. The identification of endangered and threatened species and their habitats is found in 50 CFR Parts 17 and 402. The endangered, threatened, and candidate species found in the vicinities of the hydropower facilities are listed in Tables 3.8, 3.9, 3.10, 3.11, and 3.12.

A state is expressly permitted to continue to legislate and regulate with respect to endangered and threatened species of animals and plants within that state provided such legislation or regulation does not impair the effectiveness or relax the requirements of Federal law or contravene the terms of a Federal permit or exemption.

The Arizona Game and Fish Commission Heritage Fund (Arizona Revised Statutes, Title 17) authorizes the Arizona Game and Fish Commission to perform habitat evaluations relative to proposed projects. The evaluators are to assess the status, condition, and ecological value of potentially affected habitat and to make recommendations regarding management, conservation, or other protection measures, or mitigation measures (including reasonable alternatives) for a project that might affect such habitat. In Arizona, the Game and Fish Commission adopted the Federal list of threatened and endangered species (50 CFR 17.11, revised as of April 10, 1987) (Arizona Revised Statutes, Title 17, Article 6, Section 17-296). However, Arizona also recognizes threatened native wildlife species listed in *Threatened Native Wildlife in Arizona*, published by the Arizona Game and Fish

Department (1988) (Arizona Administrative Code, Title 12, Chapter 4, Section R12-4-401). These species are included in Tables 3.8 and 3.9.

Under the Colorado Non-Game, Endangered, or Threatened Species Conservation Act (Colorado Revised Statutes, Title 33, Article 2), the Colorado Wildlife Commission is to establish a list of those species and, where necessary, subspecies of wildlife indigenous to the state that are determined to be endangered or threatened within the state. It is unlawful for any person to take, possess, transport, export, process, sell or offer for sale, or ship any species or subspecies of wildlife appearing on such list. These species are included in Table 3.12.

Under the Wildlife Resources Code of Utah, it is unlawful for any person to take any protected wildlife (Utah Code Annotated, Title 23, Chapter 20, Section 23-20-3). Utah has also adopted the definition of threatened and endangered wildlife as designated in the Federal Endangered Species Act of 1973 (Utah Code Annotated Title 23, Chapter 13, Section 23-13-2). In addition, it is unlawful for any person, company, or corporation owning or controlling any reservoir or other waterway leading from or into any state waterway containing protected aquatic wildlife to drain or divert sufficient water so as to endanger protected aquatic wildlife therein, without giving five days written notice to the Division of Wildlife Resources (Utah Code Annotated, Title 23, Chapter 15, Section 23-15-5). It is also unlawful for any person to pollute any waters deemed necessary by the Wildlife Board for wildlife purposes or any waters containing protected aquatic wildlife and stoneflies (Plecoptera), mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), water bugs (Hemiptera), caddisflies (Trichoptera), spongillid flies (Neuroptera) and crustaceans (Utah Code Annotated, Title 23, Chapter 15, Section 23-15-6). Utah-listed species are also included in Tables 3.10 and 3.11.

9.4.2 Migratory Bird Treaty Act (16 USC §§ 703 *et seq.*)

The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns through North America. The act regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. The act stipulates that it is unlawful at any time, by any means, or in any manner to "kill . . . any migratory bird." Although no permit is required under this act, Western would consult with the Fish and Wildlife Service, as appropriate, regarding impacts to migratory birds and ways to avoid or minimize those impacts. Sections 3.4 and 4.2.4 include discussions of birds present near facilities and impacts that would occur under various hydropower operational scenarios.

9.4.3 Bald and Golden Eagle Protection Act (16 USC §§ 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States. No permits or approval procedures are required unless a nest interferes with resource development. In that case, a permit must be obtained from the Department of the

Interior to relocate the nest. Bald eagles are common during the winter and migration period below Glen Canyon Dam, Flaming Gorge Dam, and along the shores of all three Aspinall reservoirs. Neither the proposed action, any alternative, nor any hydropower operational scenario under consideration, however, is expected to have important impacts on the bald eagle (Sections 4.2.4.1.3, 4.2.4.2.3, 4.2.4.3.3).

9.4.4 Fish and Wildlife Coordination Act (16 USC §§ 661 *et seq.*)

The Fish and Wildlife Coordination Act is intended to ensure that wildlife conservation receives equal consideration and is coordinated with other features of water resource development programs through effective planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. The act applies whenever the waters of any stream or other body of water greater than or equal to 10 acres in surface area are proposed or authorized to be controlled or modified by any department or agency of the United States. Western is required to consult with the USFWS and the head of the state agency administering the wildlife resources of the state in which the modification is to be constructed [16 USC § 662(a)]. The department or agency is also requested to provide for the development and improvement of wildlife resources in conjunction with the proposed action.

Western is consulting with representatives of the USFWS and of the appropriate wildlife agencies in Arizona, Colorado, and Utah. The consultation, conference, and biological assessment procedures under Section 7 of the Endangered Species Act of 1973 can be consolidated with interagency cooperation procedures required by the Fish and Wildlife Coordination Act (50 CFR 402.06). The recommendations of the USFWS shall be given full consideration relative to determining possible damage to wildlife resources caused by the implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration and relative to determining means and measures that should be adopted to prevent the loss of or damage to such wildlife resources. Justifiable means and measures for wildlife protection will be discussed in the FEIS.

9.4.5 DOE Order 4300.1C — Real Property Management, Chapter V: Management of Natural Resources

The DOE will integrate fish and wildlife management with other natural resources activities at all DOE facilities. Cooperation with state and Federal fish and conservation agencies is required of all DOE facilities. A management program that complies with accepted scientific practices must be established.

9.5 HISTORICAL, ARCHAEOLOGICAL, AND CULTURAL RESOURCE REQUIREMENTS

9.5.1 National Historic Preservation Act (16 USC §§ 470 *et seq.*) and Archaeological and Historic Preservation Act (16 USC §§ 469a *et seq.*)

The National Historic Preservation Act provides that agencies consider the effects of their actions on sites that are eligible for inclusion in the National Register of Historic Places (NRHP). Regulations established in 36 CFR Part 800 require consultation with the State Historic Preservation Officer (SHPO) and notification of the Advisory Council on Historic Preservation if a proposed action could impact such sites. Consultation generally results in execution of a Memorandum of Agreement that stipulates measures to minimize adverse impacts.

If a determination is made that Western's actions will have an effect on an archaeological site or historic structure, Western shall, in consultation with the appropriate SHPO, apply the Criteria of Adverse Effect [36 CFR 800.5(c)]. The effect of an undertaking is deemed adverse when it may diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Such effects include, but are not limited to, (1) physical destruction, damage, or alteration; (2) isolation of the property from or alteration of the character of the property's setting, when that character contributes to the property's qualification for the NRHP; (3) introduction of visual, audible, or atmospheric elements that are out of character with the property or its setting; or (4) neglect of a property resulting in its deterioration or destruction [36 CFR 800.9(b)].

If the effect is found to be adverse, Western must notify the Advisory Council and consult with the appropriate SHPO to seek ways to avoid or reduce the effect. Such consultation may involve other interested persons, including local government or Indian tribal representatives. In addition, an adequate opportunity must be provided for members of the public to receive information and express their views [36 CFR 800.5(e)(4)]. If Western and the SHPO agree upon how the effects will be taken into account, they are to execute a Memorandum of Agreement and submit it to the Advisory Council. If an agreement cannot be reached and there is no Memorandum of Agreement, Western is to request Advisory Council comments. Western then is to consider the Advisory Council's comments in reaching a final decision on the proposed undertaking [36 CFR 800.6(c)(2)].

9.5.2 American Indian Religious Freedom Act (42 USC § 1996)

The American Indian Religious Freedom Act is intended to protect and preserve for Native Americans their inherent right of freedom to believe, express, and protect the traditional religions of Native Americans, including access to religious or traditional sites, use and possession of sacred objects, and freedom to worship through ceremonies and traditional rites.

During preparation of this EIS, representatives of the San Juan Southern Paiute, Southern Ute Tribe, Ute Mountain Tribe, and Ute Indian Tribe (Uintah and Ouray Reservation) were contacted for identification of cultural resources. The sites, areas, or resources of religious or cultural significance in the Glen Canyon affected area are discussed in Sections 3.5 and 4.2.5. No sites, areas or resources of Native American religious or cultural significance currently have been identified to date in the affected areas at Flaming Gorge Dam or the Aspinall Unit.

9.5.3 DOE Order 4300.1C — Real Property Management, Chapter V: Management of Natural Resources

DOE field elements should be guided by the Archaeological Resources Protection Act and American Indians Religious Freedom Act in managing cultural resources.

9.5.4 Wilderness Act of September 3, 1964 (16 USC §§ 1131 *et seq.*)

The Wilderness Act of September 3, 1964, establishes the National Wilderness Preservation System to ensure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States, leaving no lands designated for preservation and protection in their natural condition. Each agency administering an area designated as wilderness is responsible for carrying out its duties so as to preserve the wilderness character.

In the Notice of the Availability of the Final Wilderness Environmental Impact Statement, the Bureau of Land Management (BLM) found that 35,380 acres of the Diamond Breaks Wilderness Study Area (which abuts a segment of the Green River) may be suitable for preservation as wilderness in the National Wilderness Preservation System under Section 1(c) of the act (55 Fed. Reg. 48,915, November 23, 1990). The BLM will next make a report to the President. Designation of the area as wilderness would require a recommendation of the President and approval by an act of Congress.

During the period of review and until Congress has determined otherwise, the BLM shall continue to manage such lands so as not to impair their suitability for preservation as wilderness. The BLM shall take appropriate action to prevent unnecessary or undue degradation of the lands and their resources and to afford environmental protection (Federal Land Policy and Management Act of 1976, 43 USC § 1782; 43 CFR Part 8560). Therefore, Western should consult with the BLM before implementing any power project action that could adversely effect this area [16 USC § 1134(d)(4)].

In addition to the Diamond Breaks Wilderness Study Area, much of Dinosaur National Monument and of Grand Canyon National Park are being considered for designation as wilderness.

9.6 MANAGEMENT OF WASTES AND HAZARDOUS MATERIALS

Development and implementation of power marketing criteria by Western Power Administration will not result in the generation of solid or hazardous wastes under the Resources Conservation and Recovery Act (42 USC §§ 6901 *et seq.*) or the release to the environment of hazardous substances requiring cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (42 USC §§ 9601 *et seq.*).

10 CONSULTATION, COORDINATION, AND PUBLIC INVOLVEMENT

In preparing the Electric Power Marketing EIS, agencies, organizations, professional experts, and the public were contacted for information. This information was used (1) in formulating the scope of the impact assessment, (2) in determining the types of resources that could be affected by commitment-level alternatives, (3) in describing the nature and status of resources in the affected environment, (4) as input into models used to analyze impacts, and (5) in determining the scope of potential cumulative effects. This chapter presents a synopsis, by resource, of the various contacts that were made. In addition, a summary of the results of scoping are presented.

10.1 CONSULTATION AND COORDINATION

10.1.1 Socioeconomics

Much of the information used in the socioeconomic analyses was obtained from existing data sources or modeling systems developed by academic and commercial entities. Some additional data were obtained from the Energy Information Administration of DOE and various Rural Electrification Associations. Analyses for power systems, financial viability and rates, and demand-side management relied on information obtained from individual long-term firm sales power customers (i.e., the Colorado River Energy Distributor's Association members) and investor-owned utilities likely to be affected by changes in electricity rates under Western power marketing programs. These contacts provided ANL with confidential information concerning utility system loads, resources and contracts, and the effects of energy and spot market activities associated with existing and potential Western power marketing activities.

Reclamation was contacted for information on the operational characteristics of SLCA/IP hydroelectric facilities. Reclamation also supplied data on the methods used by the CRSS to model the monthly operations of hydroelectric facilities.

In addition, HBRS, Inc., was consulted regarding data on the dollar value of recreation (both angling and white-water boating) that were developed as part of the Glen Canyon Environmental Studies. These data were also used in the assessment of the economic value of recreation below Flaming Gorge Dam.

10.1.2 Air Resources

Information and data on the region's climate, meteorology, ambient air quality, and ambient air quality monitoring stations were obtained from a number of Federal, state, and local agencies. A selected list of these agencies include the following:

- Air Quality Division, National Park Service, Fort Collins, Colorado;

- Arizona Office of Air Quality, Department of Environmental Quality, Phoenix, Arizona;
- Clark County Air Pollution Control Division, Clark County Health District, Las Vegas, Nevada;
- Colorado Air Pollution Control Division, Colorado Department of Health, Denver, Colorado;
- State Climatologist's Offices, Colorado, Utah, and Nevada;
- State of New Mexico Air Quality Bureau, New Mexico Environmental Department, Santa Fe, New Mexico;
- Upper Colorado River Basin Commission, Salt Lake City, Utah;
- Utah Bureau of Air Quality, Air Monitoring Center, Salt Lake City, Utah; and
- Wyoming Air Quality Division, Department of Environmental Quality, Cheyenne, Wyoming.

10.1.3 Water Resources

Information on past reservoir operations (dam releases and reservoir levels), hourly and daily river flow, sediment load, and future release patterns was obtained from several agencies. Some of this information was available from Western's own records for each facility. Other information was obtained through contacts with the following institutions and agencies:

- Arizona State University;
- National Park Service;
- Northern Arizona University;
- Uncompahgre Valley Water User's Association;
- University of Arizona;
- U.S. Bureau of Reclamation, Salt Lake City, Utah;
- U.S. Geological Survey, Boulder, Colorado; Denver, Colorado; Salt Lake City, Utah; and
- U.S. Fish and Wildlife Service, Denver, Colorado.

10.1.4 Ecological Resources

To obtain information and data on ecological resources, agencies responsible for managing lands within the affected area were contacted. Information on ecological resources downstream of the Glen Canyon Dam was also obtained from the Glen Canyon Dam EIS (Reclamation 1993). Of greatest interest were those resources or species deemed important or sensitive by resource agencies. These resources included important habitats (e.g., riparian habitat), game animals, nongame animals of concern (either listed as threatened or endangered or being actively managed as an important resource), recreational fish species (e.g., trout), and nongame fish. Included here are contacts made as part of Section 7 consultations for compliance with the Endangered Species Act. The agencies contacted are listed below.

10.1.4.1 Glen Canyon Dam

- Arizona Game and Fish Department;
- Bureau of Land Management, Shivlitz and Vermillion Resource Area;
- National Park Service, Arches National Park;
- National Park Service, Canyonlands National Park;
- National Park Service, Glen Canyon National Recreation Area;
- National Park Service, Grand Canyon National Park;
- National Park Service, Lake Mead National Recreation Area;
- Northern Arizona University, Cooperative Park Study Unit;
- U.S. Fish and Wildlife Service, Phoenix District Office;
- U.S. Fish and Wildlife Service, Ecological Services, Phoenix District; and
- U.S. Forest Service, Kaibab National Forest.

10.1.4.2 Flaming Gorge Dam

- Bureau of Land Management, Bookcliffs Recreation Area;
- Bureau of Land Management, Grand Resource Area;
- Bureau of Land Management, Diamond Mountain Resource Area;
- Bureau of Land Management, Moab District Office;

- Bureau of Land Management, Price River Resource Area;
- Bureau of Land Management, San Juan Resource Area;
- Bureau of Land Management, San Rafael Resource Area;
- Bureau of Land Management, Vernal District Office;
- Colorado Division of Wildlife, Northwest Region;
- Colorado National Heritage Program;
- National Park Service, Canyonlands National Park;
- National Park Service, Dinosaur National Monument;
- U.S. Fish and Wildlife Service, Browns Park National Wildlife Refuge;
- U.S. Fish and Wildlife Service, Utah-Colorado Office;
- U.S. Fish and Wildlife Service, Colorado River Fishery Project;
- U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Utah-Colorado Field Office;
- U.S. Fish and Wildlife Service, Vernal Field Office, Utah;
- U.S. Forest Service, Ashley National Forest;
- U.S. Forest Service, Flaming Gorge National Recreation Area;
- Utah Department of Wildlife Resources, Browns Park Wildlife Management Area; and
- Utah Natural Heritage Program.

10.1.4.3 Aspinall Unit

- Bureau of Land Management, Gunnison Resource Area;
- Bureau of Land Management, Uncompahgre Basin Resource Area;
- Colorado Division of Wildlife, Northwest and Southwest Regions;
- Denver Botanic Gardens, Colorado Native Plant Society;
- National Park Service, Black Canyon of the Gunnison National Monument;

- National Park Service, Curecanti National Recreation Area;
- San Juan College;
- The Nature Conservancy, Colorado National Heritage Program;
- U.S. Fish and Wildlife Service, Colorado River Fishery Project;
- U.S. Fish and Wildlife Service, Grand Junction Field Office;
- U.S. Fish and Wildlife Service, Utah-Colorado Field Office;
- U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Western Colorado Sub-office; and
- U.S. Forest Service, Grand Mesa, Uncompahgre, and Gunnison National Forests.

10.1.5 Cultural Resources

Background material for the cultural resources sections was obtained from several agencies. In addition, consultations for compliance with the National Historic Preservation Act and the American Indian Religious Freedom Act were conducted and are referenced here. Consultations for Glen Canyon Dam were not conducted separately for the Electric Power Marketing EIS, but were adopted from the Glen Canyon EIS. Consultations for the Glen Canyon EIS were conducted between Reclamation, NPS, the Arizona State Historic Preservation Office, Indian Tribes (Hopi Tribe, Navajo Nation, Pueblo of Zuni, San Juan Southern Paiute Tribe, Southern Utah Paiute Consortium), and the Advisory Council on Historic Preservation, and a programmatic agreement was developed. The agencies contacted in preparation of the Electric Power Marketing EIS are listed below.

10.1.5.1 Glen Canyon Dam

- National Park Service, Grand Canyon National Park; and
- U.S. Geological Survey, Boulder, Colorado.

10.1.5.2 Flaming Gorge Dam

- Colorado Historical Society, Office of Archaeology and Historic Preservation, Denver, Colorado;
- Bureau of Land Management, Green River Resource Area;
- Bureau of Land Management, Pinedale Resource Area;

- Bureau of Land Management, Vernal District;
- Colorado Historical Society, Office of Archaeology and Historic Preservation;
- National Park Service, Dinosaur National Monument;
- State Historic Preservation Office, Salt Lake City, Utah;
- Uintah and Ouray Reservation, Fort Duschene, Utah; and
- U.S. Forest Service, Vernal, Utah.

10.1.5.3 Aspinall Unit

- Colorado Historical Society, Office of Archaeology and Historic Preservation; and
- National Park Service, Midwest Archaeological Center.

10.1.6 Land Use

Information for the analysis of land use in the affected areas was derived from a variety of sources, such as state and local units of government, Federal agencies, and private citizens involved in the land management process. Contacts for the affected areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are listed below.

10.1.6.1 Glen Canyon Dam

- Bureau of Land Management, Arizona Strip District Office;
- City of Page, Planning and Zoning Department, Page, Arizona;
- Coconino County Department of Planning and Community Development, Flagstaff, Arizona;
- Mohave County Planning and Zoning Commission, Kingman, Arizona;
- National Park Service, Grand Canyon National Park; and
- National Park Service, Western Team Planning Section, Denver, Colorado.

10.1.6.2 Flaming Gorge Dam

- Bureau of Land Management, Colorado State Office;
- Bureau of Land Management, Craig District Office;
- Bureau of Land Management, Vernal District Office;
- Colorado Board of Land Commissioners, Denver, Colorado;
- Colorado Division of Local Government, Denver, Colorado;
- Colorado Division of Property Taxation, Denver, Colorado;
- Daggett County Zoning and Planning Board, Manila, Utah;
- Moffat County, Office of County Clerk, Craig, Colorado;
- National Park Service, Western Team Planning Section, Denver, Colorado;
- National Park Service, Dinosaur National Monument;
- Uintah County Planning Office, Vernal, Utah;
- U.S. Forest Service, Ashley National Forest;
- U.S. Forest Service, Flaming Gorge National Recreation Area;
- Utah Department of Transportation, Salt Lake City, Utah; and
- Utah Office of Planning and Budget, Salt Lake City, Utah.

10.1.6.3 Aspinall Unit

- Bureau of Land Management, Colorado State Office;
- Bureau of Land Management, Montrose District Office;
- Colorado Board of Land Commissioners, Denver, Colorado;
- Colorado Division of Local Government, Denver, Colorado;
- Colorado Division of Property Taxation, Denver, Colorado;
- Gunnison County Department of Planning, Building, and Environmental Health, Gunnison, Colorado;

- Montrose County Land Use Department, Montrose, Colorado;
- National Park Service, Black Canyon of the Gunnison National Monument;
- National Park Service, Curecanti National Recreation Area;
- National Park Service, Western Team Planning Section, Denver, Colorado; and
- U.S. Forest Service, Regional Forester, Lakewood, Colorado.

10.1.7 Recreation

Information for the analysis of recreation in the affected areas was obtained from state and local units of government, Federal agencies, and citizens and firms involved in providing recreational services. These contacts are listed below.

10.1.7.1 Glen Canyon Dam

- Coconino County Department of Planning and Community Development, Flagstaff, Arizona;
- National Park Service, Glen Canyon National Recreation Area, Page, Arizona; and
- National Park Service, Grand Canyon National Park, Grand Canyon, Arizona.

10.1.7.2 Flaming Gorge Dam

- Bureau of Land Management, Colorado State Office, Lakewood, Colorado;
- Bureau of Land Management, Craig District Office, Craig, Colorado;
- Bureau of Land Management, Vernal District Office, Vernal, Utah;
- Colorado Division of Wildlife, Denver, Colorado;
- Flaming Gorge Natural History Association, Dutch John, Utah
- Hatch River Expeditions, Vernal, Utah;
- National Park Service, Denver Service Center, Western Team Planning Section, Denver, Colorado;

- National Park Service, Dinosaur National Monument, Dinosaur, Colorado;
- Uintah County Planning Office, Vernal, Utah;
- Utah Department of Transportation, Salt Lake City, Utah;
- Utah Division of Parks and Recreation, Salt Lake City, Utah;
- Utah Division of Wildlife Resources, Salt Lake City, Utah;
- U.S. Forest Service, Ashley National Forest; and
- U.S. Forest Service, Flaming Gorge National Recreation Area.

10.1.7.3 Aspinall Unit

- Bureau of Land Management, Colorado State Office, Lakewood, Colorado;
- Bureau of Land Management, Montrose District Office;
- Colorado Department of Natural Resources, Division of Wildlife, Denver, Colorado;
- Elk Creek Marina, Inc. Gunnison, Colorado;
- National Park Service, Denver Service Center, Western Team Planning Section, Denver, Colorado;
- National Park Service, Black Canyon of the Gunnison National Monument; and
- National Park Service, Curecanti National Recreation Area.

10.1.8 Visual Resources

Information used in the analysis of visual resources in the affected areas was obtained from the few Federal agencies that have almost exclusive jurisdiction. These are listed below for each facility.

10.1.8.1 Glen Canyon Dam

- National Park Service, Glen Canyon National Recreation Area; and
- National Park Service, Grand Canyon National Park.

10.1.8.2 Flaming Gorge Dam

- Bureau of Land Management, Vernal District Office;
- National Park Service, Dinosaur National Monument; and
- U.S. Forest Service, Ashley National Forest.

10.1.8.3 Aspinall Unit

- National Park Service, Curecanti National Recreation Area.

10.2 PUBLIC INVOLVEMENT

10.2.1 Scoping Process

An extensive effort was made to notify all potentially interested parties about the EIS process. This effort included notification in the Federal Register, mailings of letters and informational packets to interested parties, press releases, and paid advertising concerning the schedule for the public scoping meetings. The Federal Register notice of the scoping period was published on April 4, 1990.

In addition to the Federal Register notice, a press release was sent to approximately 1,000 media representatives throughout the areas where the public meetings were to be held. Ads were run for several days before each scoping meeting in major newspapers in the cities where the meetings were held.

A letter announcing the EIS was also mailed to approximately 1,300 groups and individuals. The mailing list used for this process was compiled through records already in existence at Western and originating from a variety of sources, including previous environmental processes in which Western has participated. This list was supplemented with the names of individuals who specifically requested that they be placed on the mailing list for the EIS.

A special information packet was also prepared and mailed to this same list of interested parties. The packet summarized the reasons for the EIS and some of the issues under consideration. It also provided a list of power marketing terms and their definitions, as well as a schedule for the full EIS process.

A letter inviting state agencies to comment on the scoping process was sent to state clearinghouses in Utah, Arizona, New Mexico, Colorado, and Wyoming. The letter explained the rationale behind the EIS and explained that Western representatives would be available to discuss the EIS process with any state agencies desiring a briefing on the subject. In

addition, several Federal and state agencies were included on the mailing list of the letter to interested parties announcing the EIS.

An EIS update brochure was also sent to the list of interested parties. The brochure contained the most recent information concerning the EIS (e.g., schedules, scoping meeting attendance, new meeting times, etc.) and an offer for Western officials to speak with organizations about the EIS.

Seven public scoping meetings were held in Utah, Colorado, New Mexico, and Arizona. Meeting locations were chosen according to two key factors. The first was the general service area affected by the marketing program, that is, that geographic area with utility customers that would be directly influenced by the marketing program decisions made subsequent to the EIS. The second factor was related to areas in which there had already been considerable interest expressed in the operation of the dams within Western's marketing territory. Western scheduled the meetings in those cities so that the greatest numbers of interested persons could attend. The meetings generally lasted 2 to 2.5 hours. A total of 322 persons attended the meetings, with 110 individuals presenting comments.

While public scoping meetings were held, individuals were invited by Western to submit written comments regarding the EIS. More than 20,000 pieces of correspondence were received. The period for submittal of written comments was between April 4 and December 31, 1990.

The environmental, recreational, and utility groups attempted to solicit opinions through grassroots campaigns in addition to their direct and written testimony. For example, an "issue alert" was mailed to members of Friends of the River. The issue alert asked that constituents write letters to Western with the following:

Your letter should urge WAPA officials to consider the following in the Scope of their EIS:

- *WAPA must identify and evaluate the effects of peak power marketing on downstream river resources — habitat, beaches, fisheries, wildlife, and recreation.*
- *WAPA must evaluate the effects of peak power marketing on regional energy production and air quality.*
- *WAPA must consider alternatives for the amount of power produced at different times of day, including specific minimum and maximum flows and the option of producing power at a steady rate around the clock.*
- *WAPA must consider alternatives for the selection of its preference power customers, including alternatives that will encourage energy conservation and environment compliance.*

- *WAPA must consider alternatives for power pricing to encourage energy conservation.*

The National Wildlife Federation distributed an "action alert" with a similar message to its constituents. Western received 182 letters reflecting these solicitations. Additional letters came from individuals throughout the country, some of which were in response to the issue and action alerts, but that also included other substantive points.

The Intermountain Consumer Power Association initiated a postcard campaign through their member utilities to induce its customers to submit a prewritten comment. Western received 19,522 of these postcards. The postcard stated: "The scope of the study should be limited to the impacts of the marketing criteria. It should not encompass operations of the Colorado River beyond the proposed marketing criteria. Economic impacts of any alternatives to the present marketing criteria should be fully evaluated, including the impact on power costs."

The greatest number of those who signed and submitted these cards were in favor of this message. Also, 577 individuals wrote additional comments on the card in support of this approach to the EIS. However, 120 individuals either changed the wording on the card to reverse its intended message or submitted a card with a note that stated they did not support their utility's position on the EIS.

Western also received letters from individuals living or doing business near the locations of the scoping hearings. Some of these individuals were not aware of the hearing in their community or could not come. In some cases, they attended the hearings and did not testify, choosing instead to write a comment letter at a later time. Comments were also received from state and regional agencies and government entities.

Another type of letter received by Western was written follow-up to oral testimony. In some cases, the written submittal added comments not included in the oral presentation. In other cases, these comments changed over time as issues were raised at the scoping meetings.

Although some individuals submitted comments on their own behalf during the scoping period, by far the greatest number of comments came from representatives of established organizations. Some of the organizations most frequently represented during the scoping period include those described below:

Intermountain Consumer Power Association: Intermountain Consumer Power Association (ICPA) represents about 37 municipal utilities and rural electric cooperatives scattered throughout the states of Utah, Arizona, and Nevada. The utilities in ICPA serve about 25% of the population of Utah.

Colorado River Energy Distributor's Association: The Colorado River Energy Distributor's Association (CREDA) is a Colorado corporation representing nonprofit public utilities that purchase most of the power generated by the Colorado River Storage Project.

CREDA's members are located in Arizona, Colorado, New Mexico, Nevada, Utah, and Wyoming and serve some 3 million consumers.

National Wildlife Federation: The National Wildlife Federation is the nation's largest conservation-education organization with more than 5.8 million members and supporters and 51 state and territorial affiliates.

National Audubon Society: The Rocky Mountain States Region of the Audubon Society represents about 25,000 members scattered throughout these states in more than 50 chapters.

The Wilderness Society: The Wilderness Society is a nonprofit membership organization dedicated to the preservation and wise management of public lands and natural ecosystems. The society has a membership of 420,000 people.

Colorado Wildlife Federation: The Colorado Wildlife Federation is an affiliate of the National Wildlife Federation. It is Colorado's largest conservation-education organization, with more than 14,000 nationwide members.

Arizona Municipal Power Users Association: The Arizona Municipal Power Users Association has a collective membership that delivers approximately half the electricity in the state of Arizona.

Trout Unlimited: Trout Unlimited is a national conservation organization dedicated to preserving, protecting, and enhancing the coldwater resource.

Grand Canyon Trust: The Grand Canyon Trust is a regional nonprofit organization advocating the responsible conservation of the natural resources of the Colorado Plateau.

National Parks Conservation Association: The National Parks Conservation Association is a national nonprofit organization representing 200,000 members nationwide. The association works to protect and enhance units in the national park system.

Sierra Club: The Sierra Club is a national nonprofit organization representing approximately 500,000 members that works to protect the environment.

Grand Canyon River Guides: The Grand Canyon River Guides is a not-for-profit association of Grand Canyon white-water river guides and interested members of the general public whose mission is to protect the Grand Canyon, set the standards for the guiding profession, and to promote the highest quality river experience.

Utah Guides and Outfitters: The Utah Guides and Outfitters is an organization representing professional outfitters operating in Utah. It includes a large body of river outfitters.

10.2.2 Alternatives Development

Western solicited public comments on draft commitment-level alternatives and hydropower operational scenarios developed for the EIS. Alternatives and scenarios were presented in a series of five public meetings held in June 1992 in Salt Lake City, Utah; Phoenix and Flagstaff, Arizona; Albuquerque, New Mexico; and Denver, Colorado. For the most part, the meetings were well attended and there was active public participation at each of the presentations. As a result of these meetings, Western received 30 written comments on the alternatives, operational scenarios, and other aspects of the EIS, particularly scope. These comments were taken into consideration in developing the final set of commitment-level alternatives and hydropower operational scenarios evaluated in the EIS.

11 REFERENCES

- Aber, J.P., 1992, letter from Aber (Coconino County Department of Community Development, Flagstaff, Ariz.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Dec. 7.
- Aldrich, T., 1992, letter from Aldrich (Utah Department of Natural Resources, Waterfowl Program, Salt Lake City, Utah) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Nov. 2.
- Allison, T., and P. Griffes, 1994, *Regional Economic Impacts of Changes in Electricity Rates Resulting from Western Area Power Administration's Power Marketing Alternatives*, ANL/DIS/TM-5, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.
- Anderson, L.S., and G.A. Ruffner, 1987, *Effects of the Post-Glen Canyon Dam Flow Regime on the Old High Water Line Plant Community along the Colorado River in Grand Canyon*, U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Salt Lake City, Utah, Jan. 31.
- Andrews, E.D., 1986, "Downstream Effects of Flaming Gorge Reservoir on the Green River, Colorado and Utah," *Geological Society of America Bulletin* 97:1012-1023.
- Annear, T.C., 1980, *A Characterization of Yampa and Green River Ecosystems*, M.Sc. Thesis, Utah State University, Logan, Utah.
- Arizona Game and Fish Department, 1988, *Threatened Native Wildlife in Arizona*, Phoenix, Ariz., July 21.
- Arizona Game and Fish Department, 1993, *Glen Canyon Environmental Studies Phase II 1992 Annual Report*, prepared for the U.S. Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Flagstaff, Ariz.
- Arizona Office of Air Quality, 1988, *1987 Air Quality Control for Arizona: Annual Report*, Department of Environmental Quality, Phoenix, Ariz., Aug.
- Arizona Office of Air Quality, 1989, *1988 Air Quality Control for Arizona: Annual Report*, Department of Environmental Quality, Phoenix, Ariz., Aug.
- Arizona Office of Air Quality, 1990, *1989 Air Quality Control for Arizona: Annual Report*, Department of Environmental Quality, Phoenix, Ariz., Aug.
- Arizona Office of Air Quality, 1991, *1990 Air Quality Control for Arizona: Annual Report*, Department of Environmental Quality, Phoenix, Ariz., Aug.
- Armbruster, M.J., 1990, *Characterization of Habitat Used by Whooping Cranes during Migration*, Biological Report 90(4), U.S. Fish and Wildlife Service, Washington, D.C., May.

- Baird, A., 1992, personal communication from Baird (U.S. Forest Service, Vernal District, Vernal, Utah) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), June 3.
- Bajwa, R.S., et al., 1992, *Agricultural Irrigation and Water Use*, Agriculture Information Bulletin No. 638, U.S. Department of Agriculture, Economic Research Service, Resources and Technology Division, Washington, D.C., Jan.
- Balsom, J.R., 1985, *Visitor and Natural Impacts upon Cultural Resources along the Colorado River September-October 1984*, National Park Service, Grand Canyon National Park, Grand Canyon, Ariz.
- Balsom, J.R., 1989, *October Resources Monitoring and Research River Trip, October 11-28, 1989*, memorandum from Balsom (Grand Canyon National Park, Grand Canyon, Ariz.) to Chief, Resources Management and Planning (Grand Canyon National Park, Grand Canyon, Ariz.), Dec. 5.
- Bestgen, K.R., 1990, *Status Review of the Razorback Sucker, Xyrauchen texanus*, Contribution 44, Larval Fish Laboratory, Colorado State University, Fort Collins, Colo., Oct.
- Bishop, R.C., et al., 1987, *Glen Canyon Dam Releases and Downstream Recreation: An Analysis of User Preferences and Economic Values*, Report to the Recreation Subteam of the Glen Canyon Environmental Studies, Flagstaff, Ariz., by HBRS, Inc., Madison, Wis., Jan.
- Blinn, D.W., and G.A. Cole, 1991, "Algal and Invertebrate Biota in the Colorado River: Comparison of Pre- and Post-Dam Conditions," in *Colorado River Ecology and Dam Management: Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico*, National Academy Press, Washington, D.C., pp. 102-123.
- BLM (Bureau of Land Management), 1986, *Little Snake Draft Resource Management Plan and Environmental Impact Plan*, Craig, Colorado District, Craig, Colo., Feb.
- BLM, 1990, *Diamond Mountain Resource Management Plan, Management Situation Analysis*, Diamond Mountain Resource Area, Vernal District, Vernal, Utah.
- BLM, 1991, *Diamond Mountain Resource Area Draft Resource Management Plan and Environmental Impact Plan*, BLM-UT-PT-91-031-1610, Vernal District, Vernal, Utah, Nov.
- Bodmer, E., et al., 1994, *Impacts of Western Area Power Administration's Power Marketing Alternatives on Retail Electricity Rates and Utility Financial Viability*, ANL/DIS/TM-6, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.
- Bogan, M.A., et al., 1983, *Baseline Studies of Riparian Vertebrates of the Yampa and Green River Corridors within Dinosaur National Monument, June and July, 1982*, U.S. Fish and Wildlife Service, Fort Collins, Colo., in cooperation with the U.S. National Park Service, Rocky Mountain Region, Denver, Colo., March 3.

Breternitz, D.A., 1970, *Archaeological Excavations in Dinosaur National Monument, Colorado-Utah, 1964-1965*, University of Colorado Studies, Series in Anthropology, No. 17, University of Colorado Press, Boulder, Colo., Aug.

Breternitz, D.A., 1974, *Report of Archaeological Reconnaissance, Crystal Dam and Reservoir, Montrose County, Colorado*, memorandum from Breternitz (Archaeological Research Center, University of Colorado, Mesa Verde National Park, Cortez, Colo.) to Chief (National Park Service, Midwest Archaeological Center, Lincoln, Neb.), July 5.

Brian, N.J., 1987, *Aerial Photography Comparison of 1983 High Flow Impacts to Vegetation at Eight Colorado River Beaches*, prepared by U.S. National Park Service, Grand Canyon National Park, Grand Canyon, Ariz., for U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Salt Lake City, Utah, May.

Brown, B.T., 1988, *Monitoring Bird Population Densities along the Colorado River in Grand Canyon: 1987 Breeding Season*, Glen Canyon Environmental Studies, GCEIS/25-87, prepared by National Park Service, Cooperative Park Study Unit, Tucson, Ariz., for U.S. Bureau of Reclamation, Salt Lake City, Utah, Sept. 15.

Brown, B.T., et al., 1981, *Checklist of the Birds of the Grand Canyon Area*, Grand Canyon Natural History Association, Grand Canyon, Ariz.

Brown, B.T., et al., 1984, *Birds of the Grand Canyon Region: An Annotated Checklist*, 2nd ed., Monograph No. 1, Grand Canyon Natural History Association, Grand Canyon, Ariz.

Brown, B.T., et al., 1987, *Grand Canyon Birds, Historical Notes, Natural History, and Ecology*, The University of Arizona Press, Tucson, Ariz.

Brown, T.C., and T.C. Daniel, 1991, "Landscape Aesthetics of Riparian Environments: Relationship of Flow Quantity to Scenic Quality along a Wild and Scenic River," *Water Resources Research* 27(8):1787-1795.

Buckles, W., 1964, *Archaeological Survey of the Morrow Point Dam Area, Montrose and Gunnison Counties, Colorado*, National Park Service, Midwest Archaeological Center, Lincoln, Neb.

Calzonetti, F., et al., 1991, *Why Manufacturing Plants Locate Where They Do: Factors Affecting the Choice of Region and Locality, with Special Emphasis on Electricity*, prepared for the U.S. Department of Commerce, Economic Development Administration, Washington, D.C.

Carlson, J.L., 1992, *Site Visits to Black Canyon, Gunnison Gorge, Dinosaur National Monument, and Flaming Gorge*, memorandum from Carlson (Argonne National Laboratory, Argonne, Ill.) to R.C. Hemphill (Argonne National Laboratory, Argonne, Ill.), June 23.

Carlson, J.L., 1994, *Effects of Hydropower Operations on Recreational Use and Nonuse Values at Glen Canyon and Flaming Gorge Dams*, ANL/DIS/TM-7, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.

Carothers, S.W., and B.T. Brown, 1991, *The Colorado River through Grand Canyon — Natural History and Human Change*, The University of Arizona Press, Tucson, Ariz.

Cavallo, J., et al., 1994, *Impacts of Western Area Power Administration's Power Marketing Alternatives on Utility Demand-Side Management and Conservation and Renewable Energy Programs*, ANL/DIS/TM-8, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.

Chapman, J.F., 1993a, memorandum from Chapman (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Feb. 1.

Chapman, J.F., 1993b, letter from Chapman (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Nov. 29.

Cherry, S., 1993, *Colorado River Use Statistics*, memorandum from Cherry (National Park Service, Grand Canyon National Park, Grand Canyon, Ariz.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Jan. 19.

Chun, K.C., et al., 1994, *Impacts of Western Area Power Administration's Power Marketing Alternatives on Air Quality and Noise*, ANL/EAD/TM-7, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Clark County Air Pollution Control Division, 1991, *Trends: 1987 - 1990*, Clark County Health District, Las Vegas, Nev.

COE (U.S. Army Corps of Engineers), 1987, *Corps of Engineers Wetlands Delineation Manual*, Technical Report Y-87-1, Waterways Experiment Station, Environmental Laboratory, Vicksburg, Miss., Jan.

Colorado Air Pollution Control Division, 1988, *Colorado Air Quality Data Report: 1987*, Colorado Department of Health, Denver, Colo.

Colorado Air Pollution Control Division, 1989, *Colorado Air Quality Data Report: 1988*, Colorado Department of Health, Denver, Colo.

Colorado Air Pollution Control Division, 1990, *Colorado Air Quality Data Report: 1989*, Colorado Department of Health, Denver, Colo.

Colorado Air Pollution Control Division, 1991, *Colorado Air Quality Data Report: 1990*, Colorado Department of Health, Denver, Colo.

Colorado Division of Wildlife, 1991, *Colorado Fishing Map*, Department of Natural Resources, Denver, Colo.

Cooke, G.D., et al., 1986, *Lake Restoration and Reservoir Restoration*, Butterworth Publishers, Stoneham, Mass.

Cowardin, L.M., et al., 1979, *Classification of Wetlands and Deepwater Habitats of the United States*, FWS/OBS-79/31, U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C., Dec.

Coyner, J., 1990, *Report for Population Study Spiranthes diluvialis*, Bureau of Land Management in cooperation with Red Butte Gardens, University of Utah, Salt Lake City, Utah.

Day, K.C., and D.S. Dibble, 1963, *Archaeological Survey of the Flaming Gorge Reservoir Area Wyoming-Utah*, University of Utah Anthropological Papers 65 (Glen Canyon Series 19), University of Utah Press, Salt Lake City, Utah.

Delaney, R.W., 1989, *The Ute Mountain Utes*, University of New Mexico Press, Albuquerque, N.M.

Distel, D., 1992, letter from Distel (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Feb. 11.

Doland, M., 1992, telecommunication from Doland (National Park Service, Glen Canyon National Recreation Area, Page, Ariz.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Dec. 4.

Eason, N.J., 1992a, letter from Eason (National Park Service, Dinosaur National Monument, Dinosaur, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Sept. 30.

Eason, N.J., 1992b, telecommunication from Eason (National Park Service, Dinosaur National Monument, Dinosaur, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Sept. 21.

Eason, N.J., 1992c, telecommunication from Eason (National Park Service, Dinosaur National Monument, Dinosaur, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Nov. 12.

Eason, N.J., 1993a, letter from Eason (National Park Service, Dinosaur National Monument, Dinosaur, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Aug. 25.

Eason, N.J., 1993b, letter from Eason (National Park Service, Dinosaur National Monument, Dinosaur, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Sept. 7.

5 of 5

Eddy, F.W., et al., 1982, *The Archaeological Mitigation Program and Excavations at Site 5MF605, Brown's Park National Wildlife Refuge, Moffat County, Colorado*, prepared by Science Applications, Inc., Boulder, Colo., for the National Park Service, Interagency Archaeological Service, Denver, Colo., March.

Elliott, J.G., et al., 1984, *Sediment Transport in the Lower Yampa River, Northwestern Colorado*, Water Resources Investigation Report 84-4141, U.S. Geological Survey, Lakewood, Colo.

EPA (U.S. Environmental Protection Agency), 1974, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*, Report 550/9-74-004, U.S. Environmental Agency, Washington, D.C., March.

EPA, 1986, *Industrial Source Complex (ISC) Dispersion Model User's Guide*, 2nd ed., Vols. 1 and 2, EPA-450/4-86-005a and b, Research Triangle Park, N.C.

Euler, R.C., 1966, *Southern Paiute Ethnohistory*, University of Utah Anthropological Papers 78 (Glen Canyon Series 28), University of Utah, Anthropology Department, Salt Lake City, Utah.

Euler, R.C., 1967, "The Canyon Dwellers," *The American West* 4(2):22-27, 67-71.

Euler, R.C., and W.W. Taylor, 1966, "Additional Archaeological Data from the Upper Grand Canyon: Nankoweap to Unkar Revisited," *Plateau* 39(1):26-45.

Evans, L., and B. Belknap, 1973, *Flaming Gorge, Dinosaur National Monument, Dinosaur River Guide*, Westwater Books, Evergreen, Colo.

Fairley, H.C., 1989a, "Prehistory," in *Man, Models and Management: An Overview of the Archaeology of the Arizona Strip and the Management of its Cultural Resources*, J.H. Altschul and H.C. Fairley (editors), prepared by Statistical Research, Plateau Archaeology, and Dames and Moore, Inc., for the U.S. Forest Service, pp. 85-152.

Fairley, H.C., 1989b, "History," in *Man, Models and Management: An Overview of the Archaeology of the Arizona Strip and the Management of its Cultural Resources*, J.H. Altschul and H.C. Fairley (editors), prepared by Statistical Research, Plateau Archaeology, and Dames and Moore, Inc., for the U.S. Forest Service, pp.153-218.

Fairley, H.C., et al., 1991, *The Grand Canyon River Corridor Survey Project: Archaeological Survey along the Colorado River between Glen Canyon Dam and Separation Canyon*, National Park Service, Grand Canyon National Park, Grand Canyon, Ariz., Dec. 31.

Fischer, N.T., et al., 1983, *Vegetation along Green and Yampa Rivers and Response to Fluctuating Water Levels, Dinosaur National Monument*, Biology Department, University of New Mexico, Albuquerque, N.M., April 30.

- Fisher, A., and R. Raucher, 1984, "Intrinsic Benefits of Improved Water Quality: Conceptual and Empirical Perspectives," in *Advances in Applied Micro-Economics*, V.K. Smith and A.D. Witte (editors), Vol. 3, pp. 30-66, JAI Press, Greenwich, Conn.
- Flaim, S.J., et al., 1994, *Impacts on Irrigated Agriculture of Changes in Electricity Costs Resulting from Western Area Power Administration's Power Marketing Alternatives*, ANL/DIS/TM-9, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.
- Frank, M., 1993, letter from Frank (National Park Service, Curecanti National Recreation, Gunnison, Colo.) to J.M. Pffingston (Argonne National Laboratory, Argonne, Ill.), Jan. 25.
- Fritz, P.S., 1941, *Colorado: The Centennial State*, Prentice-Hall, New York, N.Y.
- Fuller, R.L., and K.W. Stewart, 1977, "The Food Habits of Stoneflies (Plecoptera) in the Upper Gunnison River, Colorado," *Environmental Entomology* 6(2):293-302.
- Garner, J., 1992, letter from Garner (Colorado Division of Wildlife, Denver, Colo.) to J.W. Hayse (Argonne National Laboratory, Argonne, Ill.), Oct. 9.
- Gordon C., et al., 1978, *The Development of Procedures for the Prediction of the Core Noise of Power Transformers*, Report No. 3697, prepared by Bolt, Beranek and Newman, Inc., Canoga Park, Calif., for Bonneville Power Administration, Portland, Ore., Jan. 27.
- Gordon C., et al., 1980, *The Development of Procedures for the Prediction of the Core Noise of Power Transformers (Addendum)*, Report No. 3697a, prepared by Bolt, Beranek and Newman, Inc., Canoga Park, Calif., for Bonneville Power Administration, Portland, Ore., Nov.
- Gordon, N.D., et al., 1992, *Stream Hydrology: An Introduction for Ecologists*, John Wiley and Sons, New York, N.Y.
- Gosse, J.C., 1982, *Microhabitat of Rainbow and Cutthroat Trout in the Green River Below Flaming Gorge Dam, Vol. 1: Narrative Report*, prepared by Aqua-Tech Biological Consulting Firm, Logan, Utah, for Utah Division of Wildlife Resources, Salt Lake City, Utah.
- Grabowski, S.J., and S.D. Hiebert, 1989, *Some Aspects of Trophic Interactions in Selected Backwaters and the Main Channel of the Channel of the Green River, Utah, 1987-1988*, U.S. Bureau of Reclamation, Research and Laboratory Services Division, Denver, Colo., July.
- Grady, J., 1984, *Northwest Colorado Prehistoric Context*, State Historical Society of Colorado, Denver, Colo.
- Hafen, L.R. (editor), 1948, *Colorado and Its People: A Narrative of Topical History of the Centennial State*, Vol. 1, Lewis Historical Publishing Co., New York, N.Y.
- Hafen, L.R. (editor), 1972, *The Mountain Men and Fur Trade of the Far West*, Arthur H. Clark Co., Glendale, Calif.

- Haines, G., and H.M. Tyus, 1990, "Fish Associations and Environmental Variables in Age-0 Colorado Squawfish Habitats, Green River, Utah," *Journal of Freshwater Ecology* 5(4): 427-435.
- Hall, M., 1992, memorandum from Hall (Vernal, Utah) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), June 12.
- Hansen, W.R., 1975, *The Geologic Story of the Uinta Mountains*, Geological Survey Bulletin 1291, U.S. Geological Survey, Alexandria, Va.
- Hansen, W.R., 1987, *The Black Canyon of the Gunnison in Depth*, Southwest Parks and Monuments Association, Tucson, Ariz.
- Harris, R.E., 1991, letter from Harris (U.S. Fish and Wildlife Service, Salt Lake City, Utah) to L. Greiner (Western Area Power Administration, Salt Lake City, Utah), July 10.
- Harris, R.E., 1992, *Gunnison River Study Flows — Aspinall Section 7 Consultation*, memorandum from Harris (Field Supervisor, U.S. Fish and Wildlife Service, Colorado/Utah Fish and Wildlife Enhancement, Salt Lake City, Utah) to Project Manager (Bureau of Reclamation, Grand Junction Project Office, Grand Junction, Colo.), April 16.
- Haury, L.R., 1986, *Zooplankton of the Colorado River Glen Canyon Dam to Diamond Creek*, prepared for U.S. Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Salt Lake City, Utah, Oct.
- Hebein, S., 1992, letter from Hebein (Colorado Division of Wildlife, Montrose, Colo.) to J.W. Hayse (Argonne National Laboratory, Argonne, Ill.), Dec. 7.
- Hebein, S., 1993, telecommunication from Hebein (Colorado Division of Wildlife, Gunnison, Colo.) to I. Hlohowskyj (Argonne National Laboratory, Argonne, Ill.), Aug. 17.
- Hereford, R., et al., 1993, *Surficial Geology, Geomorphology, and Erosion of Archaeologic Sites along the Colorado River, Eastern Grand Canyon National Park, Arizona*, Open-File Report 93-517, U.S. Geological Survey, Denver, Colo.
- Hoffmeister, D.F., 1986, *Mammals of Arizona*, University of Arizona Press, Tucson, Ariz.
- Holden, M., 1992, *Information for WAPA EIS, Utah*, letter from Holden (Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah) to J.W. Hayse (Argonne National Laboratory, Argonne, Ill.), July 8.
- Holden, P.B., 1991, "Ghosts of the Green River: Impacts of Green River Poisoning on Management of Native Fishes," in *Battle Against Extinction: Native Fish Management in the American West*, W.L. Minckley and J.E. Deacon (editors), University of Arizona Press, Tucson, pp. 43-54.

- Holden, P.B., and L.W. Crist, 1981, *Documentation of Changes in the Microinvertebrate and Fish Populations in the Green River Due to Inlet Modification of Flaming Gorge Dam*, Final Report, No. PR-16-5, BIO/WEST, Inc., Logan, Utah, March.
- Holmgren, A.H., 1962, *The Vascular Plants of the Dinosaur National Monument*, Utah State University, Logan, Utah.
- Howe, F., 1992, letter from Howe (Utah Department of Natural Resources, Division of Wildlife Resources, Nongame Avian Program, Salt Lake City, Utah) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Oct. 30.
- Huffman, D.K., 1992, letter from Huffman (Dinosaur National Monument, Dinosaur, Colo.) to R.L. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Oct. 28.
- Hughes, J.D., 1977, *American Indians in Colorado*, Pruett Publishing Co., Boulder, Colo.
- Jennings, J.D., 1978, *Prehistory of Utah and Eastern Great Basin*, University of Utah Anthropological Papers 98, University of Utah Press, Salt Lake City, Utah.
- Jennings, J.D., 1989, *Prehistory of North America*, 3rd ed., Mayfield Publishing Co., Mountain View, Calif.
- Johnson, C.D., 1992, letter from Johnson (U.S. Fish and Wildlife Service, Salt Lake City, Utah) to I. Hlohowskyj (Argonne National Laboratory, Argonne, Ill.), March 30.
- Johnson, J.E., et al., 1987, *Flaming Gorge Tailwater Fisheries Investigations: Growth, Survival and Microhabitat Selection in the Green River of Utah, 1978-1982*, Publication No. 87-13, Utah Division of Wildlife Resources, Salt Lake City, Utah.
- Johnson, W., 1992, letter from Johnson (Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Oct. 26.
- Jones, B.A., 1986, *The Curecanti Archaeological Project: 1981 Investigation in Curecanti National Recreation Area, Colorado*, Midwest Archaeological Center Occasional Papers in Anthropology, No. 14, National Park Service, Midwest Archaeological Center, Lincoln, Neb.
- Jones, B.A., 1992, letter from Jones (National Park Service, Midwest Archaeological Center, Lincoln, Neb.) to K.L. Moeller (Argonne National Laboratory, Argonne, Ill.), Jan. 9.
- Kaeding, L.R., and D.B. Osmundson, 1988, "Interaction of Slow Growth and Increased Early-Life Mortality: An Hypothesis on the Decline of the Colorado Squawfish in the Upstream Regions of Its Historic Range," *Environmental Biology of Fishes* 22(4):287-298.
- Kaeding, L.R., and M.A. Zimmerman, 1983, "Life History and Ecology of the Humpback Chub in the Little Colorado and Colorado Rivers of the Grand Canyon," *Transactions of the American Fisheries Society* 112(5):577-594.

- Kaeding, L.R., et al., 1986, "Recent Capture of a Bonytail (*Gila elegans*) and Observations on this Nearly Extinct Cyprinid from the Colorado River," *Copeia* 1986(4):1021-1023.
- Karp, C.A., and H.M. Tyus, 1990a, "Behavioral Interactions between Young Colorado Squawfish and Six Fish Species," *Copeia* 1990(1):25-34.
- Karp, C.A., and H.M. Tyus, 1990b, "Humpback Chub (*Gila cypha*) in the Yampa and Green Rivers, Dinosaur National Monument, with Observations on Roundtail Chub (*G. robusta*) and Other Sympatric Fishes," *Great Basin Naturalist* 50(3):257-264.
- Kelly, I.T., 1964, *Southern Paiute Ethnography*, University of Utah Anthropological Papers 69 (Glen Canyon Series 21), University of Utah Press, Salt Lake City, Utah.
- Kjos, C.G., 1992, "Bald Eagle Numbers Continue to Rise," *U.S. Fish and Wildlife Service Endangered Species Technical Bulletin* 17(1-2):3-4.
- Klein, M.L., 1992, letter from Klein (The Nature Conservancy, Boulder, Colo.) to J.W. Hayse (Argonne National Laboratory, Argonne, Ill.), March 17.
- Lanigan, S.H., and H.M. Tyus, 1989, "Population Size and Status of the Razorback Sucker in the Green River Basin, Utah and Colorado," *North American Journal of Fisheries Management* 9:68-73.
- Leach, L.L., 1970, "Swelter Shelter, 42UN40," in *Archaeological Excavations in Dinosaur National Monument, Colorado-Utah, 1964-1965*, University of Colorado Studies, Series in Anthropology, No. 17, D.A. Breternitz (editor), University of Colorado Press, Boulder, Colo., pp. 127-135, Aug.
- Lehman, R., 1992, transmittal from Lehman (Uncompaghe Valley Water Association, Montrose, Colo.) to S.C.L. Yin (Argonne National Laboratory, Argonne, Ill.), Sept. 21.
- Leibfried, W.C., and D.W. Blinn, 1987, *The Effects of Steady Versus Fluctuating Flows on Aquatic Macroinvertebrates in the Colorado River below Glen Canyon Dam, Arizona*, prepared for the Arizona Game and Fish Department, Phoenix, Ariz., June.
- Leopold, L.B., et al., 1964, *Fluvial Processes in Geomorphology*, W.H. Freeman and Co., San Francisco, Calif.
- Lindsay, L.W., 1986, *Brown's Park Chaining Archaeological Survey Project*, Utah Division of State History, Antiquities Section, Salt Lake City, Utah.
- Lister, R.H., 1962, *Archaeological Survey of the Blue Mesa Reservoir, Colorado*, U.S. National Park Service, Midwest Archaeological Center, Lincoln, Neb., Aug.
- Loomis, J.B., 1987, *An Economic Evaluation of Public Trust Resources of Mono Lake*, Institute of Ecology Report No. 30, University of California, Davis, Calif.

- Maddux, H.R., et al., 1987, *Evaluation of Varied Flow Regimes on Aquatic Resources of Glen and Grand Canyons*, prepared for U.S. Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Salt Lake City, Utah, April.
- Madsen, D.B., and K. Sargent, 1979, *An Archaeological Inventory of the Brown's Park Land Exchange*, Bureau of Land Management, Utah State Office, Salt Lake City, Utah, May 24.
- Malm, W.C., 1989, "Atmospheric Haze: Its Source and Effects on Visibility in Rural Areas of the Continental United States," *Environmental Monitoring and Assessment* 12:203-225.
- Malm, W.C., et al., 1990, "An Investigation of the Dominant Source Regions of Fine Sulfur in the Western United States and Their Areas of Influence," *Atmospheric Environment* 24A(12):3047-3060.
- Marsh, C.S., 1982, *The Utes of Colorado: People of the Shining Mountains*, Pruett Publishing Co., Boulder, Colo.
- Marsh, P.C., and D.R. Langhorst, 1988, "Feeding and Fate of Wild Larval Razorback Sucker," *Environmental Biology of Fishes* 21(1):59-67.
- McAda, C.W., and L.R. Kaeding, 1989, *Relations between Maximum-Annual River Discharge and the Relative Abundance of Age-0 Colorado Squawfish and Other Fishes in the Upper Colorado River*, U.S. Fish and Wildlife Service, Colorado River Fisheries Project, Grand Junction, Colo.
- McFadden, T., 1978, *A Cultural Resource Survey of the Northwest Corporation Pipeline Pinyon-Juniper Pushover*, U.S. Forest Service, Region Four, Ashley National Forest, Vernal, Utah, Nov. 2.
- Minckley, W.L., 1991, "Native Fishes of the Grand Canyon Region: An Obituary?" in *Colorado River Ecology and Dam Management: Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico*, National Academy Press, Washington, D.C., pp. 124-177.
- Minckley, W.L., and G.K. Meffe, 1987, "Differential Selection by Flooding in Stream-Fish Communities of the Arid American Southwest," in *Community and Evolutionary Ecology of North American Stream Fishes*, W.J. Matthews and D.C. Heins (editors), University of Oklahoma Press, Norman, Okla., pp. 93-104.
- Minckley, W.L., et al., 1991, "Management toward Recovery of the Razorback Sucker," in *Battle against Extinction: Native Fish Management in the American West*, W.L. Minckley and J.E. Deacon (editors), University of Arizona Press, Tucson, Ariz., pp. 303-357.
- Modde, T., 1993, telecommunication from Modde (U.S. Fish and Wildlife Service, Vernal, Utah) to I. Hlohowskyj (Argonne National Laboratory, Argonne, Ill.), Aug. 17.

Modde, T., et al., 1991, *Evaluation of Factors Influencing Population Characteristics and Habitat Utilization of Trout in the Flaming Gorge Tailwater, 1987-1989*, Publication No. 91-10, Flaming Gorge Tailwater Studies, Utah Division of Wildlife Resources, Salt Lake City, Utah.

Moeller, K.L., et al., 1993a, *Class I Overview of Cultural Resources for the Western Area Power Administration Salt Lake City Area Integrated Projects Electric Power Marketing Environmental Impact Statement*, ANL/EAD/TM-1, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Moeller, K.L., et al., 1993b, unpublished data, Argonne National Laboratory, Argonne, Ill.

Morey, M.J., and M.D. Ungson, 1993, *Statistical Analysis of the Demand for Electricity and Forecasts of Demand and Load Growth by Major Rate Class and System for Customers of the Western Area Power Administration*, prepared by Center for Regulatory Studies, for Argonne National Laboratory, Argonne, Ill., April 22.

Naumann, T., 1990, *Inventory of Plant Species of Special Concern and the General Flora of Dinosaur National Monument 1987-1989*, prepared by Colorado Natural Areas Program for National Park Service, Denver, Colo., April 3.

Nevada Bureau of Air Quality, 1989, *1987-1988 Trend Report*, Department of Conservation and Natural Resources, Division of Environmental Protection, Carson City, Nev.

Norman, V.G., and D.B. Merrill, 1981, *Cultural Resources Survey of the Flaming Gorge Peaking Power Project*, MESA CRM Paper No. 4, prepared by MESA Corporation, Salt Lake City, Utah, for Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah, Nov. 9.

NPS (National Park Service), undated, *Dinosaur National Monument River Mileage and Campsite Information*, National Park Service, Dinosaur National Monument, Dinosaur, Colo.

NPS, 1980, *Curecanti National Recreation Area General Management Plan*, National Park Service, Denver, Colo., July.

NPS, 1985, *Statement for Management, Grand Canyon National Park, Arizona*, National Park Service, Grand Canyon National Park, Grand Canyon, Ariz., April.

NPS, 1986a, *General Management Plan, Development Concept Plans, Land Protection Plan, Environmental Assessment, Dinosaur National Monument, Moffat County, Colorado and Uintah County, Utah*, U.S. Department of the Interior, Washington, D.C.

NPS, 1986b, *Dinosaur National Monument, Colorado/Utah*, National Park Service, Washington, D.C.

NPS, 1988, *Monthly Public Use Report*, National Park Service, Dinosaur National Monument, Dinosaur, Colo., Dec.

NPS, 1989, *Monthly Public Use Report*, National Park Service, Dinosaur National Monument, Dinosaur, Colo., Dec.

NPS, 1990a, *Curecanti National Recreation Area Statement for Management*, NPS D-13f, National Park Service, Washington, D.C., Nov.

NPS, 1990b, *Recent Archaeological Surveys in Curecanti National Recreation Area*, Midwest Archaeological Center, National Park Service, Lincoln, Neb., March 16.

NPS, 1990c, *Monthly Use Report*, National Park Service, Dinosaur National Monument, Dinosaur, Colo., Dec.

NPS, 1991, *Monthly Public Use Report*, National Park Service, Dinosaur National Monument, Dinosaur, Colo., Dec.

NPS, 1992a, *Annual Visitation Grand Canyon National Park, 1915-1991*, National Park Service, Grand Canyon, Ariz.

NPS, 1992b, Unpublished boating data on file, Dinosaur National Monument, Dinosaur, Colo.

NPS, 1993, *Final Wilderness Recommendation 1993 Update*, Grand Canyon National Park, Grand Canyon, Ariz.

O'Kane, S.L., Jr., 1988, "Colorado's Rare Flora," *Great Basin Naturalist* 48:434-484.

Omernik, J.M., and A.L. Gallant, 1987a, *Ecoregions of the Southwest States*, EPA/600/D-87/316, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Ore., Sept.

Omernik, J.M., and A.L. Gallant, 1987b, *Ecoregions of the South Central States*, EPA/600/D-87/315, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Ore., Sept.

Osmundson, D.B., and L.R. Kaeding, 1991, *Recommendations for Flows in the 15-Mile Reach During October-June for Maintenance and Enhancement of Endangered Fish Populations in the Upper Colorado River, Final Report*, U.S. Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, Colo.

Pague, K.E., 1992, letter from Pague (Colorado Natural Heritage Program, Boulder, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Nov. 3.

Palmer, S.C., and J. Ancrile, 1993, *The Stanley Palmer Alternatives Screening Method (SPASM)*, Western Area Power Administration, Salt Lake City, Utah.

Peterson, R.T., 1990, *A Field Guide to Western Birds: A Completely New Guide to Field Marks of All Species Found in North America West of the 100th Meridian and North of Mexico*, 3rd ed., Houghton Mifflin Co., Boston, Mass.

- Powell, J.W., 1875, *Exploration of the Colorado River of the West and Its Tributaries*, Government Printing Office, Washington, D.C.
- Pratt, J., et al., 1991, *The Recreation Use Capacity of the Green River Corridor below Flaming Gorge Dam*, Institute for Human Ecology, Sonoma, Calif., April.
- Pucherelli, M.J., 1986, *Evaluation of Riparian Vegetative Trends in the Grand Canyon Using Multitemporal Remote Sensing Techniques*, prepared by U.S. Bureau of Reclamation, Denver Engineering and Research Center, Denver, Colo., for Glen Canyon Environmental Studies, Salt Lake City, Utah, March 26.
- Pucherelli, M.J., et al., 1990, *Mapping Backwater Habitat on the Green River as Related to the Operation of Flaming Gorge Dam and Using Remote Sensing and GIS*, U.S. Bureau of Reclamation, Applied Sciences Branch, Research and Laboratory Services Division, Denver, Colo., Sept.
- Purdy, W.M., 1959, *An Outline of the History of the Flaming Gorge Area*, University of Utah Anthropological Papers, 37 (Upper Colorado Series 1), University of Utah Press, Salt Lake City, Utah, March.
- Reclamation (U.S. Bureau of Reclamation), 1983, *Colorado River Storage Project (Under Construction), Arizona, New Mexico, Colorado, Utah, and Wyoming*, U.S. Bureau of Reclamation, Upper Colorado Region, Denver, Colo., Oct.
- Reclamation, 1988, *Glen Canyon Environmental Studies Final Report* (Revised May 1989), U.S. Bureau of Reclamation, Salt Lake City, Utah, Jan.
- Reclamation, 1990a, *Historic Streamflows, Water Releases, and Reservoir Storage for Glen Canyon and Lake Powell, Baseline Reference Data for Glen Canyon Dam EIS*, U.S. Bureau of Reclamation, Denver, Colo.
- Reclamation, 1990b, *Final Environmental Impact Statement, AB Lateral Hydropower Facility, Uncompahgre Valley Reclamation Project, Montrose and Delta Counties, Colorado*, Vol. I, U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah, Aug. 28.
- Reclamation, 1992, *Public Information Packet, Proposed Contract to Deliver Water from the Wayne N. Aspinall Unit to the Black Canyon of the Gunnison National Monument*, U.S. Bureau of Reclamation, National Park Service, Bureau of Land Management, and Colorado Water Conservation Board, Grand Junction, Colo.
- Reclamation, 1993, *Operation of Glen Canyon Dam Colorado River Storage Project, Arizona, Draft Environmental Impact Statement*, U.S. Bureau of Reclamation, Salt Lake City, Utah.
- Riley, L., 1992, letter from Riley (Arizona Game and Fish Department, Phoenix, Ariz.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Oct. 28.

Rose, A., and O. Frias, 1993, *Economic Impacts of Water-Related Recreational Activity in the Flaming Gorge and Aspinall Regions*, prepared by Adam Rose and Associates, State College, Penn., for Argonne National Laboratory, Argonne, Ill., Feb. 10.

Rose, K.L., 1992, letter from Rose (U.S. Fish and Wildlife Service, Grand Junction, Colo.) to I. Hlohowskyj (Argonne National Laboratory, Argonne, Ill.), Jan. 8.

Sabo, D., 1992a, letter from Sabo (Western Area Power Administration, Salt Lake City Area Office, Salt Lake City, Utah) to L. Duncan (Ute Indian Tribe of the Uintah and Ouray Reservation, Uintah and Ouray Tribal Business Committee, Fort Duchesne, Utah), Aug. 3.

Sabo, D., 1992b, letter from Sabo (Western Area Power Administration, Salt Lake City Area Office, Salt Lake City, Utah) to E. James (San Juan Southern Paiute Tribal Council, Tuba City, Ariz.), J. Knight-Frank (Ute Mountain Tribe, Towaoc, Colo.), and L. Burch (Southern Ute Tribe, Ignacio, Colo.), Oct. 15.

Sams, S.T., 1992, letter from Sams (U.S. Forest Service, Flaming Gorge Ranger District, Manila, Utah) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), July 10.

Sanders, L.D., et al., 1990, "Toward Empirical Estimation of the Total Value of Protecting Rivers," *Water Resources Research* 26(7):1345-1357.

Schaible, G.D., et al., 1989a, *A User's Manual for the Irrigation Production Data System (IPDS)*, U.S. Department of Agriculture, Economic Research Service, Resources and Technology Division, Washington, D.C., April.

Schaible, G.D., et al., 1989b, *Irrigation Production Data System (IPDS)*, U.S. Department of Agriculture, Economic Research Service, Resources and Technology Division, Washington, D.C. (accessed March 1993).

Schmidt, R.S., 1992, letter from Schmidt (Bureau of Land Management, Colorado State Office, Branch of Realty Programs, Lakewood, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), July 29.

Schnurr, P.M., 1992, letter from Schnurr (Colorado Department of Natural Resources, Division of Wildlife, Denver, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), Oct. 29.

Schroedl, A.R., 1977, "The Paleo-Indian Period on the Colorado Plateau," *Southwestern Lore* 43(3):1-9.

Schwartz, D.W., 1963, "An Archaeological Survey of Nankoweap Canyon, Grand Canyon National Park," *American Antiquity* 28(3):289-302.

Schwartz, D.W., 1965, "Nankoweap to Unkar: An Archaeological Survey of the Upper Grand Canyon," *American Antiquity* 30(3):278-296.

- Scott, W.B., and E.J. Crossman, 1973, "Kokanee and Sockeye Salmon *Oncorhynchus nerka* (Walbaum)," in *Freshwater Fishes of Canada*, Bulletin 184, Fisheries Research Board of Canada, Ottawa, pp. 165-171.
- Shelby, B., et al., 1992, *Streamflow and Recreation*, General Technical Report RM-209, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., Jan.
- Sigler, W.F., and J.W. Sigler, 1987, "Sockeye Salmon (Kokanee) *Oncorhynchus nerka* (Walbaum)," in *Fishes of the Great Basin: A Natural History*, University of Nevada Press, Reno, Nev., pp. 96-99.
- Smith, G., and R.G. Green, 1991, *Flaming Gorge Consolidated Hydrology Report*, U.S. Fish and Wildlife Service, Division of Water Resources, Region 6, Denver, Colo., Jan.
- Smithsonian Institution, 1920, "Explorations and Field-Work of the Smithsonian Institution in 1919: Archaeological Investigations in Utah and Arizona," *Smithsonian Miscellaneous Collections* 72(1):66-69.
- Spiller, S.F., 1991, memorandum from Spiller (U.S. Fish and Wildlife Service, Phoenix, Ariz.) to Field Supervisor (Utah/Colorado Field Office, U.S. Fish and Wildlife Service, Salt Lake City, Utah), May 9.
- Stanford, J.A., and J.V. Ward, 1982, "The Effects of Regulation on the Limnology of the Gunnison River: A North American Case Study," in *Regulated River*, A. Lillehammer and S.J. Salveit (editors), Universitetsforlaget AS, Oslo, Norway, pp. 467-480.
- Stanford, J.A., and J.V. Ward, 1991, "Limnology of Lake Powell and the Chemistry of the Colorado River," in *Colorado River Ecology and Dam Management*, National Academy Press, Washington, D.C., pp. 75-101.
- State of New Mexico Air Quality Bureau, 1990 *Annual Report: 1985-1988*, EID/AIR-90/1, New Mexico Environmental Department, Santa Fe, N.M.
- State of New Mexico Air Quality Bureau, 1991, *Annual Report: 1989-1990*, NMED/AQB-91/1, New Mexico Environmental Department, Santa Fe, N.M.
- Stebbins, R.C., 1966, *A Field Guide to Western Reptiles and Amphibians: Field Marks of All Species in Western North America*, Houghton Mifflin Co., Boston, Mass.
- Stephens, H.G., and E.M. Shoemaker, 1987, *In the Footsteps of John Wesley Powell: An Album of Comparative Photographs of the Green and Colorado Rivers, 1871-72 and 1968*, Johnson Books, Boulder, Colo., and The Powell Society, Denver, Colo.
- Stevens, L.E., and T.J. Ayers, 1993, *The Impacts of Glen Canyon Dam on Riparian Vegetation and Soil Stability in the Colorado River Corridor, Grand Canyon, Arizona: 1992 Final Report*, U.S. National Park Service, Cooperative Studies Unit, Flagstaff, Ariz., Jan. 31.

- Stevens, L.E., and G.L. Waring, 1986, *Effects of Post-Dam Flooding on Riparian Substrates, Vegetation, and Invertebrate Populations in the Colorado River Corridor in Grand Canyon, Arizona*, prepared by the National Park Service, Grand Canyon National Park, Grand Canyon, Ariz., for U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Salt Lake City, Utah, April 15.
- Stiger, M.A., 1977, *Archaeological Inventory and Cultural Assessment, Curecanti Recreation National Area, Colorado, Part II: Documentation*, University of Colorado, Mesa Verde Research Center, Boulder, Colo., Oct.
- Stiger, M.A., 1980, *Archaeological Inventory and Evaluation of Curecanti Recreation Area*, U.S. National Park Service, Midwest Archaeological Center, Lincoln, Neb.
- Taylor, W.W., 1958, "A Brief Survey through the Grand Canyon of the Colorado River," *Museum of Northern Arizona Bulletin* 30:18-30.
- Tennent, W.L., 1981, *John Jarvie of Brown's Park*, Cultural Resources Series, No. 7, Bureau of Land Management, Utah State Office, Salt Lake City, Utah.
- Tollefson, B.A., 1992, memorandum from Tollefson (Bureau of Land Management, Gunnison Resource Area, Gunnison, Colo.) to R.A. Van Lonkhuyzen (Argonne National Laboratory, Argonne, Ill.), March 31.
- Truesdale, J.A., et al., 1989, *Archaeological Investigations along the Echo Park Road, Dinosaur National Monument, Moffat County, Colorado*, U.S. National Park Service, Rocky Mountain Region, Dinosaur National Monument, Dinosaur, Colo., July 7.
- Tyus, H.M., 1987, "Distribution, Reproduction, and Habitat Use of Razorback Sucker in the Green River, Utah 1979-1986," *Transactions of the American Fisheries Society* 116:111-116.
- Tyus, H.M., 1990, "Potamodromy and Reproduction of Colorado Squawfish in the Green River Basin, Colorado and Utah," *Transactions of the American Fisheries Society* 119:1035-1047.
- Tyus, H.M., 1991a, "Ecology and Management of Colorado Squawfish," in *Battle against Extinction: Native Fish Management in the American West*, W.L. Minckley and J.E. Deacon (editors), University of Arizona Press, Tucson, Ariz., pp. 379-402.
- Tyus, H.M., 1991b, "Movements and Habitat Use of Young Colorado Squawfish in the Green River, Utah," *Journal of Freshwater Ecology* 6(1):43-51.
- Tyus, H.M., and J.M. Beard, 1990, "*Esox lucius* (Esocidae) and *Stizostedion vitreum* (Percidae) in the Green River Basin, Colorado and Utah," *Great Basin Naturalist* 50(1):33-39.
- Tyus, H.M., and G.B. Haines, 1991, "Distribution, Habitat Use, and Growth of Age-0 Colorado Squawfish in the Green River Basin, Colorado and Utah," *Transactions of the American Fisheries Society* 120:79-89.

- Tyus, H.M., and C.A. Karp, 1990, "Spawning Movements of Razorback Sucker, *Xyrauchen texanus*, in the Green River Basin of Colorado and Utah," *The Southwestern Naturalist* 35(4): 427-433.
- Tyus, H.M., and C.A. Karp, 1991, *Habitat Use and Streamflow Needs of Rare and Endangered Fishes in the Green River, Utah*, U.S. Fish and Wildlife Service, Flaming Gorge Studies Program, Colorado River Project Office, Vernal, Utah, July 31.
- Tyus, H.M., and N.J. Nikirk, 1990, "Abundance, Growth, and Diet of Channel Catfish, *Ictalurus punctatus*, in the Green and Yampa Rivers, Colorado and Utah," *Southwestern Naturalist* 35(2):188-198.
- Tyus, H.M., et al., 1982, "Fishes of the Upper Colorado River Basin: Distribution, Abundance and Status," in *Fishes of the Upper Colorado River System: Present and Future*, W.H. Miller et al. (editors), Western Division, American Fisheries Society, Bethesda, Md., Dec., pp. 12-70.
- U.S. Bureau of the Census, 1989, *1987 Census of Agriculture, Vol. 1: Geographic Area Series Part 6, Colorado State and County Data*, AC87-A-06, U.S. Department of Commerce, Washington, D.C.
- U.S. Bureau of the Census, 1991a, *1990 Census of Population and Housing: Summary Population and Housing Characteristics: Arizona*, CPH-1-4, U.S. Department of Commerce, Washington, D.C., Aug.
- U.S. Bureau of the Census, 1991b, *1990 Census of Population and Housing: Summary Population and Housing Characteristics: Utah*, CPH-1-46, U.S. Department of Commerce, Washington, D.C.
- U.S. Bureau of the Census, 1991c, *1990 Census of Population and Housing: Summary Population and Housing Characteristics: Colorado*, CPH-1-7, U.S. Department of Commerce, Washington, D.C.
- USFS (U.S. Forest Service), 1973, *National Forest Landscape Management*, Vol. 1, Agriculture Handbook Number 434, Department of Agriculture, U.S. Forest Service, Washington, D.C., Feb.
- USFS, 1974, *National Forest Landscape Management Plan*, Vol. 2, Agriculture Handbook Number 462, Department of Agriculture, U.S. Forest Service, Washington, D.C., April.
- USFS, 1984, *Green River Scenic Corridor Management Plan*, U.S. Forest Service, Ashley National Forest, Vernal, Utah.
- USFWS (U.S. Fish and Wildlife Service), 1977, *American Peregrine Falcon Recovery Plan (Rocky Mountain and Southwest Populations)*, Washington, D.C., Aug. 3.
- USFWS, 1978, *Impacts of Coal-Fired Power Plants on Fish, Wildlife, and their Habitats*, FWS/OBS-78/29, Office of Biological Services, Washington, D.C.

USFWS, 1990a, "Regional News, Region 6," *Endangered Species Technical Bulletin* 15(10):14.

USFWS, 1990b, "Ute Ladies'-tresses (*Spiranthes diluvialis*)," *Endangered Species Technical Bulletin* 15(12):4-5.

USFWS, 1990c, *Humpback Chub 2nd Revised Recovery Plan*, Colorado River Fishes Recovery Team, Region 6, Denver, Colo., Sept. 16.

USFWS, 1990d, *Bonytail Chub Revised Recovery Program*, Colorado River Fishes Recovery Team, Region 6, Denver, Colo., Sept. 4.

USFWS, 1991a, *Endangered and Threatened Wildlife and Plants (50 CFR 17.11 & 17.12)*, July 15, U.S. Government Printing Office, Washington, D.C.

USFWS, 1991b, *Colorado Squawfish Revised Recovery Plan*, Colorado Fishes Recovery Team, Region 6, Denver, Colo., Aug. 6.

USFWS, 1991c, "Endangered and Threatened Wildlife and Plants; the Razorback Sucker (*Xyrauchen texanus*) Determined to Be an Endangered Species (50 CFR Part 17)," *Federal Register* 56(205):54957-54967, Oct. 23.

USFWS, 1991d, "Endangered and Threatened Wildlife and Plants: Animal Candidate Review for Listing as Endangered or Threatened Species, Proposed Rule (50 CFR Part 17)," *Federal Register* 56(225):58804-58836, Nov. 21.

USFWS, 1992a, "Endangered and Threatened Wildlife and Plants; Final Rule to List the Kanab Ambersnail as Endangered (50 CFR Part 17)," *Federal Register* 57(75):13657-13661, April 17.

USFWS, 1992b, *Final Biological Opinion on the Operation of Flaming Gorge Dam*, Fish and Wildlife Service, Mountain-Prairie Region, Denver, Colo., Nov. 25.

USFWS, 1993a, "Endangered and Threatened Wildlife and Plants: Proposed Determination of Critical Habitat for the Colorado River Endangered Fishes: Razorback Sucker, Colorado Squawfish, Humpback Chub, and Bonytail Chub (50 CFR Part 17)," *Federal Register* 58(18):6578-6597, Jan. 29.

USFWS, 1993b, "Endangered and Threatened Wildlife and Plants: Proposed Determination of Critical Habitat for the Colorado River Endangered Fishes: Razorback Sucker, Colorado Squawfish, Humpback Chub, and Bonytail Chub; Correction (50 CFR Part 17)," *Federal Register* 48(48):13732, March 15.

USFWS, 1993c, "Endangered and Threatened Wildlife and Plants; Proposed Rule to List the Southwestern Willow Fly Catcher as Endangered with Critical Habitat (50 CFR Part 17)," *Federal Register* 58(140):39495-39522, July 23.

- USGS (U.S. Geological Survey), 1985, *1:2,000,000 Hydrologic Unit Map of the Conterminous United States*, Rev. 1.1, Reston, Va. (USGS database accessed Dec. 20, 1991).
- Usher, H.D., et al., 1987, *Cladophora glomerata and Its Diatom Epiphytes in the Colorado River through Glen and Grand Canyons: Distribution and Desiccation Tolerance*, prepared by Arizona Game and Fish Department, Phoenix, Ariz., for U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah, Sept.
- Utah Bureau of Air Quality, 1991, *Annual Air Quality Report, 1987 - 1990*, Air Monitoring Center, Salt Lake City, Utah.
- Utah Division of Wildlife Resources, 1992, *The Reintroduction of River Otter to the Green River, Utah: Progress Report II*, A cooperative study between Utah Division of Wildlife Resources, Non-Game Section; Brigham Young University; U.S. Forest Service, Ashley National Forest; and Bureau of Land Management, Salt Lake City, Utah, May.
- Valdez, R.A., and W.J. Masslich, 1989, *Winter Habitat Study of Endangered Fish — Green River: Wintertime Movement and Habitat of Adult Colorado Squawfish and Razorback Suckers*, Report No. 136-2, BIO/WEST Inc., Logan, Utah, April.
- Van Buren, R.S., and W.T. Burkhard, 1981, *Final Report for Kokanee Salmon Study of the Blue Mesa Peaking Power Modification Project*, Colorado Division of Wildlife, Grand Junction, Colo., Aug.
- Veselka, T.S., et al., 1994a, *Impacts of Western Area Power Administration's Power Marketing Alternatives on Electric Utility Systems*, ANL/DIS/TM-10, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.
- Veselka, T.S., et al., 1994b, *Relationships between Western Area Power Administration's Power Marketing Program and Hydropower Operations at Salt Lake City Area Integrated Projects*, ANL/DIS/TM-11, Argonne National Laboratory, Decision and Information Sciences Division, Argonne, Ill.
- Viessman, W., Jr., et al., 1977, *Introduction to Hydrology*, 2nd ed., Harper and Row, New York, N.Y.
- Walsh, R.G., et al., 1980, *An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow*, Completion Report No. 101, Colorado State University, Water Resources Research Institute, Fort Collins, Colo., Oct.
- Webb, R., 1986, *If We Had a Boat: Green River Explorers, Adventurers, and Runners*, University of Utah Press, Salt Lake City, Utah.
- Weber, D.A., 1991, *Cultural Resources Survey of Part of the Gunnison State Wildlife Area, Gunnison County, Colorado*, Colorado Division of Wildlife, Denver, Colo., March.

Wegner, D.L., 1992, *Interim Test Flows, Glen Canyon Environmental Studies Update*, Flagstaff, Ariz., Summer issue, p. 1.

Western (Western Area Power Administration), 1991a, "Intent to Prepare an Environmental Impact Statement on the Proposal to Establish an Energy Planning and Management Program," *Federal Register* 56(19):995-996, May 1.

Western, 1991b, "EIS Statement of Scope," in *Electric Power Marketing EIS Update for the Salt Lake City Area Integrated Projects*, Western Area Power Administration, Salt Lake City Area Office, Salt Lake City, Utah, April 22.

Wheat, D.C., 1989, *The Floater's Guide to Colorado*, The Falcon Press, Helena, Mont.

White, S., 1992, letter from White (Mohave County Planning and Zoning Commission, Kingman, Ariz.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Dec. 9.

Williams, G.P., and M.G. Wolman, 1984, *Downstream Effects of Dams on Alluvial Rivers*, Professional Paper 1286, U.S. Geological Survey, Washington, D.C.

Williams, J.M., 1993, letter from Williams (Gunnison County, Department of Planning, Building and Sanitation, Gunnison, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Jan. 22.

Williams, R.D., 1992, letter from Williams (U.S. Fish and Wildlife Service, Salt Lake City, Utah) to D. Sabo (Western Area Power Administration, Salt Lake City, Utah), Nov. 16.

Wuebbles, D.J., and J. Edmonds, 1991, *Primer on Greenhouse Gases*, Lewis Publishers, Chelsea, Mich.

Wyoming Air Quality Division, 1988, *Wyoming's Air Quality: Ambient Air Monitoring Data - 1987*, Department of Environmental Quality, Cheyenne, Wyo.

Wyoming Air Quality Division, 1989, *Wyoming's Air Quality: Ambient Air Monitoring Data - 1988*, Department of Environmental Quality, Cheyenne, Wyo.

Wyoming Air Quality Division, 1990, *Wyoming's Air Quality: Ambient Air Monitoring Data - 1989*, Department of Environmental Quality, Cheyenne, Wyo.

Wyoming Air Quality Division, 1991, *Wyoming's Air Quality: Ambient Air Monitoring Data - 1990*, Department of Environmental Quality, Cheyenne, Wyo.

Yates, C., 1992a, personal communication from Yates (U.S. Forest Service, Flaming Gorge National Recreation Area, Dutch John, Utah) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), June 9.

Yates, C., 1992b, telecommunication from Yates (U.S. Forest Service, Flaming Gorge National Recreation Area, Dutch John, Utah) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Nov. 13.

Yin, S.C.L., 1994a, *Effects of Flaming Gorge Dam Hydropower Operations on Flow and Stage in the Green River, Utah and Colorado*, ANL/EAD/TM-4, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Yin, S.C.L., 1994b, *Reservoir Release Patterns for Hydropower Operations at the Aspinall Unit on the Gunnison River, Colorado*, ANL/EAD/TM-5, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Zichterman, P., 1992a, letter from Zichterman (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Sept. 11.

Zichterman, P., 1992b, letter from Zichterman (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), Sept. 25.

Zichterman, P., 1992c, personal communication from Zichterman (National Park Service, Curecanti National Recreation Area, Gunnison, Colo.) to J.M. Pfingston (Argonne National Laboratory, Argonne, Ill.), July 9.

Western Reading Rooms

Copies of correspondence and other materials cited in this list that are not otherwise available to the public are available in the following reading rooms:

Arizona:

Flagstaff Public Library
300 W. Aspen
Flagstaff, Arizona 86001
(602) 779-7670

Page Public Library

697 Vista
P.O. Box 1776
Page, Arizona 86040
(602) 645-4270

Phoenix Public Library

Business and Science Department
12 E. McDowell
Phoenix, Arizona 85004
(602) 534-0596

Western Area Power Administration

Phoenix Area Office
615 S. 43rd Avenue
Phoenix, Arizona 85009-5313
(602) 352-2522

Colorado:**Denver Public Library**

Government Publications
1357 Broadway
Denver, Colorado 80203
(303) 640-8847

Western Area Power Administration

Loveland Area Office
5555 East Crossroads Blvd.
Loveland, Colorado 80537-8986
(303) 490-7201

Montrose Public Library

Reference
343 S. 1st Street
Montrose, Colorado
(303) 249-9656

New Mexico:**General Library**

University of New Mexico
Government Publications
Albuquerque, New Mexico 87131-1466
(505) 277-7180

Utah:**Salt Lake City Public Library**

209 E. 500 South
Salt Lake City, Utah 84111
(801) 524-8200

Uintah County Library

155 E. Main St.
Vernal, Utah 84078
(801) 789-0091

Washington, D.C.:**U.S. Department of Energy**

FOI Reading Room
Forrestal Building, Room 1E-190
1000 Independence Ave., S.W.
Washington, D.C. 20585
(202) 586-6020

12 LIST OF PREPARERS

This environmental impact statement (EIS) has been prepared by the Western Area Power Administration (Western) with contractual assistance from the Environmental Assessment and Information Sciences Division of Argonne National Laboratory (ANL). The following Western and ANL staff have contributed to the preparation of this EIS.

Name	Education/Experience	Contribution
David Sabo (Western)	M.S. Biology; 15 years experience in NEPA coordination; 7 years experience in utility power contracts, marketing, and operation	Summary, Ch. 1 Introduction, Ch. 2 Alternatives
S. Clayton Palmer (Western)	M.A. Economics; 8 years experience in energy and natural resource economics; 3 years experience in NEPA coordination	Summary, Ch. 1 Introduction, Ch. 2 Alternatives, Socioeconomics
Jeffrey J. McCoy (Western)	B.S. Civil Engineering; 10 years experience in power marketing resource planning and analysis	Ch. 2 Alternatives, Socioeconomics
Timothy Allison (ANL)	M.A. Geography, MS Mineral and Energy Resource Economics; 10 years experience in regional analysis and economic development policy	Regional Economics
J. Lon Carlson (ANL)	Ph.D. Economics; 11 years experience in environmental and resource economics and environmental regulation	Project Leader, Socioeconomics, Recreation
James Cavallo (ANL)	Ph.D. Economics; 13 years experience in energy demand modeling and forecasting impacts of demand-side management programs	Demand Management, Conservation and Renewable Energy
Young-Soo Chang (ANL)	Ph.D. Chemical Engineering; 6 years experience in air quality impact analysis	Air Resources
Eugene Cho (ANL)	B.S. Physics; 3 years experience in groundwater analysis	Water Resources
Kyong C. Chun (ANL)	Ph.D. Environmental Health Engineering; 20 years experience in air quality and environmental assessment	Air Resources
John D. DePue (ANL)	M.S. Biology, 22 years experience in editing and journalism	Technical Editor
Lisa Durham (ANL)	M.S. Geology; 5 years experience in hydrogeologic analysis	Water Resources
Brian Edwards (ANL)	Ph.D. Economics; 15 years experience in energy, regional and resource economics	Agricultural Economics

Name	Education/Experience	Contribution
Silvio J. Flaim (ANL)	Ph.D. Economics; 20 years experience in energy and regional economic assessment	Summary, Ch. 1 Introduction, Ch. 2 Alternatives, Agricultural Economics
Rebecca Haffenden (ANL)	J.D. Law; 3 years experience in environmental assessment	Statutes, Regulations, Orders, Permits
John Hayse (ANL)	Ph.D. Ecology; 7 years experience in aquatic ecology	Aquatic Ecology, Threatened and Endangered Species (Flaming Gorge)
Ross Hemphill (ANL)	Ph.D. Resource Economics; 15 years experience in energy, regulatory and environmental economics	Finance and Rates
Ihor Hlohowskyj (ANL)	Ph.D. Zoology; 19 years experience in aquatic and terrestrial ecosystems; 16 years experience in environmental assessment	Ecological Resources, Aquatic Ecology, Threatened and Endangered Species
John R. Hoffecker (ANL)	Ph.D. Anthropology; 17 years experience in archaeological research; 9 years experience in environmental assessment	Cultural Resources
Kirk E. LaGory (ANL)	Ph.D. Zoology; 19 years experience in ecological research; 10 years experience in environmental assessment	Project Leader, Natural Resources, Terrestrial Ecology, Wetlands, Threatened and Endangered Species
Konstance L. Moeller (ANL)	M.A. Anthropology; 6 years experience in cultural resources assessment	Cultural Resources
Lee Northcutt (ANL)	Administrative Aide; 3 years experience in environmental impact statements; 12 years of editorial and program management assistance	Glossary, Acronyms, List of Preparers, List of Recipients
John M. Pfingston (ANL)	M.A. History; M.P.A. Environmental Administration; 5 years experience in energy and natural resource research; 3 years experience in environmental assessment and land-use analysis	Land Use, Recreation, Visual Resources
David Tomasko (ANL)	Ph.D. Civil Engineering; 18 years experience in water resources	Water Resources
Robert Van Lonkhuyzen (ANL)	B.A. Biology; 4 years experience in ecological and environmental research, wetlands delineation and assessment	Terrestrial Ecology, Wetlands, Threatened and Endangered Species

Name	Education/Experience	Contribution
Bruce Verhaaren (ANL)	Ph.D. Archaeology; 9 years experience in archaeological analysis; 5 years experience with environmental impact statements	References
Tom Veselka (ANL)	M.S. Meteorology; 13 years experience in environmental modeling and power systems application	Power Systems
Gustavious Williams (ANL)	B.S. Civil Engineering; 4 years experience in environmental hydrology	Water Resources
Dimis J. Wyman (ANL)	M.S. Botany; M.A. Library Science; 18 years experience in technical editing	Technical Editor
Stephen C.L. Yin (ANL)	M.S. Water Resources; 19 years experience in hydrological analysis, water resource planning, and environmental assessment	Water Resources

13 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

AFS	American Fisheries Society
AGC	automatic (automated) generation control (see glossary)
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
AOAQ	Arizona Office of Air Quality
AQCR	Air Quality Control Region (see glossary)

BART	Best Available Retrofit Technology
BLM	Bureau of Land Management

C&RE	conservation and renewable energy
CAPCD	Colorado Air Pollution Control Division
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second (see glossary)
Cir.	Circuit
Co.	County
CO	carbon monoxide
CO ₂	carbon dioxide
COE	Corps of Engineers (U.S. Army)
CPI	Consumer Price Index
CRSP	Colorado River Storage Project (see glossary)
CRSS	Colorado River Simulation System
CV	contingent valuation
C _v	coefficient of variation
CWA	Clean Water Act

d	day(s)
dBA	decibel (A-weighted) (see glossary)
D/E	debt-to-equity ratio
DEIS	draft environmental impact statement
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DSM	demand-side management

EA	environmental assessment
e.g.	for example
EIA	Energy Information Administration
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EPAMP	Energy Planning and Management Program
EPRI	Electric Power Research Institute
et al.	and others
et seq.	and the following
ex rel.	out of other things

Fed. Reg.	Federal Register
FEIS	Final Environmental Impact Statement
FONSI	Finding of No Significant Impacts
ft	foot (feet)
ft/s	feet per second
ft ²	square feet
ft ² /mi	square feet per mile
GCES	Glen Canyon Environmental Studies
GRP	gross regional product (see glossary)
GWh	gigawatt hour(s)
h	hour(s)
ha	hectare(s)
h/day	hours per day
H ₂ S	hydrogen sulfide
I	interstate
i.e.	that is
in.	inch(es)
I-O	input-output
IP	Integrated Projects
IPP	Inland Power Pool
IRP	Integrated Resource Plan
km	kilometer(s)
kV	kilovolt(s)
kW	kilowatt(s) (see glossary)
kWh	kilowatt-hour(s) (see glossary)
LDC	load duration curve
L _{dn}	day-night-weighted equivalent sound level (see Section 3.2.3)
L _{eq}	equivalent sound level (see Section 3.2.3)
LTF	long-term firm
m	meter(s)
m ³ /s	cubic meters per second
maf	million acre-feet
max	maximum
μg	microgram(s)
μg/m ³	micrograms per cubic meter
μm	micrometer(s)
mg	milligram(s)
mg/L	milligrams per liter
mi	mile(s)
mi ²	square mile(s)
mm	millimeter(s)
mph	miles per hour
MSL	mean sea level
MSS	multispectral scanner

MW	megawatt(s) (see glossary)
MWh	megawatt-hour(s)
NAAQS	National Ambient Air Quality Standards (see glossary)
NBAQ	Nevada Bureau of Air Quality
NCDC	National Climatic Data Center
NCF	net cash flow
NEPA	National Environmental Policy Act
No.	number
NO ₂	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO _x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NPV	net product value
NRA	National Recreational Area
NRHP	National Register of Historic Places (see glossary)
NWF	National Wildlife Federation
O ₃	ozone
Pb	lead
PDEIS	preliminary draft environmental impact statement
PEPCO	Potomac Electric Power Company
P.L.	Public Law
PM	particulate matter
PM ₁₀	particulate matter with a diameter of $\leq 10 \mu\text{m}$
PMI	Power Marketing Initiative
RCRA	Resource Conservation and Recovery Act
RM	river mile
ROD	Record of Decision
SAAQS	State Ambient Air Quality Standards
SHPO	State Historic Preservation Officer
SLCA	Salt Lake City Area
SLCA/IP	Salt Lake City Area Integrated Projects
SLCAO	Salt Lake City Area Office
SMN	Spot Market Network
SNMAQB	State of New Mexico Air Quality Board
SO ₂	sulfur dioxide
spp	many species
SRP	Salt River Project
Stat.	statute
STF	short-term firm
Supp.	Supplement
TM	Technical Memorandum
TSP	total suspended particulate(s)

UBAQ	Utah Air Quality Board
UPA	urban planning area
U.S.	United States
USC	U.S. Code
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
vol	volume
WAQD	Wyoming Air Quality Division
WAUC	Western Area Upper Colorado (control area)
WTP	willingness to pay (see glossary)
WUA	weighted usable area (see glossary)
yr	year(s)
~	approximately
#	number
\$/kWh	price per kilowatt hour
\$/MWh	price per megawatt hour
%	percent
+	plus
-	minus
/	per
<	less than
<= or ≤	less than or equal to
>= or ≥	greater than or equal to
=	equals
>	greater than
°	degrees
°C	degrees Celsius
°F	degrees Fahrenheit
±	plus or minus

14 GLOSSARY

A

abiotic: The physical, nonliving portion of the environment. (See biotic.)

absorption (electromagnetic): The taking up of energy from radiation by the medium through which the radiation is passing.

acoustic: Containing, producing, carrying, arising from, actuated by, related to, or associated with sound.

acre-foot: Volume of water (43,560 cubic feet) that would cover 1 acre, 1 foot deep.

aesthetic: Pertaining to the beautiful or pleasing; generally, an emotional judgment of that perceived.

affected environment: Existing biological, physical, social, and economic conditions of an area subject to change, both directly and indirectly, as the result of a proposed human action.

aggradation: Process of filling and raising the level of a streambed or floodplain by deposition of sediment.

aggregation: Process of combining or collecting data or results to describe a whole from the sum or combination of its parts.

air quality: Measure of the health-related and visual characteristics of the air, often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances.

Air Quality Control Region (AQCR): An interstate area designated by the

U.S. Environmental Protection Agency as necessary or appropriate for the attainment and maintenance of national ambient air quality standards.

air quality standards: The prescribed level of constituents in the outside air that cannot be exceeded during a specific time in a specified area.

algae: Primarily aquatic, nonvascular plants containing chlorophyll. (See *Cladophora* and diatoms.)

algorithm: A procedure for solving a mathematical problem in a finite number of steps that frequently involve repetition of an operation.

alluvial, alluvium: Relating to material deposited by running water, such as clay, silt, sand, and gravel. Sedimentary material transported and deposited by the action of flowing water.

alluvial fan: Cone-shaped deposits of alluvium made by a stream. Fans generally form where streams emerge from mountains onto the lowland. (See fans and debris fans.)

ambient: The surrounding natural conditions (or environment) in a given place and time.

ambient air: The surrounding atmosphere as it exists around people, plants, and structures.

amphibians: A class of vertebrate animals that are capable of living either in water or on land but that must lay eggs in water (e.g., salamanders, frogs, toads).

amphipod: Any of a large group of small crustaceans with a laterally compressed body.

annual capacity factor: The ratio of the energy produced by a power plant during one year compared with the energy it could have produced if operated at maximum capacity under continuous operation during the whole year.

anthropogenic: Relating to or resulting from the presence of human beings and human activities.

anticline: A convex upward fold of rock.

aquatic: Living in or growing on the water.

archaeology: The scientific study of extinct peoples or of past phases of the culture of historic people through skeletal remains, fossils, and objects of human workmanship (artifacts) found in the earth.

armored, armoring: Removal of fine river-bed and river-bank sediments by high-velocity water movement.

arroyo: A gully or channel cut by an intermittent stream.

artifact: A man-made object of archaeological or historical interest.

attenuation: Decrease in the height and velocity of a water wave caused by interactions with deep pools, backwaters, and banks along the flow path.

automatic generation control (AGC): A computer control system to regulate the power output of electric generators within a range of operations to provide instantaneous response to changes in system frequency, control area load, system time

error and tie-line loading so as to maintain the scheduled generation in accordance with prescribed parameters.

B

backwater: Generally shallow area of a river with little or no current. May occur along the shoreline or within the river channel behind islands and sand or gravel bars.

baseline, electric power marketing: In this EIS, the baseline for electric power marketing is the 1978 Colorado River Storage Project (CRSP) Marketing Plan with certain modifications made by the court. The electric power marketing baseline includes the full complement of power resources available under historical programs for Provo River, Collbran, and Rio Grande Projects.

baseline, socioeconomic: In this EIS, the conditions predicted to prevail under the post-1989 marketing criteria for the years 1993 through 2008.

baseload: The minimum assigned load in a power system over a given period of time. Generation resource that is best suited to deliver relatively constant amounts of power over the entire day. Baseload may also refer to the minimum assigned load on a power system over a period of time.

beach: Depositional area along a shoreline covered by mud, sand, gravel, or larger rock fragments and extending into the water for some distance.

bedrock: Solid rock exposed at the surface of the earth or overlain by unconsolidated material.

benthic: Associated with the bottoms of surface waters, including rivers, lakes, and oceans.

benthos: Organisms living in or on the bottom of a lake, pond, stream, etc.

Biological Opinion: A document that states the opinion of the U.S. Fish and Wildlife Service as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.

biota: The plant and animal life of a region.

biotic: Pertaining to life or living organisms; the living portion of the environment. (See abiotic.)

C

candidate species: Plant or animal species that are not yet officially listed as threatened or endangered but are undergoing status review by the U.S. Fish and Wildlife Service. They are candidates for possible addition to the list of threatened and endangered species. (See Appendix D.)

capacity: The rated output of a generator, and also the capability of a transmission line to carry power. Capacity is frequently used to define the amount of generation reserved for an entity's use under a contract. Capacity is measured in such terms as watts, kilowatts, and megawatts. The load for which a generator, turbine, transformer, transmission, transmission circuit, apparatus, station, or system is rated. Capacity is used synonymously with capability. Capacity is

also used to define the maximum amount of power that Western's customers may take at any point in time.

channel: Natural or artificial watercourse with a definite bed and banks to confine and conduct continuously or periodically flowing water.

channel margin bar: Narrow sand deposits that continuously or discontinuously line a riverbank.

chironomid: Type of fly commonly referred to as a midge. Eggs are laid in freshwater and hatch into worm-like larvae that remain aquatic. When mature, chironomids leave the water, often in large, flying swarms of gnat-like adults.

Cladophora: Filamentous green alga occurring in flowing water that attaches itself to hard substrates such as cobble and boulders; grows in long, moss-like strands.

Class I, II, III (rapids): Class I rapids feature small riffle-like waves and slow-to-moderate currents ideal for beginning boaters; Class II rapids generate waves up to one foot high and faster currents that require basic white-water skills. Class III or above rapids require superior white-water skills and can generate fast currents and waves up to three feet high.

colluvial (deposits): Relating to deposition by a combination of gravity and water.

Colorado River Basin States: States that are drained by or entitled to water from the Colorado River and its tributaries.

Colorado River Storage Project: Act of Congress establishing the legislative

authority to construct, operate, and maintain impoundments, diversions, hydro-power generation facilities, and other features on the Colorado River and its tributaries.

commitment-level alternatives: The level of Western's commitment for sales of long-term, firm power and energy generated by the Salt Lake City Area Integrated Projects, as well as power and energy purchased from other sources. (See Section 2.2.2 for a description of these alternatives.)

community: A group of organisms comprising a number of different species that co-occur in the same habitat or area.

concentration values: Theoretical city-wide average pollutant concentrations developed over urban areas, based on a simple dispersion model, normalized for uniform average area emission rate.

constriction ratio: Ratio of narrowed channel width to unblocked channel width.

contingent valuation: Method asking for the maximum values that users would pay for access to a particular activity.

cooperative: Joint venture organized to supply electric energy to a specified area.

coverage ratio: Measure of the ratio of cash flow or interest expense on debt. It is an industry-wide standard that the coverage ratio should be >2.0 .

criteria: Elements of Western's power marketing programs that define the amounts and conditions for delivery of long-term firm power and energy offered for sale. The criteria have been known as marketing and eligibility criteria under the

1978 marketing plan because the criteria also specify who qualifies for an allocation. (See preference customers.)

crustaceans: Any of a large class of mostly aquatic arthropods, including lobsters, shrimp, crabs, water fleas, barnacles, crayfish, and gammarus.

cubic foot per second (cfs): Unit of discharge, or volume rate of flow, equal to 0.0283 cubic meters per second. As a rate of streamflow, a cubic foot of water passing a referenced section in one second of time. A measure of a moving volume of water ($1 \text{ cfs} = 0.0283 \text{ m}^3/\text{s}$).

cultural resources: Areas or objects that are of cultural significance to Native Americans and other ethnic groups.

cutbanks: Bank of river or stream eroded by water to near vertical face; usually on outside bend of meander.

D

dampening: Decrease in amplitude and velocity of a wave caused by interactions along the flowpath.

debris fans: Sloping mass of boulders, cobbles, gravel, sand, silt, and clay formed by debris flows at the mouth of a tributary/stream valley.

debris flows: Flash flood consisting of a mixture of rocks and sediment containing $<40\%$ water by volume; forms debris fans.

debt service coverage: Represents how much cash flow a retail utility needs to meet its financial obligations.

debt-to-equity (D/E ratio): A general measure of an entity's ability to pay off its debts with available equity.

decibel, A-weighted (dBA): Unit of weighted sound-pressure level, measured by the use of a metering characteristic and the "A" weighting specified in ANSI Specification for Sound Level Meters ANSI S1.4-1983 (R1988) and Amendment S1.4A-1985 (Acoustical Society of America 1983, 1985).

degradation: Geologic process wherein the elevation of streambeds and floodplains is lowered by erosion; the opposite of aggradation.

delta: Sediment deposit formed at the mouth of a river or stream.

demand: The energy requirement (load) placed upon a utility's generation at any specific point in time. A utility's demand (i.e., energy needed) increases and decreases instantaneously as consumers turn on or off their electrical appliances. Demand is increased or decreased in such terms as watts, kilowatts, and megawatts.

deposition: Settlement of material out of the water column and onto the streambed. Occurs when the energy of the flowing water is unable to support the load of suspended sediment.

desiccation: Removal of moisture from a substance; drying up.

dewatering: Draining of water.

diatoms: Microscopic, single-celled or colonial algae having cell walls of silica.

disaggregation: Process of examining a whole and inferring something about the parts that make up the whole.

diurnal: Pertaining to daylight hours; opposite of nocturnal.

downcutting: Lowering of water surface elevation resulting from erosion of the river or stream bed.

down ramp, down ramping: At hydro-electric facilities, a reduction in generation with a corresponding reduction in water releases through the penstocks and turbines. Also called ramp down. (See ramping.)

drift: Biotic and abiotic material present in the water column of streams and rivers that is being transported by the current of the water.

E

ecological resources: Components of terrestrial or aquatic ecosystems that are valued by humans.

ecology: That branch of the biological sciences that studies the relationships between living organisms and their environment.

economic indicators: In this EIS, estimates of output, employment, and disposable income that when combined, provide an overview of the aggregate level of economic activity in each of the nine subregions.

ecoregion: Large area with similarities in ecological characteristics as related to geology and climate.

ecosystem: Complex system composed of community organisms and their physical environment interacting as a unit.

eddies: Areas within a stream or river where the local currents move against the main current in a circular motion; occur near obstructions to flow.

electric power: Term used in the electric power industry to mean inclusively power and energy (used here to mean capacity and not energy).

electric power marketing baseline: (See baseline, electric power marketing.)

endangered species: Any species or subspecies of animal or plant whose survival is threatened with extinction throughout all or a significant portion of its range. (See Appendix D.)

energy: Amount of power generated over a given period of time (usually one hour).

energy, firm: Electric energy that is considered to have ensured availability to the customer to meet all or any agreed-upon portion of the customer's load requirements; electric energy that is sold by Western under short-term or long-term contracts.

energy, nonfirm: Energy sold by Western that varies in amount and price according to market conditions and hydrologic availability. Nonfirm energy is usually marketed on a short-term basis and is generally interruptible on short notice.

entrainment: Involuntary capture and inclusion of organisms in streams of flowing water. Entrained organisms may include phyto- and zooplankton; fish (eggs,

larvae, juveniles, or adults); shellfish larvae; and other forms of aquatic life.

ephemeral: Lasting a short time (e.g., plants that grow, flower, and die within a few days).

epiphytic: Refers to plants that grow on other plants but are not parasitic on them (e.g., diatoms living on *Cladophora*).

equilibrium: Conditions in which no net erosion or aggradation is occurring. Conditions in which opposing forces are balanced, resulting in a relatively unchanging state.

equivalent sound (pressure) level: The equivalent steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time-varying sound. For example, $L_{eq\ 1-}$ and $L_{eq\ 24-}$ are the 1-hour and 24-hour equivalent sound levels, respectively.

erosion: Removal of sediments by water, wind, or anthropogenic activities.

evapotranspiration: Combined process by which water is transferred from the earth's surface to the atmosphere; evaporation of liquid or solid water plus transpiration from plants.

exchanges: (See interchange, purchases, and interchanges.)

extirpated: A species that is no longer present due to extinction in a given area.

F

fan: Accumulation of debris brought down by a stream descending through a steep ravine and emerging in the plain beneath,

where the detritus spreads out in the shape of a fan. (See alluvial fan, debris fan.)

fauna: All animal life associated with a given habitat, area, or period.

firm electric service: Energy and capacity sold by Western that is considered to have ensured delivery.

firm energy: (See energy, firm.)

firming purchases: Purchases of capacity or energy that are required to meet the contractual provisions of long-term firm service.

firm power: Power that is guaranteed by the supplier to be available at all times, except for reasons of certain uncontrollable events or continuity of service provisions. (See power and nonfirm power.)

firm transmission service: Service provided by Western to transport energy from one place to another under contracts that ensure delivery without interruption.

floodplain: Portion of a river valley (adjacent to the river) that is covered with water when the river overflows its banks at flood stages.

flora: All plant life associated with a given habitat, country, or period.

flow: Daily water-release patterns; the volume of water passing a given point per unit of time.

flow regime: The daily, monthly, or seasonal pattern of flow in a river.

fluctuating flows: Variation in water flows throughout the day due to changes in generation to accommodate load patterns.

fluctuation zone: Area of the stream bed that is exposed on a daily basis by fluctuating flows.

fluvial: (sediment) Of, found in, or produced by a river.

frequency: Number of cycles per second that an alternating current passes. In the U.S. electric utility industry, frequency has been generally standardized at 60 cycles per second (60 hertz).

frequency exceedance: Fraction of time a variable exceeds a given threshold.

fry: Life stage of fish between the egg and fingerling stages.

full pool: The volume of water in a reservoir at maximum design elevation.

G

gaging station: A place where systematic observations of hydrologic data are obtained.

gastropod: Large class of mollusks composed of snails and slugs.

genera: Plural of genus, a category in biological classification comprising one or more related and similar species.

generation: Process of producing electrical energy by transforming other forms of energy; also, amount of electric energy produced, expressed in kilowatt hours.

geology: The science that studies the earth; the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks and their formation and structure.

geomorphology: Study of the configuration and evolution of land forms and earth features.

gigawatt (GW): Unit of power equal to 1 billion watts, 1 million kilowatts, or 1 thousand megawatts.

gigawatt hour (GWh): One million kilowatt hours of electrical energy.

gross regional product (GRP): Value of the total output of a region measured in constant (base year) prices.

H

habitat: Area where a plant or animal lives.

headwaters: The source and uppermost part of a stream or reservoir.

hectare: A unit (in the metric system) used to measure surface area equal to 10,000 square meters (2.471 acres).

herbaceous: Pertaining to nonwoody plant life.

high water zone: Riparian vegetation above the normal maximum water level.

Holocene: That period of time since the last ice age.

hydroelectric plant: Electric power plant using falling water as its motive force.

hydroelectric power: Electrical capacity produced by water.

hydrograph: Graph showing, for a given point in a stream, the discharge, stage, or

other property of water with respect to time.

hydrologic cycle: The continuous circulation of water from the atmosphere to earth by precipitation and from earth to the atmosphere by evaporation and transpiration. The land phase includes infiltration, runoff, and exchange between surface water and groundwater.

hydrology: The science that studies the properties, distribution, and circulation of natural water systems.

I

igneous: Rocks formed by solidification of hot mobile magma.

input-output (I-O): Analysis utilizing information on the relationships among the inputs and outputs in an economy to analyze the effects of a change in some measure of economic activity, such as expenditures, on the resulting levels of income, output, and employment in the economy.

Integrated Projects: The Salt Lake City Area Integrated Projects, which include facilities on the Upper Colorado River and its tributaries. The facilities and features of the SLCA/IP are described in Chapter 3 of this document.

interchange energy: Energy in kilowatt-hours delivered to or received by one electric utility system from another. It may be returned in kind at a later time or may be accumulated as energy balances until the end of a stated period. Settlement under an interchange agreement may be by payment or by delivery of equivalent amounts of electricity.

interchanges: Agreements Western has with other utilities to trade generation resources from different locales to increase total system efficiency or avoid transmission limits that would occur without such agreements; also called exchanges.

interties: An interconnection permitting passage of current between two or more electric utility systems.

introduced species: Species not indigenous to a given area; not naturally occurring (native in a given area but present due to human activities, e.g., stocked or accidentally released).

inundation: To cover with impounded waters or floodwaters.

invertebrate: Animals lacking a backbone.

isopleth: In meteorology, a line drawn through points on a graph at which a given quantity has the same numerical values (or occurs with the same frequency) as a function of the two coordinate variables.

K

kilovolt (kV): 1,000 volts.

kilowatt (kW): Unit of electric energy equal to 1,000 watts or about 1.34 horsepower.

kilowatt hour (kWh): Basic unit of electric energy, equaling an average of one kilowatt of power applied over one hour.

L

larval, larvae: A stage in development between hatching and attainment of adult form.

lithic: Pertaining to stone or a stone tool (e.g., lithic artifact).

littoral: Pertaining to the shore of a river, stream, or lake.

load: The amount of power or energy required at any specified point on a system. Load is the sum of all customer demands plus electricity required for station services and project uses.

load factor: Ratio of the average load in kilowatts supplied during a designated period to the peak or maximum load in kilowatts occurring in that period. Load factors represent, in general terms, the type of service offered under the contracts, which is meant to service either the baseload or peaking portion of customer loads. Load factor, in percent, may be derived by multiplying the kilowatt hours in the period by 100 and dividing by the product of the maximum demand in kilowatts and the number of hours in the period.

load shaping: Either the arrangement and operation of generating resources to meet a given load or the arrangement of a load to meet a given resource over specified periods of time. Load shaping on a hydrosystem usually involves the adjustment of storage releases so that the generation and the load are continuously in balance.

long-term firm contracts: Contracts that are greater than 1 year and legally limited to 40 years in duration.

long-term firm power: Capacity that is sold by Western under long-term contracts. Power or capacity is considered to have ensured availability to the customer over long periods of time to meet all or any agreed-upon portion of the customer's load requirements.

M

macroinvertebrate: Invertebrate organisms that are visible to the naked eye.

main channel: The main course of a stream.

main stem: The main course of a stream.

marketing criteria: Defines how much electrical power Western will sell under long-term contract and the terms and conditions for the receipt of Integrated Projects' power. Allocation criteria, which are normally developed with the marketing criteria, define the eligibility requirements to receive Integrated Projects' power and the methods to distribute the power to successful applicants.

mean: Average value in a distribution.

median: Middle value in a distribution, above and below which lie an equal number of values.

megawatt (MW): A unit of power equal to one million watts. MW defines electricity produced.

megawatt hour (MWh): One million watt-hours of electrical energy.

million-acre feet (maf): A unit of volume; the volume of water that would cover one million acres at a depth of one foot.

minimum schedule requirements: Quantity of capacity that Western must provide and that a contract customer must accept on an hourly basis.

mitigation: Action taken to avoid, reduce the severity of, or eliminate an adverse impact.

mixing layer (or height or depth): The layer above the surface through which relatively vigorous vertical mixing occurs.

N

nameplate generating capacity: Full-load continuous rating of a generator or other electrical equipment under specified conditions designated by the manufacturer. This rating is specified on the nameplate that is attached to all such equipment by the manufacturer.

National Ambient Air Quality Standards (NAAQS): Air quality standards established by the Clean Air Act. The primary NAAQS are intended to protect the public health with an adequate margin of safety; the secondary NAAQS are intended to protect the public welfare from any known or anticipated adverse effects of a pollutant.

National Register of Historic Places (NRHP): A list maintained by the National Park Service of architectural, historic, archaeological, and cultural sites of local, state, or national significance.

Native American: Refers to indigenous peoples of the Western Hemisphere (e.g., American Indian, Eskimo, Aleut).

need: In this EIS, to determine the level of long-term, firm power and energy

commitment from the SLCA/IP that Western will make available to its customers and that will form the basis for its SLCA/IP power marketing program. (See Chapter 1.)

nonattainment areas: An air quality control region (or portion thereof) in which the U.S. Environmental Protection Agency has determined that ambient air concentrations exceed national ambient air quality standards for one or more criteria pollutants.

nonfirm power: Power or power-producing capacity supplied or available under an arrangement that does not have the guaranteed continuous availability feature of firm power, generally interruptible on short notice; capacity (power) sold by Western that varies in amount and price according to market.

nonfirm transmission service: Service provided by Western to transport energy from one place to another on an interruptible basis.

nonimpulsive noise: Noise of longer duration (continuous) than that of impulse noise, which is typically less than one second.

nonpreference customers: Investor-owned utilities or other power marketing entities that do not qualify for allocations of SLCA/IP long-term firm power and energy commitments.

nonuse value: The economic benefit that arises from the knowledge that a resource exists (existence value), has been preserved for potential use in the future (option value), and will be available for use by one's heirs (bequest value). Nonuse value is theoretically and conceptually distinct

from use value. Contingent valuation is the only technique currently available for estimating nonuse value.

O

off-peak: Period between late evening and early morning (11:00 p.m. to 11:00 a.m.) when electrical loads for most utilities are much lower than other times during the day.

oligotrophic: Lakes and reservoirs low in nutrients and organic productivity, having nutrient-poor sediments, few rooted aquatic plants, a low production of unattached algae (phytoplankton), and well-oxygenated deep waters.

on-peak: Energy supplied during periods of relatively high system demands as specified by the supplier.

operational scenarios: Series of historical and hypothetical constraints on SLCA/IP hydropower operations specified by setting minimum and maximum flows, ramp rates, or variation in total flows during the day. Hydropower Operational Scenarios are described in detail in Appendix A.

P

palisade: Precipitous rock cliff rising from the margin of a stream.

particulate matter: Any material, except uncombined water, that exists in a finely divided form as a liquid or solid.

peak demand: Maximum electrical demand (load) on a utility system in a stated period of time (peak load).

peaking capacity: Generating equipment operated during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on a round-the-clock basis.

peaking power: Capacity and associated energy available to help meet that portion of a customer's peak load that is above baseload. Peaking power is normally delivered during those hours of the day when the demand for energy is higher.

peaking power/peaking generation: Power plant capacity that is typically used to meet rapid increases or the highest levels of demand in a utility's load or demand profile. Peaking generation is usually oil, gas-fired, or hydropower generation.

peaking units: Generating units that are available to assist in meeting that portion of load that is greatest during the day.

peak shaving: Use of hydroelectric power plants to serve (shave) the highest electric load (peak) during a 24-hour period.

penstock: Conduit pipe used to convey water under pressure to the turbines of a hydroelectric plant.

periphyton: Organisms that live attached to underwater surfaces.

petroglyphs: Symbols or pictures engraved or painted on a rock surface.

phytoplankton: (See plankton.)

plankton: Tiny plants (phytoplankton) and animals (zooplankton) with limited

powers of locomotion, usually living free in the water away from substrates.

pool: Deep area of a stream between rapids or where the current is slow.

power: Measure of the amount of energy (work) being used at a specific point in time. Power is measured in such terms as watts, kilowatts, and megawatts. Power implies capacity in addition to energy.

power marketing initiative: Proposed or suggested combination of services and sales programs that Western, Western's customers, or other interested parties have advanced as the basis for future marketing activities.

power marketing programs: The sum total of all services and sales activities offered by Western.

power pool: Organization of interconnected electric utilities that plan and coordinate aspects of the production, transmission, or distribution of electricity. (The Inland Power Pool only shares reserves.)

preference customers: In accordance with congressional directives, publicly owned systems and nonprofit cooperatives that have preference over investor-owned systems for purchase of power from Federal projects; municipalities, nonprofit corporations, or agencies and cooperatives and other nonprofit organizations financed under the Rural Electrification Act of 1936.

price elasticity of demand: Ratio of the percentage change in quantity demanded to the percentage change in price. Indicates the sensitivity of quantity demanded to a change in price.

purchases and interchange: Activities by Western to supplement and enhance the value of hydrogeneration resources. Purchases and interchange are components of hydrothermal integration.

purchases, firming: Purchases of capacity or energy that are required to meet the contractual provisions of long-term firm service.

R

ramp down: Reduction in generation with a corresponding reduction in water release; decrease in water release per time. (Also called downramp, down ramping.)

ramp rate: The rate of change in instantaneous output from a power plant.

ramp up: Increase in water release per time; increase in water release causing an increase in stage downstream of the dam with a corresponding increase in power generation; also called upramping or ramping up.

rapid: Section of a river where the current moves very swiftly, caused by a steep descent in the riverbed through a constriction of the main channel.

reach: Any specified segment of a stream or river.

real disposable income: Total real income adjusted for taxes and transfer payments.

reattachment bar: Deposits found at the downstream edge of a recirculation zone that are important for establishing backwater areas.

recirculation zone: Area of flow composed of one or more eddies immediately downstream from a constriction in the channel, such as a debris fan.

recovery plans: Plans prepared by the USFWS to delineate reasonable actions that are believed to be required to recover and/or protect the species.

recruitment: Survival of young plants and animals from birth to a life stage less vulnerable to environmental change.

redd: Nests constructed in gravel by trout and salmon; spawning sites.

release patterns: Changes over time in the rate that water is released from a dam.

reliance levels: In this EIS, a utility is considered to have high reliance on Western power if 25% or more of its total system load is met by Western sources; less than 25% is considered low reliance.

reregulation dam: Low dam located downstream from a large hydroelectric power plant used to even out the flows further downstream.

reserves: Extra generating capacity available to meet unanticipated capacity demand for power in the event of generation loss due to scheduled or unscheduled outages of regularly used generating capacity.

reservoir: An artificially impounded body of water.

reservoir release patterns: Reservoir release rates specified for a time period on a continuous basis or at fixed-time intervals, such as one hour.

residual sound level: Represents a low-limit value to which the ambient environmental noise drops frequently but below which it seldom goes.

rewind: Act of putting new copper-insulated wire in the armature windings of a generator.

riffle: Fast-water section of stream where the shallow water flows over stones and gravel.

riparian: Of, on, or pertaining to the bank of a river, stream, or lake.

riprap: Stones placed on the face of a dam or on stream banks or other land surfaces to protect them from erosion. A loose assemblage of stones used in water or soft ground as a foundation.

riverine: Pertaining to a riverbank.

river mile (RM): A unit of measurement (in miles) used on the Colorado River with River Mile 0 located at the U.S. Geological Survey gauge at Lees Ferry; miles downstream from that point are positive and miles upstream are negative.

S

Salt Lake City Area Integrated Projects (SLCA/IP): Federally owned and operated facilities mainly on the Colorado and Rio Grande rivers and their tributaries. The facilities and features of the SLCA/IP are described in Chapter 3 of this EIS.

Salt River Project (SRP) Exchange: Agreement between Western and the Salt River Project, a utility in Phoenix whereby capacity and energy at SRP generation

units in Craig and Hayden, Colorado, are exchanged with capacity and energy at Glen Canyon dam. This agreement reduces the need for transmitting northern generation to meet southern loads, and vice versa.

sandbars: Deposits associated with eddies that exist upstream and downstream of debris fans created at the mouths of side canyons by debris flows (also called beaches, channel margin bars, separation bars, and reattachment bars).

scatter: In archaeology, a concentration of artifacts, e.g., lithic scatter.

scouring: Removing rooted plants at high water flows.

sediment: Any usually finely divided organic and/or mineral matter deposited by air or water in nonturbulent areas.

seeps: Area where groundwater discharges to the surface.

sensitive species: Species whose populations are small and widely dispersed or restricted to a few localities; species that are listed or candidates for listing by the state or Federal government.

separation bar: Sandbar located at the upstream end of a recirculation zone, where downstream flow becomes separated from the riverbank. Deposits found at the leading edge of a recirculation zone.

seston (sestonic): Total organic particulate matter suspended in water.

shale: Laminated sediment in which the constituent particles are predominantly of the clay grade; shale includes the

indurated, laminated, or fissile claystones and siltstones.

shaving: The process to reduce (shave) peak loads at specific times of the day to reduce the total load placed on a utility system.

short-term firm: Power and energy that is marketed on a noninterruptible basis for periods of time of less than one year, usually as a result of unusually wet hydrology.

sinusoidal: Having a shape like a sine function; a changing from high to low in regular cycle.

slope: Change in elevation per unit of horizontal distance.

spawn: To lay eggs; especially fish.

spawning beds: Places in which eggs of aquatic animals lodge or are placed during or after fertilization.

species: The basic category of biological classification intended to designate a single kind of animal or plant.

spills: Flows through a dam in excess of power plant capacity that do not produce power.

spillway: Overflow channel of a dam.

spinning reserves: Unloaded and available capacity of generating facilities synchronized to the interconnected electric system where automatic control action will cause such generating capacity to ensure load.

spot-market sales: Short-term nonfirm sales made in the open market at prices and conditions set by the market. Spot-

market sales may be made between any willing buyer and seller.

stage: Elevation of a water surface above or below an established reference point, such as minimum flow.

steppe: Area of grass-covered and generally treeless plains, with a semiarid climate.

step-up transformer: Transformer in which the energy transfer is from a low- to a high-voltage winding or windings. (Winding means one or more turns of wire forming a continuous coil for a transformer, relay, rotating machine, or other electric device.)

stranding pools: Areas that become isolated from the main channel of a river during declining water levels, trapping fish and other aquatic biota.

strata: Section of a formation that consists of the same type of material throughout.

stream: Natural water course.

substrate: Surface on which a plant or animal grows or is attached.

system losses: Difference between the amount of energy that is produced and the amount delivered that results from losses between the sources of supply and the metering points of delivery on a system.

T

tableland: Broad, level, elevated area.

tailwaters: That portion of the river below a reservoir that exhibits water conditions (such as temperature and clarity)

that are very similar to the conditions of the water that is being withdrawn from the reservoir.

talus: Rock debris at the base of a cliff or slope, chiefly as the result of gravitational roll or slide.

terrace: Relatively level area with steep slope facing the river.

terrain: Complex group of strata accumulated within a definite geologic epoch; area of ground considered as to its extent and natural features in relation to its use for a particular operation.

terrestrial: Pertaining to plants or animals living on land rather than in the water.

threatened species: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. (See endangered; also Appendix D.)

topography: Physical shape of the ground surface.

total suspended particulates (TSP): Particulate matter present in the atmosphere.

transect: Linear sampling unit.

tributary: River or stream flowing into a larger river or stream.

turbidity: Cloudiness of water, measured by how deeply light can penetrate into the water from the surface.

turbine: Fluid acceleration machine for generating rotary mechanical power from the energy in a stream of fluid.

turbine generator: Electric generator driven by a steam, hydraulic, or gas turbine.

U

upgrade: Increase in generating capacity.

up ramp: (See ramp up.)

use-value: Economic benefit associated with the physical use of a resource, usually measured by the consumer surplus or net economic value associated with such use. The contingent value method is one technique used to estimate use value. (See nonuse values.)

V

videography: An airborne multispectral video/radiometer remote sensing system. Videography is collected by flying over an area at a fixed altitude and videotaping the area below.

volatile organic compound (VOC): Organic compound that participates in atmospheric photochemical reactions.

W

water year: Period of time beginning October 1 of one year and ending September 30 of the following year and designated by the calendar year in which it ends.

wave heights: The difference between maximum and minimum water elevation.

weighted usable area (WUA): An estimation of the availability of potential fish habitat as a function of discharge;

includes consideration of water depth, velocity, and substrate data for a particular stream location.

wetlands: Lands or areas exhibiting hydric soils, saturated or inundated soil during some portion of the plant growing season, and plant species tolerant of such conditions (includes swamps, marshes, bogs).

wheeling: Use of the electric transmission facilities of one system to transmit power to or from another system.

Y

young-of-the-year: Fish less than one year of age.

Z

zooplankton: (See plankton.)

15 INDEX

- Affected environment, 3-1
 - Aspinall Unit, 3-4, 3-37, 3-80, 3-95, 3-101, 3-115, 3-120
 - Flaming Gorge Dam, 3-2, 3-26, 3-60, 3-92, 3-99, 3-106, 3-119
 - Glen Canyon Dam, 3-4, 3-15, 3-45, 3-89, 3-96, 3-105, 3-119
- Agriculture (see Socioeconomics)
- Air resources, 3-12, 4-25, 4-41, 5-2, B-1
- Alternatives (see Commitment-level alternatives)
- Angling, 4-36, 4-40, 4-115, 4-118
- Aspinall Unit
 - Cultural resources, 3-95, 4-112
 - Ecological resources, 3-80, 4-100, D-12, D-21, D-33, D-49
 - Hydropower operational scenarios, 2-17
 - Land use, 3-101, 4-114
 - Noise, B-25
 - Recreation, 3-115, 4-40
 - Visual resources, 3-120, 4-125
 - Water resources, 3-37, 4-64, C-26
- Archaeological resources (see Cultural resources)
- Bald eagle, 3-57, 3-59, 3-77, 3-80, 3-88, 3-89, 4-78, 4-79, 4-95, 4-97, 4-104, 4-106
- Blue Mesa Dam (see Aspinall Unit)
- Boating (see Recreation)
- Bonytail chub, 3-54, 3-55, 3-70, 3-71, 4-90, 4-93
- Climate and meteorology, 3-12, B-3
- Colorado River (see Glen Canyon Dam)
- Colorado squawfish, 3-54, 3-55, 3-70, 3-72, 4-91, 4-94
- Commitment-level alternatives, 2-1, 4-1, 4-126, 5-1, 6-1, 7-1, 8-1
- Consultation and coordination, 10-1
- Crystal Dam (see Aspinall Unit)
- Cultural resources, 3-89, 4-32, 4-108, 5-5
 - Aspinall Unit, 3-95, 4-112
 - Flaming Gorge Dam, 3-92, 4-109
 - Glen Canyon Dam, 3-89, 4-108
- Cumulative impacts, 5-1
- Demand-side management (see Socioeconomics)
- Ecological resources, 3-45, 4-31, 4-67, 5-3, D-1
 - Aquatic, 4-31
 - Aspinall Unit, 3-81, 4-100, D-12, D-33
 - Flaming Gorge Dam, 3-60, 4-82, D-8, D-25
 - Glen Canyon Dam, 3-45, 4-67, D-4
 - Terrestrial, 4-31
 - Aspinall Unit, 3-84, 4-101, D-21, D-33, D-49
 - Flaming Gorge Dam, 3-66, 4-86, D-17, D-30, D-40
 - Glen Canyon Dam, 3-49, 4-71, D-14, D-36

Economics (see Socioeconomics)

Environmental consequences, 4-1, 5-1, 6-1, 7-1, 8-1

Commitment-level alternatives, 2-8, 4-1, 4-126

Hydropower operational scenarios, 2-17, 4-33, 4-132

Fish

Introduced species

Aspinall Unit, 3-81, 4-100, D-12

Flaming Gorge Dam, 3-62, 4-82, D-8

Glen Canyon Dam, 3-46, 4-67, D-4

Native species

Aspinall Unit, 3-82, 4-100, D-12

Flaming Gorge Dam, 3-63, 4-84, D-8, D-29

Glen Canyon Dam, 3-47, 4-70, D-4

Fishing (see Angling)

Flaming Gorge Dam

Cultural resources, 3-92, 4-109

Ecological resources, 3-60, 4-82, D-8, D-17, D-24, D-25, D-30, D-40

Hydropower operational scenarios, 2-15

Land use, 3-99, 4-113

Noise, B-24

Recreation, 3-106, 4-39, 4-118

Visual resources, 3-119, 4-124

Water resources, 3-26, 4-50, C-3

Floating (see Boating)

Flow

Aspinall Unit, 3-39, 4-64, C-26

Flaming Gorge Dam, 3-28, 4-51, C-3

Glen Canyon Dam, 3-15, 4-44

Glen Canyon Dam

Cultural resources, 3-89, 4-108

Ecological resources, 3-45, 4-67, D-4, D-14, D-36

Hydropower operational scenarios, 2-13

Land use, 3-96, 4-113

Noise, B-21

Recreation, 3-105, 4-35, 4-115

Visual resources, 3-119, 4-124

Water resources, 3-15, 4-44

Green River (see Flaming Gorge Dam)

Gunnison River (see Aspinall Unit)

Humpback chub, 3-53, 3-69, 4-75, 4-77, 4-90, 4-93

Hydropower operational scenarios, 2-9, 4-33, 4-132, 5-1, 6-1, 7-1, 8-1

Aspinall Unit, 2-17

Flaming Gorge Dam, 2-15

Glen Canyon Dam, 2-13

Kanab ambersnail, 3-56, 3-57, 4-78, 4-79

Land use, 3-96, 4-32, 4-113, 5-5

Aspinall Unit, 3-101, 4-114

Flaming Gorge Dam, 3-99, 4-113

Glen Canyon Dam, 3-96, 4-113

Meteorology (see Climate and meteorology)

Mexican spotted owl, 3-58, 3-77, 3-80, 4-80, 4-81, 4-98, 4-100

Morrow Point Dam (see Aspinall Unit)

Native American cultural resources

Aspinall Unit, 3-96, 4-113

Flaming Gorge Dam, 3-94, 4-112

Glen Canyon Dam, 3-92, 4-109

Noise, 3-14, 4-30, 4-43

Aspinall Unit, B-25

Flaming Gorge Dam, B-24

Glen Canyon Dam, B-21

Non-use values (see Socioeconomics)

Peregrine falcon, 3-57, 3-59, 3-77, 3-80, 3-88, 3-89, 4-80, 4-81, 4-98, 4-99, 4-106, 4-108

Rafting (see Recreation)

Razorback sucker, 3-54, 3-56, 3-70, 3-73, 4-75, 4-78, 4-91, 4-94

Recreation, 3-2, 4-32, 4-114, 5-6, A-32

Aspinall Unit, 3-115, 4-40, 4-122

Flaming Gorge Dam, 3-106, 4-39, 4-118

Glen Canyon Dam, 3-105, 4-35, 4-115

Riparian vegetation, D-30, D-34

Aspinall Unit, 3-84, 4-101, D-21, D-33, D-49

Flaming Gorge Dam, 3-66, 4-86, D-17, D-30, D-40

Glen Canyon Dam, 3-50, 4-71, D-14, D-36

Sediment

Aspinall Unit, 3-40, 4-65

Flaming Gorge Dam, 3-34, 4-57

Glen Canyon Dam, 3-22, 4-46

Socioeconomics, 3-1, 4-1, 4-34, 5-2, A-1

Demand-side management, A-16

Electric demand analysis, A-3

Electric power marketing baseline, 3-8

Financial analysis, A-19

Impacts

Agriculture, 4-24, A-37

Conservation and renewable energy, 4-21, A-25

Employment, 4-22

Gross Regional Product, 4-22

Income, 4-22

Non-use values, 4-34

Recreational economics, 4-34, A-32

Socioeconomics (cont.)

Impacts (cont.)

Regional economy, 4-21, 4-34, A-26

Utility industry, 4-5

Power systems analysis, A-4

Regions of influence, 3-1

Socioeconomic baseline, 3-4

Southwestern willow flycatcher, 3-58, 3-60, 4-80, 4-82

Stage

Aspinall Unit, 3-39, 4-64

Flaming Gorge Dam, 3-28, 4-57

Glen Canyon Dam, 3-15, 4-46

Threatened and endangered species

Aspinall Unit, 3-86, 4-104

Flaming Gorge Dam, 3-69, 4-89

Glen Canyon Dam, 3-52, 4-74

Trout

Aspinall Unit, 3-81

Flaming Gorge Dam, 3-62, 4-82, D-27

Glen Canyon Dam, 3-46, 4-67

Ute ladies-tresses, 3-74, 3-75, 4-95, 4-96

Visual resources, 3-118, 4-32, 4-123, 5-6

Aspinall Unit, 3-120, 4-125

Flaming Gorge Dam, 3-119, 4-124

Glen Canyon Dam, 3-119, 4-124

Water resources, 3-14, 4-31, 4-43, 5-2, C-1

Aspinall Unit, 3-37, 4-64, C-26

Flaming Gorge Dam, 3-26, 4-50, C-3

Glen Canyon Dam, 3-15, 4-44

Wetlands (see Riparian vegetation)

Whooping crane, 3-74, 3-76, 3-86, 3-87, 4-95, 4-97, 4-104, 4-106

Wildlife

Aspinall Unit, 3-85, 4-102, D-21

Flaming Gorge Dam, 3-68, 4-87, D-17

Glen Canyon Dam, 3-52, 4-73, D-14

16 LIST OF RECIPIENTS

U.S. Congress

Hon. Wayne Allard
U.S. House of Representatives
Washington, DC

Hon. Bill Baker
U.S. House of Representatives
Washington, DC

Hon. Xavier Becerra
U.S. House of Representatives
Washington, DC

Hon. Anthony C. Beilenson
U.S. House of Representatives
Washington, DC

Hon. Robert F. Bennett
United States Senate
Washington, DC

Hon. Howard L. Berman
U.S. House of Representatives
Washington, DC

Hon. James H. Bilbray
U.S. House of Representatives
Washington, DC

Hon. Jeff Bingaman
United States Senate
Washington, DC

Hon. Barbara Boxer
United States Senate
Washington, DC

Hon. George E. Brown, Jr.
U.S. House of Representatives
Washington, DC

Hon. Hank Brown
United States Senate
Washington, DC

Hon. Richard H. Bryan
United States Senate
Washington, DC

Hon. Ken Calvert
U.S. House of Representatives
Washington, DC

Hon. Ben Nighthorse Campbell
United States Senate
Washington, DC

Hon. Gary A. Condit
U.S. House of Representatives
Washington, DC

Hon. Sam Coppersmith
U.S. House of Representatives
Washington, DC

Hon. Christopher Cox
U.S. House of Representatives
Washington, DC

Hon. Randy Cunningham
U.S. House of Representatives
Washington, DC

Hon. Dennis DeConcini
United States Senate
Washington, DC

Hon. Ronald V. Dellums
U.S. House of Representatives
Washington, DC

Hon. Julian C. Dixon
U.S. House of Representatives
Washington, DC

Hon. Calvin M. Dooley
U.S. House of Representatives
Washington, DC

Hon. John T. Doolittle
U.S. House of Representatives
Washington, DC

Hon. Pete V. Domenici
United States Senate
Washington, DC

Hon. Robert K. Dornan
U.S. House of Representatives
Washington, DC

Hon. David Dreier
U.S. House of Representatives
Washington, DC

Hon. Don Edwards
U.S. House of Representatives
Washington, DC

Hon. Karan English
U.S. House of Representatives
Washington, DC

Hon. Anna G. Eshoo
U.S. House of Representatives
Washington, DC

Hon. Vic Fazio
U.S. House of Representatives
Washington, DC

Hon. Dianne Feinstein
United States Senate
Washington, DC

Hon. Bob Filner
U.S. House of Representatives
Washington, DC

Hon. Elton Gallegly
U.S. House of Representatives
Washington, DC

Hon. Dan Hamburg
U.S. House of Representatives
Washington, DC

Hon. James V. Hansen
U.S. House of Representatives
Washington, DC

Hon. Jane Harman
U.S. House of Representatives
Washington, DC

Hon. Orrin G. Hatch
United States Senate
Washington, DC

Hon. Joel Hefley
U.S. House of Representatives
Washington, DC

Hon. Wally Herger
U.S. House of Representatives
Washington, DC

Hon. Michael Huffington
U.S. House of Representatives
Washington, DC

Hon. Duncan Hunter
U.S. House of Representatives
Washington, DC

Hon. Jay Kim
U.S. House of Representatives
Washington, DC

Hon. Jim Kolbe
U.S. House of Representatives
Washington, DC

Hon. John Kyl
U.S. House of Representatives
Washington, DC

Hon. Tom Lantos
U.S. House of Representatives
Washington, DC

Hon. Richard H. Lehman
U.S. House of Representatives
Washington, DC

Hon. Jerry Lewis
U.S. House of Representatives
Washington, DC

Hon. Matthew G. Martinez
U.S. House of Representatives
Washington, DC

Hon. Robert T. Matsui
U.S. House of Representatives
Washington, DC

Hon. John McCain
United States Senate
Washington, DC

Hon. Alfred A. McCandless
U.S. House of Representatives
Washington, DC

Hon. Scott McInnis
U.S. House of Representatives
Washington, DC

Hon. Howard P. McKeon
U.S. House of Representatives
Washington, DC

Hon. George Miller
U.S. House of Representatives
Washington, DC

Hon. Norman Y. Mineta
U.S. House of Representatives
Washington, DC

Hon. Carlos J. Moorhead
U.S. House of Representatives
Washington, DC

Hon. Bill Orton
U.S. House of Representatives
Washington, DC

Hon. Ron Packard
U.S. House of Representatives
Washington, DC

Hon. Ed Pastor
U.S. House of Representatives
Washington, DC

Hon. Nancy Pelosi
U.S. House of Representatives
Washington, DC

Hon. Richard W. Pombo
U.S. House of Representatives
Washington, DC

Hon. Harry Reid
United States Senate
Washington, DC

Hon. Bill Richardson
U.S. House of Representatives
Washington, DC

Hon. Dana Rohrabacher
U.S. House of Representatives
Washington, DC

Hon. Lucille Roybal-Allard
U.S. House of Representatives
Washington, DC

Hon. Ed Royce
U.S. House of Representatives
Washington, DC

Hon. Dan Schaefer
U.S. House of Representatives
Washington, DC

Hon. Lynn Schenk
U.S. House of Representatives
Washington, DC

Hon. Steven Schiff
U.S. House of Representatives
Washington, DC

Hon. Patricia Schroeder
U.S. House of Representatives
Washington, DC

Hon. Karen Shepard
U.S. House of Representatives
Washington, DC

Hon. Alan K. Simpson
United States Senate
Washington, DC

Hon. David E. Skaggs
U.S. House of Representatives
Washington, DC

Hon. Joe Skeen
U.S. House of Representatives
Washington, DC

Hon. Fortney Pete Stark
U.S. House of Representatives
Washington, DC

Hon. Bob Stump
U.S. House of Representatives
Washington, DC

Hon. Bill Thomas
U.S. House of Representatives
Washington, DC

Hon. Craig Thomas
U.S. House of Representatives
Washington, DC

Hon. Esteban Edward Torres
U.S. House of Representatives
Washington, DC

Hon. Walter R. Tucker, III
U.S. House of Representatives
Washington, DC

Hon. Barbara F. Vucanovich
U.S. House of Representatives
Washington, DC

Hon. Maxine Waters
U.S. House of Representatives
Washington, DC

Hon. Henry A. Waxman
U.S. House of Representatives
Washington, DC

Hon. Lynn Woolsey
U.S. House of Representatives
Washington, DC

Hon. Malcom Wallop
United States Senate
Washington, DC

Federal Officials and Agencies

Danita Agar
U.S. Department of Energy
Albuquerque, NM

Arlo Allen
U.S. Bureau of Reclamation
Salt Lake City, UT

Associate Regional Director
Rocky Mountain Regional Office
National Park Service
Denver, CO

Frank Baucom
U.S. Fish and Wildlife Service
Phoenix, AZ

Debra Bills
U.S. Fish and Wildlife Service
Phoenix, AZ

Pat Burns
U.S. Air Force
Cannon Air Force Base, NM

Robert Chandler
Grand Canyon National Park
Grand Canyon, AZ

Raymond P. Churan
Office of Environmental Affairs
Department of the Interior
Albuquerque, NM

Curecanti National Recreation Area
Resource Management
Gunnison, CO

Sheila D. David
National Academy of Sciences
Washington, DC

Jonathan Deason
Office of Environmental Affairs
Department of the Interior
Washington, DC

Raymond Gunn
National Park Service
Salt Lake City, UT

Reed Harris
U.S. Fish and Wildlife Service
Salt Lake City, UT

Dennis K. Huffman
Dinosaur National Monument
National Park Service
Dinosaur, CO

Bill Jackson
Branch of Water Operations
National Park Service
Ft. Collins, CO

Conrad G. Keyes, Jr.
International Boundary and Water
Commission
El Paso, TX

Ralph Morganweck
U.S. Fish and Wildlife Service
Denver, CO

National Park Service
To: (774)
Washington, DC

Allan O'Neill
Lake Mead National Recreation Area
National Park Service
Boulder City, NV

John P. Ritenour
Glen Canyon National Recreation Area
National Park Service
Page, AZ

Keith Rose
U.S. Fish and Wildlife Service
Grand Junction, CO

Chris Turk
Planning and Compliance
National Park Service
Denver, CO

Upper Colorado River Commission
Salt Lake City, UT

John Welch
Black Canyon of the Gunnison National
Monument
National Park Service
Montrose, CO

Wes Wilson
U.S. Environmental Protection Agency
Denver, CO

Don Wolfe
Bonneville Power Administration
Portland, OR

State Officials and Agencies

Stephen Ahearn
Arizona Energy Office
Phoenix, AZ

James S. Cannon
Energy, Minerals, and Natural
Resources Department
State of New Mexico
Santa Fe, NM

Ian Chisolm
Montana Department of Fish, Wildlife
and Parks
Libby, MT

Bill Clark
NW Regional Office
State of Colorado
Grand Junction, CO

Bob Clark
SW Regional Office
State of Colorado
Montrose, CO

Janice Dunn
Department of Commerce
State of Arizona
Phoenix, AZ

Edward A. Fowlkes
Division of Facilities Construction
Management
State of Utah
Salt Lake City, UT

David Getches
Colorado Department of Natural
Resources
State of Colorado
Denver, CO

Chuck Grand Pre
Department of Natural Resources
State of Colorado
Denver, CO

Tim Henley
Department of Water Resources
State of Arizona
Phoenix, AZ

Mark A. Holden
Department of Natural Resources
State of Utah
Salt Lake City, UT

Jon Jacquot
Wyoming Public Service Commission
Cheyenne, WY

Sheryl Jeffries
State Planning Coordinator's Office
Cheyenne, WY

Jack Kelly
New Mexico Game and Fish
Albuquerque, NM

Leo Lentsch
Utah Division of Wildlife Resources
State of Utah
Salt Lake City, UT

Debra McGuinn-Robbins
Arizona Game and Fish Department
State of Arizona
Flagstaff, AZ

John Pittenger
Department of Game and Fish
State of New Mexico
Santa Fe, NM

Larry Riley
Department of Game and Fish
State of Arizona
Phoenix, AZ

John W. Shields
Wyoming State Engineer's Office
Cheyenne, WY

John Toolen
Colorado Division of Wildlife
State of Colorado
Grand Junction, CO

Carolyn Wright
Office of Planning and Budget
Salt Lake City, UT

Utilities and Electric Power Entities

Stan Atkinson
Rocky Mountain Generation
Cooperative, Inc.
Fort Collins, CO

Clifford I. Barrett
Colorado River Energy Distributors
Association
Salt Lake City, UT

Jere Bates
Tri-State Generation and Transmission
Association
Denver, CO

Daniel A. Brickley
Salt River Project
Phoenix, AZ

Ronald Carey
Poudre Valley Rural Electric Association
Fort Collins, CO

Joe Costello
Chimney Rock Public Power
Bayard, NE

Charlie Crane
Tri-State Generation and Transmission
Association
Denver, CO

Gary Craythom
Nevada Power Company
Las Vegas, NV

Jerry Demel
Tri-State Generation and Transmission
Association
Denver, CO

Electrical District No. Five
Pinal County
Red Rock, AZ

Randy Ewell
Mt. Wheeler Power
Ely, NV

Duane J. Farmer
Public Service Company of New Mexico
Albuquerque, NM

Bill Garcia
New Mexico Public Service Commission
Santa Fe, NM

Garkane Power Association, Inc.
Richfield, UT

Patrice E. Goodkind
Plains Electric Generation and
Transmission, Inc.
Albuquerque, NM

J.J. Horenovsky
Colorado Springs Utilities
Colorado Springs, CO

Jim Iverson
Mountain Parks Electric, Inc.
Granby, CO

G. Richard Judd
Utah Municipal Power Agency
Spanish Fork, UT

J. David Lankutis
San Miguel Power Association
Nucla, CO

Paul Lane
Los Angeles Department of Water
and Power
Los Angeles, CA

Doug Larson
Western Interstate Energy Board
Denver, CO

William H. McEwan
Colorado Springs Utilities Transmission
and Distribution Department
Colorado Springs, CO

Gary Merrill
Murray City Power
Murray, UT

Clifford C. Michaelis
Bountiful City Light and Power
Bountiful, UT

Michael L. Miller
Sangre de Cristo Electric Association, Inc.
Buena Vista, CO

Dave Onstad
Arizona Power Authority
Phoenix, AZ

Dennis Paradee
Page Electric Utility
Page, AZ

John E. Pope
Intermountain REA
Sedalia, CO

R. Prasad Potturi
New Mexico Public Service Commission
Santa Fe, NM

Ronald Rayner
Electrical District No. 8
Phoenix, AZ

Chuck Silkman
Public Service of Colorado
Denver, CO

Strawberry Electric Service District
Payson, UT

Tom Uechi
Los Angeles Department of Water
and Power
Los Angeles, CA

Jerry Walker
Tri-State Generation and Transmission
Association
Montrose, CO

Morey Wolfson
Public Utilities Commission
Denver, CO

General Distribution

Deborah Addington
Advocacy Unlimited Foundation
Glendale, AZ

Marc Allred
Salt Lake City, UT

Robert Arndorfer and Mary Zeiher
Troutdale, OR

Arnold Barney
Springville, UT

Ralph Becker
Bear West
Salt Lake City, UT

John Bellmon
National Audubon Society
Sunset, UT

Glenn V. Bird
Springville, UT

Blair Brown
Sierra Club
Albuquerque, NM

Kevin Butterbaugh
EDAW, Inc.
San Francisco, CA

Ray Cainski
Albuquerque, NM

David C. Campbell
National Wildlife Federation
Washington, DC

Daniel F. Cassidy
Phoenix, AZ

Mary Nell Clark
Reston, VA

Ralph E. Clark
Gunnison, CO

William R. Coffman
Baker, NV

Jo Ann Collin
Heber City, UT

O'Connor Dale
Kanab, UT

Stephen P. Daniel
Marietta, GA

James E. Deacon
University of Nevada
Las Vegas, NV

Kent L. Devilbiss
Carbondale, CO

William A. Diamond
Page, AZ

Jean R. Dick
Canon City, CO

Gary A. Dodge
Salt Lake City, UT

Tim Donnelly
Diamond Energy
Los Angeles, CA

Dorland Edgar
Argonne National Laboratory
Argonne, IL

J.W. Engelert
Lafayette, CO

Rick Ernenwein
Littleton, CO

Alban R. Essbach
Phoenix, AZ

Judy Fahys
Salt Lake Tribune
Salt Lake City, UT

Alden Farr
Brigham City Corporation
Brigham City, UT

Steve Finucane
Washington, DC

Five County Association of Governments
St. George, UT

Stephan Flint
Logan, UT

Timothy J. Flood, MD
Phoenix, AZ

FOCUS Advisors, Inc.
Oakland, CA

H. Paul Friesema
Northwestern University
Evanston, IL

M. Geanious
Yampa, CO

John Geddie
Albuquerque, NM

Kent Gill
Camp Sherman, OR

Erick Gioso
Synergics
Annapolis, MD

Ian Goodman
The Goodman Group, Ltd.
Boston, MA

Edward W. Graeff
Phoenix, AZ

William Graf
Department of Geography
Tempe, AZ

Grand Canyon River Guides
Flagstaff, AZ

Thomas Graves
Mid-West
Denver, CO

Paul R. Grimshaw
Santa Clara, UT

T. Gunn
Marble Canyon, AZ

Ronald Harris
Phoenix, AZ

Dean Hayes
Bountiful, UT

John K. Hayes
Provo, UT

Donald R. Hearn
Duncan and Allen
Washington, DC

James G. Harris
Spring Lake, UT

Donald Henderson
St. George, UT

Steve Hinchman
High Country News
Paonia, CO

George K. and Susan Spence Hinde
Murray, UT

Kathryn A. Hines
Magnolia, MA

Leonard F. Holt
Northern Arizona Flycasters
Flagstaff, AZ

Larry Hopkins
Telluride, CO

Trevor Hughes
Logan, UT

David Hulzingh
Tempe, AZ

Norman D. James, Esq.
Ryley, Carlock, and Applewhite
Phoenix, AZ

David Jeppsen
Berkeley, CA

H.I. Jeppsen
JMT Company
Brigham City, UT

Trent Keller
Salt Lake City, UT

Daniel and Linda Kohn
Kendal Park, NJ

Robert Koons
Grand Canyon Natural History Association
Grand Canyon, AZ

William A. Lannier
San Diego, CA

Eric Larsen
Fillmore City
Fillmore, UT

James and Jennifer Le Noir
Las Cruces, NM

Bob Lippman
Friends of the Colorado River
Flagstaff, AZ

Jim Lochhead
Glenwood Springs, CO

Frank K. Loudon
Loudon Engineering Company
Las Vegas, NV

Charles E. Lusk
TranAm Group, Inc
Tulsa, OK

Mainstream Associates
North Hampton, NH

Eugene I. Majerowicz
Los Angeles, CA

Gordon A. Mankins
Phoenix, AZ

Terry Martin
National Parks and Conservation
Association
Salt Lake City, UT

J. Marvin
Flagstaff, AZ

W.M. McArthur
St. George, UT

G. McFadden
PRAXAIR, Inc.
Tonawanda, NY

David Merritt
Colorado River WCD
Colorado Springs, CO

William W. Metcalfe, Jr.
Salt Lake City, UT

Roy Michelotti
Los Alamos, NM

Dick and Marine Miles
St. George, UT

Tom Moody
Grand Canyon River Guides
Flagstaff, AZ

Edward Monk
Mt. Pleasant, UT

Janet K. Morrison
Sun City West, AZ

John Mueller
Midvale, UT

Buffy Naake
Center for Applied Research
Denver, CO

Dave Naslund
Edgewater, CO

Don and Cheryl Noble
Flagstaff, AZ

Leon Obernolte
Castro Valley, CA

Evert Oldham
Flora Vista, NM

Thomas Olsen
Flagstaff, AZ

Pacific River Supply
El Sobrante, CA

Richard A. Parrish
Southern Environmental Law Center
Charlottesville, VA

L. Cordell Peterson
St. George, UT

Patricia S. Port
San Francisco, CA

Scotch Panokin
Washington, DC

Sherry Piatt
Santa Barbara, CA

Gail Peters
Phoenix, AZ

Richard Quartaroli
Flagstaff, AZ

Scott and Debbie Rager
Flagstaff, AZ

Paul Reimann
Bountiful, UT

Claude Robbins
ERG International
Golden, CO

Mr. Bryant Rose
Grand Junction, CO

Robert Rubin
New City, NY

Kenneth R. Saline
K.R. Saline and Associates
Phoenix, AZ

Byron Schimpp
Sunnyvale, CA

Jack Schmidt
Utah State University
Logan, UT

John H. Shannon
Phoenix, AZ

Jack H. Simon
Mesa, AZ

Ken Sleight
Pack Creek Ranch
Moab, UT

Lex B. Smith, MD
Baltimore, MD

Terry N. Snyder
Sacramento, CA

Southern Environmental Law Center
Charlottesville, VA

Earle E. Spamer
The Academy of Natural Sciences
Philadelphia, PA

Spronk Water Engineers
Denver, CO

Judith Steel
Fairacres, NM

Floyd W. and LaRae Stewart
Springville, UT

D. Thayer
Los Alamos, NM

Ray Thayne
Salt Lake County Fish and Game
Association
West Valley City, UT

R. Van Valkenburgh
Palisade, CO

Charles P. Van Epps
Broomfield, CO

Mike Walker
Flagstaff, AZ

Edward Weinberg
Duncan, Weinberg, Miller and Pembroke
Washington, DC

W.G. Weinel
Mesa, AZ

Warren Welbourn
Monrovia, CA

Mark Whiting
Springville, UT

Loren Winters
Ulteig Engineers, Inc.
Fargo, ND

Walter F. Wolf
Gallup, NM

Brian Wood
Santa Fe, NM

John Wood
Utah Guides and Outfitters
Salt Lake City, UT

Worldwide Explorations, Inc.
Flagstaff, AZ

Libraries

Arizona Department of Water Resources
Library
Phoenix, AZ

Arizona State Library
Department of Library, Archives and
Public Records
Phoenix, AZ

Arizona State Regional Library for the
Blind and Physically Handicapped
Phoenix, AZ

Arizona State University
Noble Science and Engineering Library
Tempe, AZ

Arizona State University
Hayden Library
Tempe, AZ

Flagstaff City-Coconino County
Public Library
Flagstaff, AZ

Grand Canyon Community Library
Grand Canyon, AZ

Kingman Public Library
Kingman, AZ

Maricopa County Library
Phoenix, AZ

Mesa Public Library
Mesa, AZ

Mohave County Library
Kingman, AZ

Northern Arizona University
Cline Library
Flagstaff, AZ

Page Public Library
Page, AZ

Phoenix City Library
Phoenix, AZ

Scottsdale Public Library
Scottsdale, AZ

Tempe Public Library
Tempe, AZ

Tucson Public Library
Tucson, AZ

University of Arizona Library
Tucson, AZ

California State Library
Sacramento, CA

California State University
Hayward Library
Hayward, CA

California State University
University Library
Los Angeles, CA

Colorado River Board of California Library
Glendale, CA

Environmental Protection Agency
Region IX Library
San Francisco, CA

Los Angeles Public Library
Los Angeles, CA

Los Angeles Public Library
Water and Power Section
Los Angeles, CA

San Francisco Public Library
San Francisco, CA

Stanford University Libraries
Stanford, CA

University of California
General Library
Berkeley, CA

University of California
University Research Library
Los Angeles, CA

University of California
Shields Library
Davis, CA

University of Southern California
Doheny Memorial Library
Los Angeles, CA

Colorado State University Libraries
Fort Collins, CO

Denver Central Library
Denver, CO

University of Colorado at Boulder
Norlin Library
Boulder, CO

University of Denver
Penrose Library
Denver, CO

U.S. Air Force Academy
Academy Library
Colorado Springs, CO

Boulder City Library
Boulder City, NV

Clark County Library District
Las Vegas, NV

Nevada State Library
Carson City, NV

University of Nevada
Reno Library
Reno, NV

University of Nevada at Las Vegas
James Dickinson Library
Las Vegas, NV

Albuquerque Public Library
Albuquerque, NM

New Mexico State Library
Santa Fe, NM

New Mexico State University Library
Las Cruces, NM

University of New Mexico Library
Albuquerque, NM

Brigham Young University
Harold B. Lee Library
Provo, UT

Cedar City Library
Cedar City, UT

Kanab City Library
Kanab, UT

Moab City Library
Moab, UT

Salt Lake City Public Library
Salt Lake City, UT

Salt Lake County Library System
Salt Lake City, UT

Southern Utah State University Library
Cedar City, UT

University of Utah Marriott Library
Salt Lake City, UT

Utah State University
Merrill Library
Logan, UT

Utah State Library
Salt Lake City, UT

Washington County Library
St. George, UT

Weber State University
Stewart Library
Ogden, UT

Laramie County Library System
Cheyenne, WY

Rock Springs Public Library
Rock Springs, WY

University of Wyoming
Coe Library
Laramie, WY

Wyoming State Library
Cheyenne, WY

**DATE
FILMED**

6/6/94

END