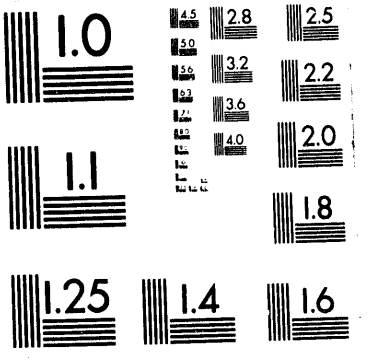

1.0
4.5
2.8
2.5
5.0
3.2
2.2
5.6
3.6
2.0
4.0
1.1
1.8
1.25
1.4
1.6

1 of 2

DOE/EIS-0150D

Salt Lake City Area Integrated Projects Electric Power Marketing

Draft Environmental Impact Statement

Volume 4: Appendixes B-D

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 4

COVER SHEET . . . . . V4 - iii

DOCUMENT CONTENTS . . . . . V4 - v

FIGURES — VOLUME 4 . . . . . V4 - viii

TABLES — VOLUME 4 . . . . . V4 - x

APPENDIX B: AIR RESOURCES B-1

B.1 Affected Environment B-3
B.1.1 Climate and Meteorology B-3
B.1.2 Air Quality B-5
B.1.3 Noise B-21
B.2 Environmental Consequences B-25
B.3 References for Appendix B B-30

APPENDIX C: WATER RESOURCES FOR FLAMING GORGE DAM AND THE ASPINALL UNIT C-1

C.1 Flaming Gorge Dam C-3
C.1.1 Reservoir Release Patterns and Downstream Flows C-3
C.1.2 Streamflow Synthesis and Reservoir Regulation Modeling for the Green River C-14
C.1.3 Multiple Regression Model for the Green River C-21
C.1.4 Sediment Transport Modeling for the Browns Park Reach of the Green River C-23
C.2 Aspinall Unit C-26
C.2.1 Release Patterns and Reservoir Elevations C-26
C.2.2 Reservoir Fluctuation Calculations C-40
C.3 References for Appendix C C-50

APPENDIX D: ECOLOGICAL RESOURCES D-1

D.1 Lists of Species Names D-3
D.2 Ecological Impact Assessment Methodologies for Flaming Gorge Dam and the Aspinall Unit D-3
D.2.1 Flaming Gorge Dam D-3
D.2.2 Aspinall Unit D-31
D.3 Wetlands Assessment D-34
D.3.1 Glen Canyon Dam D-35
D.3.2 Flaming Gorge Dam D-39
D.3.3 Aspinall Unit D-48
D.3.4 Conclusions D-51
D.4 Threatened and Endangered Species D-51
D.4.1 Federal Listing Categories D-51
D.4.2 State of Arizona D-52

CONTENTS — VOLUME 4 (Cont.)

D.4.3 State of Colorado D-53
D.4.4 State of Utah D-54
D.4.5 Correspondence Regarding Listed Species D-54
D.5 References for Appendix D D-67

FIGURES — VOLUME 4

B.1 Major Electric Power Plants in the Six-State Study Region B-11

B.2 Areas within the Six-State Study Region Designated Nonattainment for SO_2, CO, O_3, and PM_{10} B-13

B.3 Ambient Air Quality Monitoring Stations for SO_2 Operating in 1989 within the Six-State Study Region B-14

B.4 Ambient Air Quality Monitoring Stations for NO_2 Operating in 1989 within the Six-State Study Region B-15

B.5 Ambient Air Quality Monitoring Stations for CO Operating in 1989 within the Six-State Study Region B-16

B.6 Ambient Air Quality Monitoring Stations for O_3 Operating in 1989 within the Six-State Study Region B-17

B.7 Ambient Air Quality Monitoring Stations for PM_{10} Operating in 1989 within the Six-State Study Region B-18

B.8 Ambient Air Quality Monitoring Stations for TSP Operating in 1989 within the Six-State Study Region B-19

B.9 Ambient Air Quality Monitoring Stations for Lead Operating in 1989 within the Six-State Study Region B-20

B.10 Contour Plot of Summer 1984 Median Standard Visual Range for the Contiguous United States B-22

B.11 Federal Class I Air Quality Areas in the Contiguous United States B-23

C.1 Locations along the Green River where Flow Was Computed with the SSARR Model C-17

C.2 Comparison of Model-Predicted Flows Using Data from Maybell, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987 . . . . . C-19

FIGURES — VOLUME 4 (Cont.)

C.3 Comparison of Model-Predicted Flows Using Data from Deer Lodge Park, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987 . . . . . C-19

C.4 Comparison of the SSARR Model Results with the Empirical Model Results C-20

C.5 Lag Distributions for a Moderate Year, 1987 . . . . . C-22

C.6 Lag Distributions for a Dry Year, 1989 . . . . . C-22

C.7 Total Sediment Load for the Green River during a Moderate Year, 1987 . . . . . C-27

C.8 Total Sediment Load for the Green River during a Dry Year, 1989 . . . . . C-27

C.9 Total Sediment Load for the Green River during a Wet Year, 1983 . . . . . C-28

C.10 Fraction of Annual Sediment Load for the Green River during a Moderate Year, 1987 . . . . . C-28

C.11 Fraction of Annual Sediment Load for the Green River during a Dry Year, 1989 . . . . . C-29

C.12 Fraction of Annual Sediment Load for the Green River during a Wet Year, 1983 . . . . . C-29

C.13 Diagram of the Reservoir Routing Model Used to Determine Reservoir Pool Elevation Changes due to the Aspinall Unit Research-Flow Hydrographs C-47

D.1 Location of Aerial Videography Sites Used in Ecological Impact Assessment of the Green River Downstream of Flaming Gorge Dam D-24

D.2 Location of Aerial Videography Sites Used in Ecological Impact Assessment of the Aspinall Unit Reservoirs D-33

D.3 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year under the Year-Round High Fluctuation Operational Scenario at Flaming Gorge Dam D-43

D.4 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year under the Seasonally Adjusted High Fluctuation Operational Scenario at Flaming Gorge Dam D-44

FIGURES — VOLUME 4 (Cont.)

D.5 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year under the Seasonally Adjusted Moderate Fluctuation Operational Scenario at Flaming Gorge Dam D-45

D.6 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year under the Seasonally Adjusted Steady Flow Operational Scenario at Flaming Gorge Dam D-46

TABLES — VOLUME 4

B.1 National Ambient Air Quality Standards and State Ambient Air Quality Standards for Criteria Pollutants Applicable to the Six States in the Study Region B-6

B.2 Designated Nonattainment Areas within the Colorado River Basin and the Six-State Study Region B-8

B.3 Annual Emissions of SO_2, NO_x, and VOCs from Electric Utility and Other Sectors within the Six-State Study Region, 1981-1990 . . . . . B-9

B.4 Annual Emissions of CO_2 from Electric Utility and Other Sectors within the Six-State Study Region and the United States, 1981-1990 . . . . . B-10

B.5 Key to Figure B.1 . . . . . B-12

B.6 State of Colorado Regulations on Maximum Permissible Noise Levels B-24

B.7 Annual Emissions of SO_2, NO_x, TSP, and CO_2 from Electric Energy Generated by 17 Utility Systems under Selected Commitment-Level Alternatives for 1993, 1998, and 2008 . . . . . B-26

B.8 Annual Emissions of SO_2, NO_x, TSP, and CO_2 from Electric Energy Generated by 17 Utility Systems under Selected Operational Scenarios for 1993, 1998, and 2008 . . . . . B-28

C.1 Daily Reservoir Release Patterns for a Moderate Year, 1987 . . . . . C-4

C.2 Daily Reservoir Release Patterns for a Dry Year, 1989 . . . . . C-5

C.3 Daily Reservoir Release Patterns for a Wet Year, 1983 . . . . . C-6

C.4 Allowable Release Fluctuations for Flaming Gorge Reservoir C-8

TABLES — VOLUME 4 (Cont.)

C.5 Criteria for Developing Flaming Gorge Seasonally Adjusted Releases C-10

C.6 Daily Green River Flows in a Moderate Year, 1987, under the Year-Round High Fluctuating Flow Scenario C-11

C.7 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted High Fluctuating Flow Scenario C-12

C.8 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted Moderate Fluctuating Flow Scenario C-13

C.9 Stage-Discharge Relationships Used in the SSARR Model of the Green River C-18

C.10 Calibrated Parameters Used in the SSARR Modeling for the Green River C-20

C.11 Summary of Coefficient of Variation and Index of Variability for the Operational Scenarios at Flaming Gorge Dam C-24

C.12 Daily Release Patterns for Blue Mesa Reservoir C-31

C.13 Daily Release Patterns for Morrow Point Reservoir C-32

C.14 Daily Releases for Crystal Reservoir C-33

C.15 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Moderate Year, 1987 ..... C-34

C.16 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Dry Year, 1989 ..... C-36

C.17 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Wet Year, 1983 ..... C-38

C.18 Maximum Allowable Fluctuations for Morrow Point Reservoir Releases C-40

C.19 Maximum and Minimum Reservoir Surface Elevations on the First Day of the Month under the Seasonally Adjusted High Fluctuating Flow Scenario at the Aspinall Unit for a Moderate Water Year, 1987 ..... C-41

C.20 Bureau of Reclamation Coefficient Tables Used to Calculate Reservoir Elevations C-44

C.21 Elevation Changes in a Moderate Year, 1987 ..... C-45

TABLES — VOLUME 4 (Cont.)

C.22 Elevation Changes in a Dry Year, 1989 . . . . . C-46

C.23 Elevation Changes in a Wet Year, 1983 . . . . . C-49

D.1 Fish Species in the Lower Colorado River between Glen Canyon Dam and Lake Mead D-4

D.2 Fish Species in the Green River from Flaming Gorge Dam to Jensen, Utah D-8

D.3 Fish Species in the Aspinall Unit Reservoirs, Gunnison River, Colorado D-12

D.4 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species below Glen Canyon Dam, Arizona D-14

D.5 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species below Flaming Gorge Dam, Utah and Colorado D-17

D.6 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species in the Vicinity of the Aspinall Unit Reservoirs, Gunnison River, Colorado D-21

D.7 Approximate River Flows during Multispectral Aerial Videography on the Green River D-25

D.8 Wetland Classification of Riparian Habitats of the Colorado River Corridor below Glen Canyon Dam D-35

D.9 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Glen Canyon Dam D-38

D.10 Wetland Classification of Riparian Habitats of the Green River Corridor below Flaming Gorge Dam D-40

D.11 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Flaming Gorge Dam D-47

D.12 Wetland Classification of Riparian Habitats of the Aspinall Unit Reservoirs D-48

D.13 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation along the Aspinall Unit Reservoirs D-50

APPENDIX B:

AIR RESOURCES

APPENDIX B:

AIR RESOURCES

The air resources (including acoustical environment) of the six-state study region considered in this Electric Power Marketing Environmental Impact Statement (EIS) are described in Section 3.2 of the main text, and the environmental consequences of commitment-level alternatives and operational scenarios are evaluated in Sections 4.1.2 and 4.2.2, respectively. This appendix provides additional information in support of these descriptions and evaluations. Information regarding the affected environment and environmental consequences is presented in Sections B.1 and B.2, respectively.

B.1 AFFECTED ENVIRONMENT

B.1.1 Climate and Meteorology

The six-state study region includes the states of Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. The climate of this region is generally semiarid to arid. The most important factors affecting the climate of the region are the wide variations in topography and latitude and the presence of warm, moist air masses that originate over the Pacific Ocean and move eastward. Additional influences include the Gulfs of California and Mexico, which occasionally spawn summer rainstorms over the southern portion of the region; and Canadian air masses, which occasionally settle over the northern portion of the region (Upper Colorado Region State-Federal Inter-Agency Group 1971; U.S. Army Corps of Engineers [COE] 1982).

B.1.1.1 Wind

Winds in the region generally move from west to east but are greatly modified by local topographic features. Mountain slopes with westerly exposures experience high wind speeds, whereas wind speeds are relatively low in the protected valleys. During much of the year, high-pressure regions dominate, causing only light wind movement. Surface winds are most often associated with the movement of air masses up the slopes during the day and down the slopes during the night (Upper Colorado Region State-Federal Inter-Agency Group 1971). In desert and plateau regions, the strongest winds are associated with summer rainstorms and can reach speeds of up to 100 miles per hour (mph). In the northernmost regions and in the mountains, the greatest wind speeds are recorded during the winter and spring months (COE 1982).

B.1.1.2 Temperature, Humidity, and Fog

Temperatures in the region vary widely with elevation, latitude, season, and time of day. Temperatures vary about 3°F per 1,000 ft of elevation. Average temperatures range from freezing in the mountains to 50°F in the lower mountains and plateaus and up to 70°F in the desert regions in the south (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982). In New Mexico, average temperatures between points of similar elevation vary about 0.6°F per 1° of latitude; in Utah, the variation is about 1.5 to 2°F per 1° change in latitude (Ruffner 1985). The mean monthly temperature is highest in July and lowest in January. Diurnal variations are usually large in summer, averaging about 40°F and as much as 50 to 60°F in desert regions. During winter, these variations average about 20 to 25°F, although they can be higher in the desert regions (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982; Ruffner 1985).

Humidity in the region is generally quite low, especially in the deserts in the southern portion of the region. Annual average relative humidity values, based on four readings per day, range from 30% in Las Vegas, Nevada, and 36% in Phoenix, Arizona, to 55% in Salt Lake City, Utah, and 56% in Casper, Wyoming (National Oceanic and Atmospheric Administration 1990a-g). Because of the low humidity, days with heavy fog are rare, especially in the desert regions in the lower basin. The annual average number of days with heavy fog limiting visibility to 0.25 mi or less ranges from 0.7 in Las Vegas, Nevada, and 1.5 in Phoenix, Arizona, to 11.4 in Flagstaff, Arizona, and 11.5 in Salt Lake City, Utah (National Oceanic and Atmospheric Administration 1990a-g).

B.1.1.3 Precipitation and Evaporation

An average of 14 in./yr of precipitation falls on the Colorado River Basin. The local annual precipitation varies from less than 5 in. in desert regions to more than 50 in. at the highest mountain elevations. For most of the upper basin, the largest part of the annual precipitation occurs during October through April from Pacific storms. In the lower basin, summer storms from the Gulfs of California and Mexico during July through September account for the largest part of annual precipitation; however, precipitation is highly variable from year to year and can be less in summer than in winter (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982).

Evaporation rates are high throughout the river basin, as a result of the combination of high temperatures, low humidities, clear skies, and moderate winds. In northern Arizona, annual evaporation rates range from about 30 in. at high elevations to about 60 in. in the lower valleys. In central and southern Arizona, annual evaporation rates range from about 50 in. to more than 80 in. along the Colorado River (COE 1982).

B.1.1.4 Severe Weather

Thunderstorms in the basin usually result from air masses moving in from over the Gulfs of California and Mexico, and they occur most frequently in the lower basin during July through September. The thunderstorms consist of heavy downpours, which are often associated with high winds that occasionally reach speeds of up to 100 mph (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982). The annual average number of thunderstorms ranges from 7 in Yuma, Arizona, and 14 in Las Vegas, Nevada, to 42 and 51 in Tucson and Flagstaff, Arizona, respectively (National Oceanic and Atmospheric Administration 1990a-g). Tornadoes are less frequent and destructive in this region than in the Midwest (Ruffner 1985). Severe weather in the upper basin is most often associated with winter storms, which are widespread and usually last several days (COE 1982).

B.1.1.5 Atmospheric Dispersion

Atmospheric dispersion of air pollutants improves if wind speed increases, atmospheric stability lessens, and depth of mixing layer (mixing height) increases. Annual and seasonal data for average wind speed throughout the mixing layer, mixing height, and normalized average pollutant concentration values[1] for the contiguous United States have been estimated and presented as isopleth maps by Holzworth (1972). These isopleth maps indicate that the conditions for atmospheric dispersion in this region are, in general, poorer than in other regions of the United States during morning hours but somewhat better during afternoon hours. The worst conditions for atmospheric dispersion exist during the winter months, when the average mixing height is lowest in both morning and afternoon and the average wind speed in the mixing layer is reduced.

B.1.2 Air Quality

Tables B.1 through B.4 and Figures B.1 through B.9 provide detailed information regarding air quality and visibility within the six-state study region. Table B.1 presents the National Ambient Air Quality Standards (NAAQS) and State Ambient Air Quality Standards for criteria pollutants applicable to each of the six states. Table B.2 identifies the designated nonattainment areas in each state with respect to the NAAQS. Emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) in the six states are listed in Table B.3. Emissions of carbon dioxide (CO_2) in the six states are compared with U.S. CO_2 emissions in Table B.4.

Figure B.1 shows the locations of the major electric power plants located within the six-state study region. (A key to the plants is presented in Table B.5.) Figure B.2 shows the

---

[1] A theoretical, citywide average pollutant concentration over urban areas was derived on the basis of a simple dispersion model, normalized for a uniform average area emission rate (Holzworth 1972).

TABLE B.1 National Ambient Air Quality Standards (NAAQS) and State Ambient Air Quality Standards (SAAQS) for Criteria Pollutants Applicable to the Six States in the Study Region

Pollutant[a]	Averaging Time	NAAQS[b] ($\mu g/m^3$)		SAAQS ($\mu g/m^3$)					
		Primary	Secondary	Arizona[c]	Colorado[d]	Nevada[d]	New Mexico[e]	Utah[d]	Wyoming[d]
SO_2	Annual	80	-[f]	80	80	80	60	80	60
	24 hours	365	-	365	365	365	260	365	260
	3 hours	-	1,300	1,300	1,300	1,300	1,300	1,300	1,300
NO_2	Annual	100	100	100	100	100	100	100	100
	24 hours	-	-	-	-	-	200	-	-
CO	8 hours	10,000	10,000	10,000	10,000	10,000	9,200	10,000	10,000
	1 hour	40,000	40,000	40,000	40,000	40,000	14,800	40,000	40,000
O_3	1 hour	235	235	235	235	235	118	235	160
TSP[g]	Annual[h]	-	-	-	75	75	60	-	-
	24 hours	-	-	-	260	150	150	-	150
PM_{10}	Annual[i]	50	50	50	50	50	50	50	50
	24 hours	150	150	150	150	150	150	150	150
Pb	Calendar quarter	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

See footnotes on next page.

TABLE B.1 (Cont.)

[a] Notation: SO_2 = sulfur dioxide; PM = particulate matter; TSP = total suspended particulates; PM_{10} = particulate matter ≤10 µm, CO = carbon monoxide; O_3 = ozone; NO_2 = nitrogen dioxide; Pb = lead particulate matter; and H_2S = hydrogen sulfide.

[b] National Ambient Air Quality Standards (NAAQS), other than those for O_3 and PM_{10} and those based on annual averages, are not to be exceeded more than once per year. The O_3 standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above the standard is less than or equal to one. The 24-hour PM_{10} standard is attained when the expected number of days with a 24-hour average concentration above the standard is less than or equal to one. The annual arithmetic mean PM_{10} standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard.

[c] State annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year, with two exceptions.

[d] The procedures for determining attainment of the state standards are the same as for the NAAQS.

[e] All state standards are not to be exceeded.

[f] A hyphen indicates that no standard exists.

[g] The TSP standards have been replaced by the PM_{10} standards, but the former are serving as interim standards for certain states.

[h] Geometric mean of all values reported during the year.

[i] Arithmetic mean of the quarterly arithmetic means for the four calendar quarters of the year.

Sources: Code of Federal Regulations, Title 40, Part 50; Arizona Administrative Rules and Regulations, Title 18, Chapter 2, Article 2; Code of Colorado Regulations, Volume 5, Part 14; Nevada Administrative Code, Chapter 445; New Mexico Environmental Improvement Board Ambient Air Quality Standards and Air Quality Control Regulations, Sections 100-1301; Utah Air Conservation Regulations, Utah Department of Health R4446; and Wyoming Rules and Regulations of Department of Environmental Quality, Air Quality Division, Chapter 1.

TABLE B.2 Designated Nonattainment Areas within the Colorado River Basin and the Six-State Study Region[a]

State	Nonattainment Areas for Respective Pollutants[b]				
	SO_2	CO	O_3	TSP	PM_{10}
Arizona	Portions of Ajo, Douglas, Hayden, Miami, Morenci, and San Manuel	Portions of Maricopa County[c] (Phoenix area) and Pima County[d] (Tucson area)	Portion of Maricopa County[c] (Phoenix area)	Portions of Ajo, Douglas, Hayden, Joseph City, Miami, Morenci, Paul Spur, Phoenix, and Tucson	Portions of Cochise, Gila, Maricopa, Pinal, Santa Cruz, and Yuma counties[c]
Colorado	None	Colorado Springs area,[c] Denver-Boulder area,[c] Fort Collins area,[c] Greeley area,[d] and Longmont area[c]	Denver, Douglas, and Jefferson counties; portions of Adams, Arapahoe, and Boulder counties[e]	Fort Collins, Greeley, Denver UA, Boulder UA, Colorado Springs 3-C UA, and Grand Junction UA	Denver metropolitan area, Aspen, Canon City, Lamar, Pagosa Springs, and Telluride[c]
Nevada	Steptoe Valley	Lake Tahoe (Nevada) area,[d] Las Vegas area,[c] and Reno area[c]	Reno area[f] (Washoe County)	Las Vegas Valley, Carson Desert, Winnemucca segment, Lower Reese Valley, Fernley area, Truckee Meadows, Mason Valley, and Clovers area.	Portions of Washoe and Clark counties
New Mexico	Portions of Grant County	Bernalillo County[c]	None	Portions of city of Albuquerque	Portion of Dona Ana County[c]
Utah	Salt Lake County and portions of Tooele County	Salt Lake City,[d] Ogden,[c] and Provo[c]	Salt Lake and Davis counties[c]	Portions of Salt Lake and Utah counties	Salt Lake and Utah counties[c]
Wyoming	None	None	None	Trona industrial area in Sweetwater County	City of Sheridan[c]

[a] Notation: UA indicates urban area or urbanized area; 3-C UA is a planning term used to designate continuing, cooperative, and comprehensive transportation planning area boundaries.

[b] For PM_{10}, initial nonattainment area.

[c] Moderate nonattainment.

[d] Not classified.

[e] Transitional nonattainment.

[f] Marginal.

Source: Code of Federal Regulations, Title 40, Part 81, Subpart C.

TABLE B.3 Annual Emissions of SO_2, NO_x, and VOCs from Electric Utility and Other Sectors within the Six-State Study Region, 1981-1990[a]

Pollutant/ Sector	Emissions by Year (10^3 tons)									
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
SO_2										
Electric utility	458	465	451	474	397	359	379	459	469	410
Others	1,571	1,036	1,112	1,074	971	870	601	519	445	429
Total[b]	2,029	1,501	1,563	1,548	1,368	1,229	980	979	914	839
NO_x										
Electric utility	482	499	484	521	532	509	570	623	675	979
Others	839	880	940	969	753	710	733	743	769	773
Total[b]	1,322	1,380	1,424	1,490	1,284	1,219	1,304	1,366	1,444	1,752
VOCs										
Electric utility	3	3	3	3	3	3	3	3	3	3
Others	1,024	980	972	973	878	830	841	864	831	802
Total[b]	1,026	983	975	976	881	833	845	867	835	805

[a] The six states are Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

[b] Individual values may not add up to the total because of rounding.

Source: Cilek (1993).

TABLE B.4 Annual Emissions of CO_2 from Electric Utility and Other Sectors within the Six-State Study Region and the United States, 1981-1990

	Emissions (10^6 tons as carbon)					
	Six States[a]			United States		
Year	Electric Utility	Others	Total[b]	Electric Utility	Others	Total[b]
1981	39	78	117	473	1,830	2,303
1982	40	76	115	447	1,715	2,162
1983	38	75	114	459	1,671	2,130
1984	42	78	120	479	1,770	2,249
1985	44	75	120	492	1,743	2,235
1986	41	74	115	488	1,749	2,237
1987	47	75	122	506	1,806	2,313
1988	51	80	131	531	1,892	2,423
1989	52	81	134	539	1,904	2,443
1990	53	93	145	531	1,901	2,432

[a] The six states are Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

[b] Individual values may not add up to the total because of rounding.

Source: Cilek (1993).

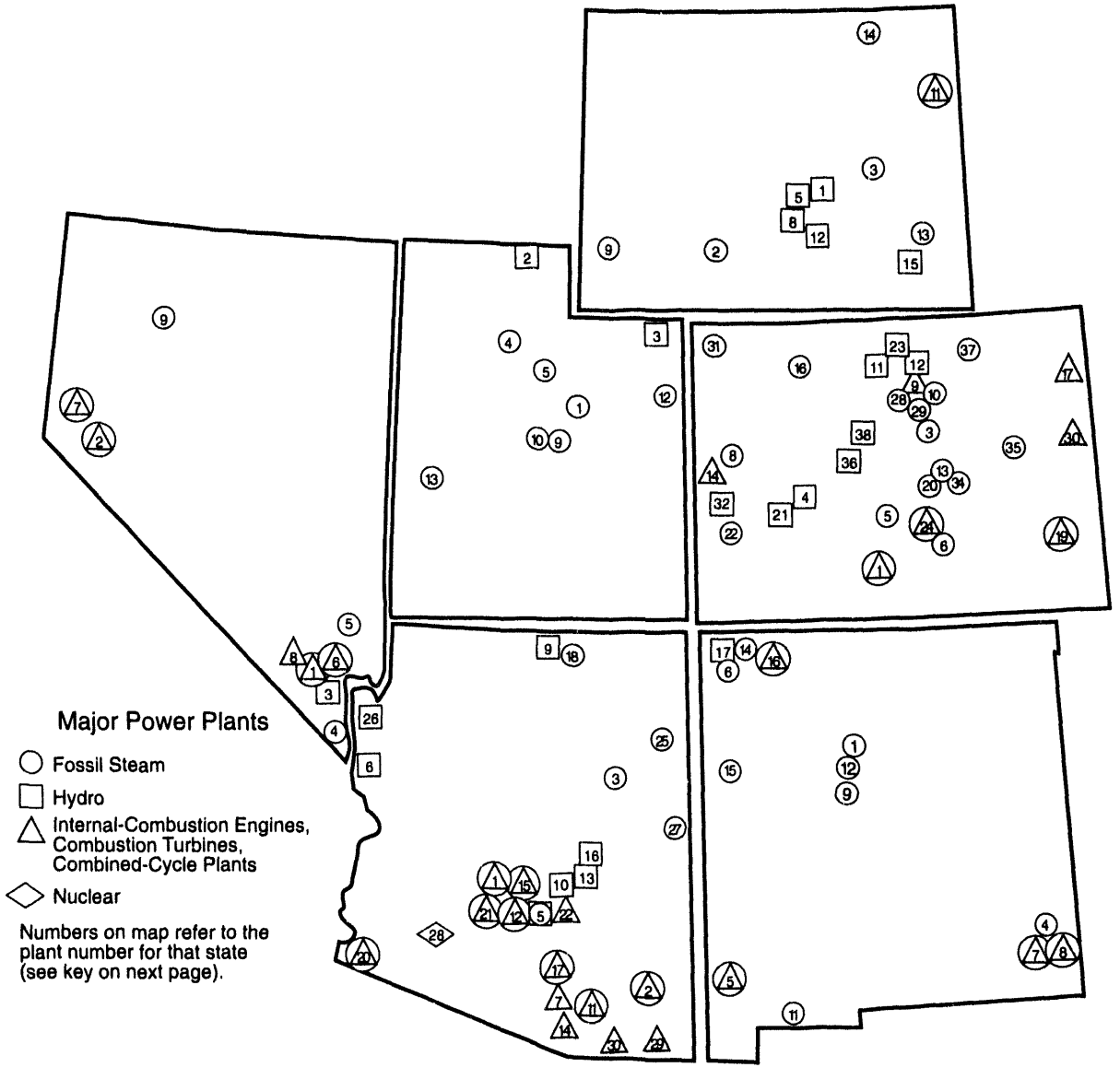


FIGURE B.1 Major Electric Power Plants in the Six-State Study Region (see Table B.5 for key to facilities) (Source: Adapted from Electric World 1992)

TABLE B.5 Key to Figure B.1

State/Power Plant	Type of Plant	MW
Arizona		
1 Aqua Fria	Fossil steam	390
	Combustion turbine	223
2 Apache	Fossil steam	399
	Combined cycle	80
	Combustion turbine	84
3 Cholla	Fossil steam	1,156
5 Cross Cut	Fossil steam	30
	Hydroelectric	3
6 Davis	Hydroelectric	225
7 De Moss-Petrie	Combustion turbine	66
9 Glen Canyon	Hydroelectric	1,267
10 Horse Mesa	Hydroelectric	130
11 Irvington	Fossil steam	505
	Combustion turbine	81
12 Kyrene	Fossil steam	108
	Combustion turbine	227
13 Mormon Flat	Hydroelectric	58
14 North Loop	Combustion turbine	108
15 Ocotillo	Fossil steam	220
	Combustion turbine	174
16 Roosevelt	Hydroelectric	35
17 Saguaro	Fossil steam	225
	Combustion turbine	114
18 Navajo	Fossil steam	2,410
20 Yuma Axis	Fossil steam	75
	Combustion turbine	148
21 Phoenix	Fossil steam	75
	Combustion turbine	106
22 Santan	Combined cycle	396
	Combustion turbine	414
25 Coronado	Fossil steam	821
26 Hoover	Hydroelectric	671
27 Springerville	Fossil steam	794
28 Palo Verde	Nuclear	3,810
29 Douglas	Combustion turbine	26
30 Valencia	Combustion turbine	50
	Internal combustion	4
Colorado		
1 Alamosa	Fossil steam	20
	Combustion turbine	58
2 Arapahoe	Fossil steam	251
4 Blue Mesa	Hydroelectric	60
5 Clark	Fossil steam	39
6 Comanche	Fossil steam	778
7 Cabin Creek	Hydroelectric	300
8 Cameo	Fossil steam	75
9 Fort Lupton	Combustion turbine	110
10 Cherokee	Fossil steam	802
11 Estes	Hydroelectric	45
12 Flatiron	Hydroelectric	74
13 Birdsall	Fossil steam	63
14 Fruita	Combustion turbine	29
16 Hayden	Fossil steam	465
17 Republican River	Combustion turbine	225
19 Lamar	Fossil steam	35
	Internal combustion	2
20 Drake	Fossil steam	282
	Combustion turbine	66
21 Morrow Point	Hydroelectric	120
22 Nucla	Fossil steam	38
23 Pole Hill	Hydroelectric	33
24 Pueblo	Fossil steam	23
	Internal combustion	10
28 Valmont	Fossil steam	282
	Combustion turbine	66
29 Zuni	Fossil steam	115
Colorado (Cont.)		
30 Burlington	Combustion turbine	118
31 Craig	Fossil steam	1,284
32 Crystal	Hydroelectric	29
34 Nixon	Fossil steam	207
35 Pawnee	Fossil steam	500
36 Mt Elbert	Hydroelectric	200
37 Rawhide	Fossil steam	255
38 Green Mountain	Hydroelectric	26
Nevada		
1 Clark	Fossil steam	190
	Combustion turbine	270
2 Fort Churchill	Fossil steam	220
3 Hoover	Hydroelectric	676
4 Mohave	Fossil steam	1,636
5 Reid Garder	Fossil steam	342
6 Sunrise	Fossil steam	82
	Combustion turbine	75
7 Tracy	Fossil steam	243
	Combustion turbine	25
8 Westside	Internal combustion	32
9 Valmy	Fossil steam	254
New Mexico		
1 Algodones	Fossil steam	51
4 Cunningham	Fossil steam	265
5 Lordsburg	Fossil steam	37
	Combined cycle	5
	Combustion turbine	13
6 Four Corners	Fossil steam	2,268
7 North Lovington	Fossil steam	49
	Internal combustion	19
8 Maddox	Fossil steam	114
	Combustion turbine	66
9 Person	Fossil steam	120
11 Rio Grande	Fossil steam	266
12 Reeves	Fossil steam	175
14 San Juan	Fossil steam	1,572
15 Plains Escalante	Fossil steam	233
16 Animas	Fossil steam	32
	Internal combustion	2
Utah		
1 Carbon	Fossil steam	189
2 Cutler	Hydroelectric	30
3 Flaming Gorge	Hydroelectric	108
4 Gadsby	Fossil steam	252
5 Hale	Fossil steam	60
9 Huntington Canyon	Fossil steam	893
10 Hunter	Fossil steam	1,338
12 Bonzana	Fossil steam	400
13 Intermountain	Fossil steam	1,522
Wyoming		
1 Alcova	Hydroelectric	36
2 Bridger	Fossil steam	2,024
3 Johnston	Fossil steam	788
5 Fremont Canyon	Hydroelectric	48
8 Kortes	Hydroelectric	36
9 Naughton	Fossil steam	711
11 Osage	Fossil steam	36
	Internal combustion	1
12 Seminoe	Hydroelectric	45
13 Laramie	Fossil steam	1,650
14 Wyodak	Fossil steam	331
15 Glendo	Hydroelectric	38

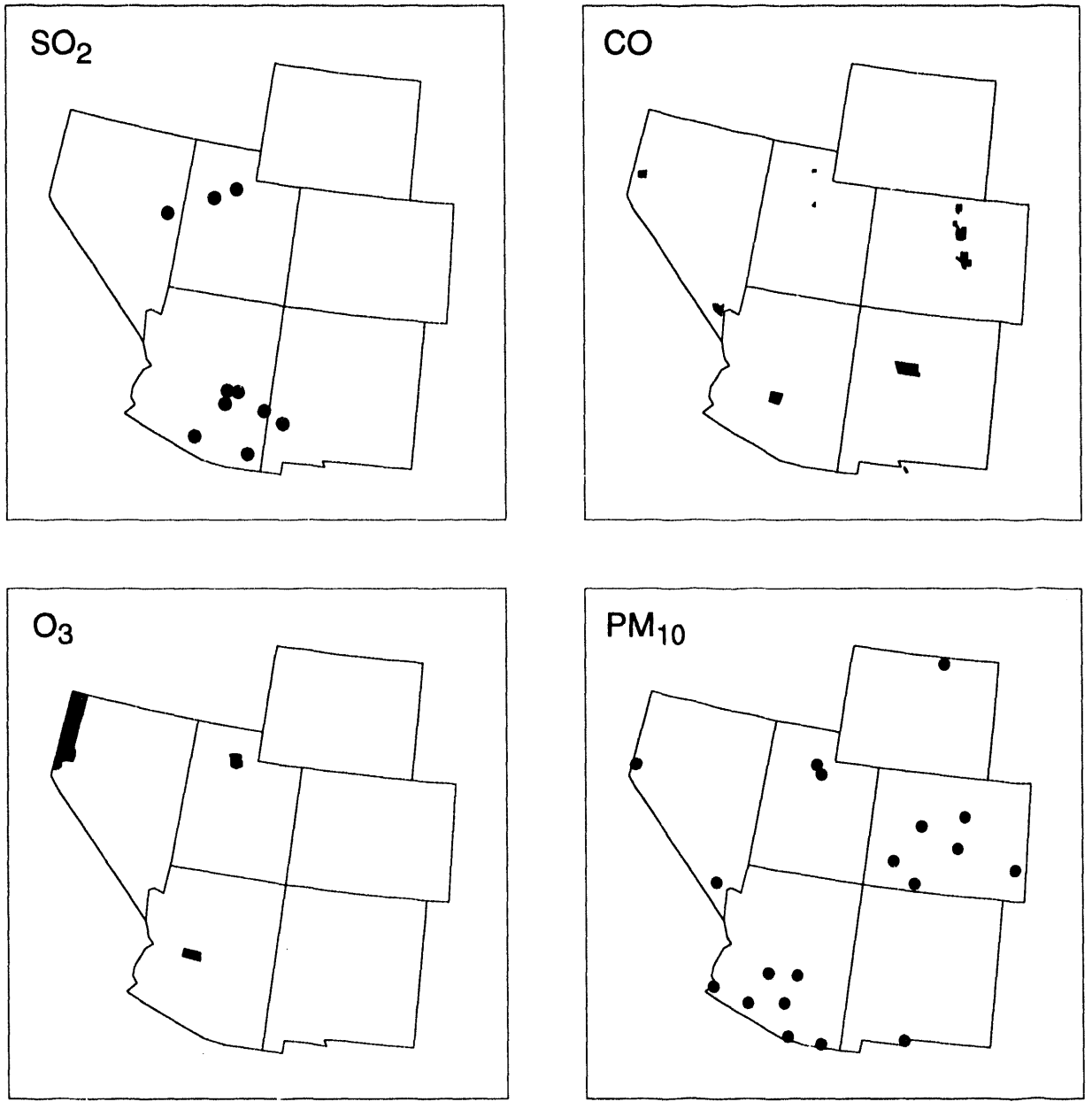


FIGURE B.2 Areas within the Six-State Study Region Designated Nonattainment for SO_2, CO, O_3, and PM_{10} (Adapted from EPA 1991)

FIGURE B.3 Ambient Air Quality Monitoring Stations for SO_2 Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

FIGURE B.4 Ambient Air Quality Monitoring Stations for NO_2 Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

FIGURE B.5 Ambient Air Quality Monitoring Stations for CO Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

FIGURE B.6 Ambient Air Quality Monitoring Stations for O_3 Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

FIGURE B.7 Ambient Air Quality Monitoring Stations for PM_{10} Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

FIGURE B.8 Ambient Air Quality Monitoring Stations for TSP Operating in 1989 within the Six-State Study Region (Chun et al. 1994)

FIGURE B.9 Ambient Air Quality Monitoring Stations for Lead Operating in 1989 within the Six-State Study Region (Source: Chun et al. 1994)

areas within the study region designated as nonattainment for SO_2, carbon monoxide (CO), ozone (O_3) and PM_{10} (particulates with a diameter ≤10 µm). Figures B.3 through B.9 show the locations of ambient air quality monitoring stations operating within the six-state study region during 1989; these stations monitored SO_2, nitrogen dioxide (NO_2), CO, O_3, PM_{10}, TSP, and lead (Pb), respectively. The regional visual range for the contiguous United States is shown in Figure B.10, and the Federal Class I air quality areas in the contiguous United States are shown in Figure B.11. Visibility has been determined to be an important value in 156 of the Class I areas (U.S. Environmental Protection Agency [EPA] 1979).

B.1.3 Noise

The EPA guideline recommends an L_{dn} of 55 dBA, which is sufficient to protect the public from the effect of broad-band environmental noise in typically quiet outdoor and residential areas (EPA 1974).[2,3] For protection against hearing loss in the general population from nonimpulsive noise, the EPA guideline recommends an L_{eq} of 70 dBA or less over a 40-year period.[4]

Under the Noise Control Act of 1972 and its amendments (Quiet Communities Act of 1978, 42 United States Code 4901-4918), the states have authority to regulate environmental noise, and governmental agencies are directed to comply with local community noise statutes and regulations. Of the six states within the study region, Colorado is the only one with quantitative noise regulations. The maximum permissible noise limits for the various classes of source areas under the Colorado Noise Abatement Law are listed in Table B.6.

B.1.3.1 Glen Canyon Dam

The acoustic environment in the areas away from the major noise sources at the Glen Canyon power plant is that of a rural location with typical residual sound levels[5] of approximately 30 to 35 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the transformer substation, the residual environmental noise levels are estimated to rise to about 55 dBA (Chun et al. 1994).

---

[2] L_{dn} is the day-night weighted equivalent sound level.

[3] dBA is the A-weighted decibel, a unit of weighted sound-pressure level, measured by the use of metering characteristics and the "A" weighing specified in the American National Standards Specification for Sound Level Meters, ANSI S1.4-1983 (R1988) and Amendment S1.4A-1985 (Acoustical Society America 1983, 1985).

[4] L_{eq} is the equivalent steady sound level that, if continuous during a specific time period, would contain the same total energy as the actual time-varying sound. For example, L_{eq} (1h) is the 1-hour equivalent sound level.

[5] A residual level represents a low-limit value to which the ambient environmental noise drops frequently, but below which it seldom goes.

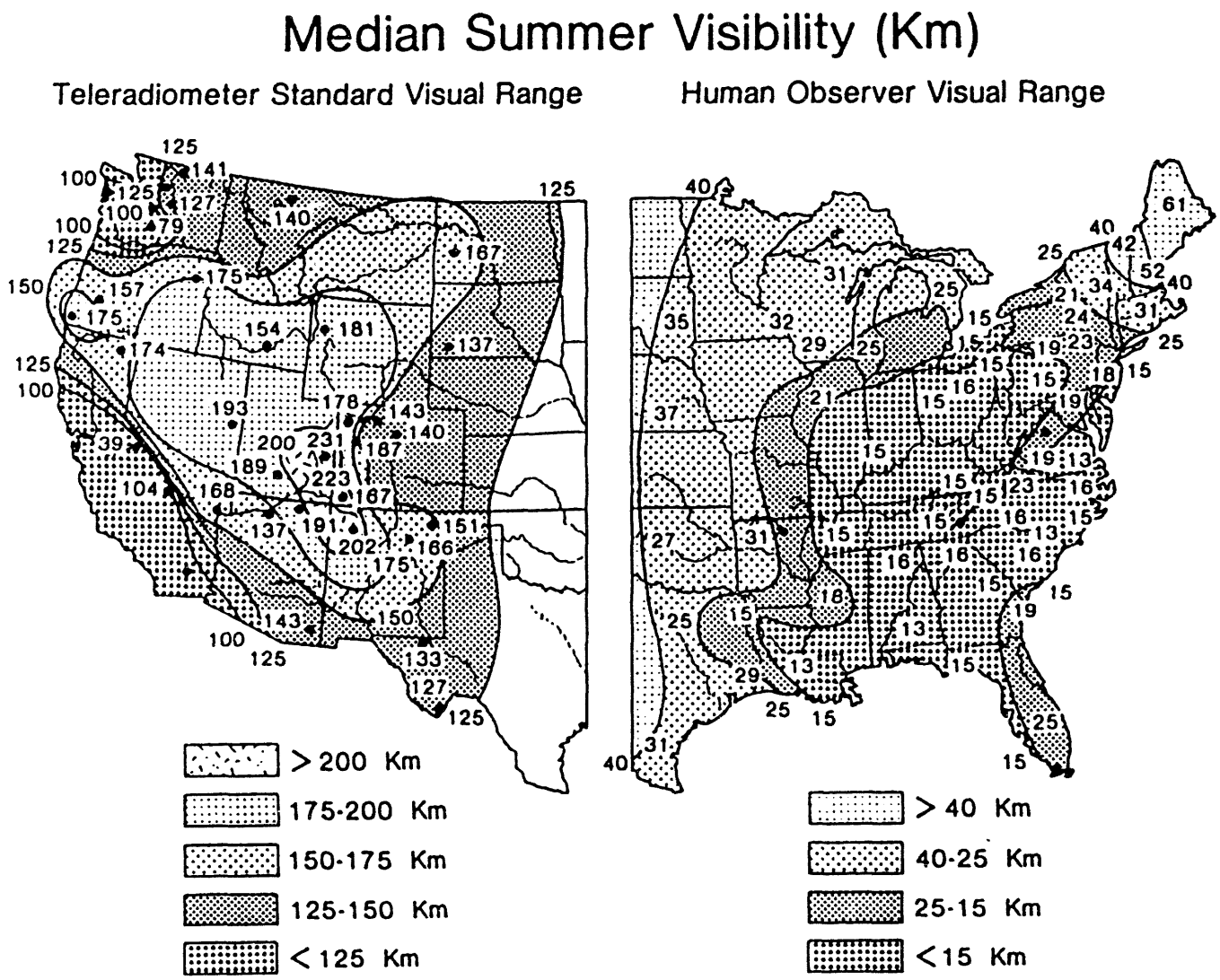


FIGURE B.10 Contour Plot of Summer 1984 Median Standard Visual Range for the Contiguous United States (Source: Malm 1989; reprinted with permission of Kluwer Academic Publishers)

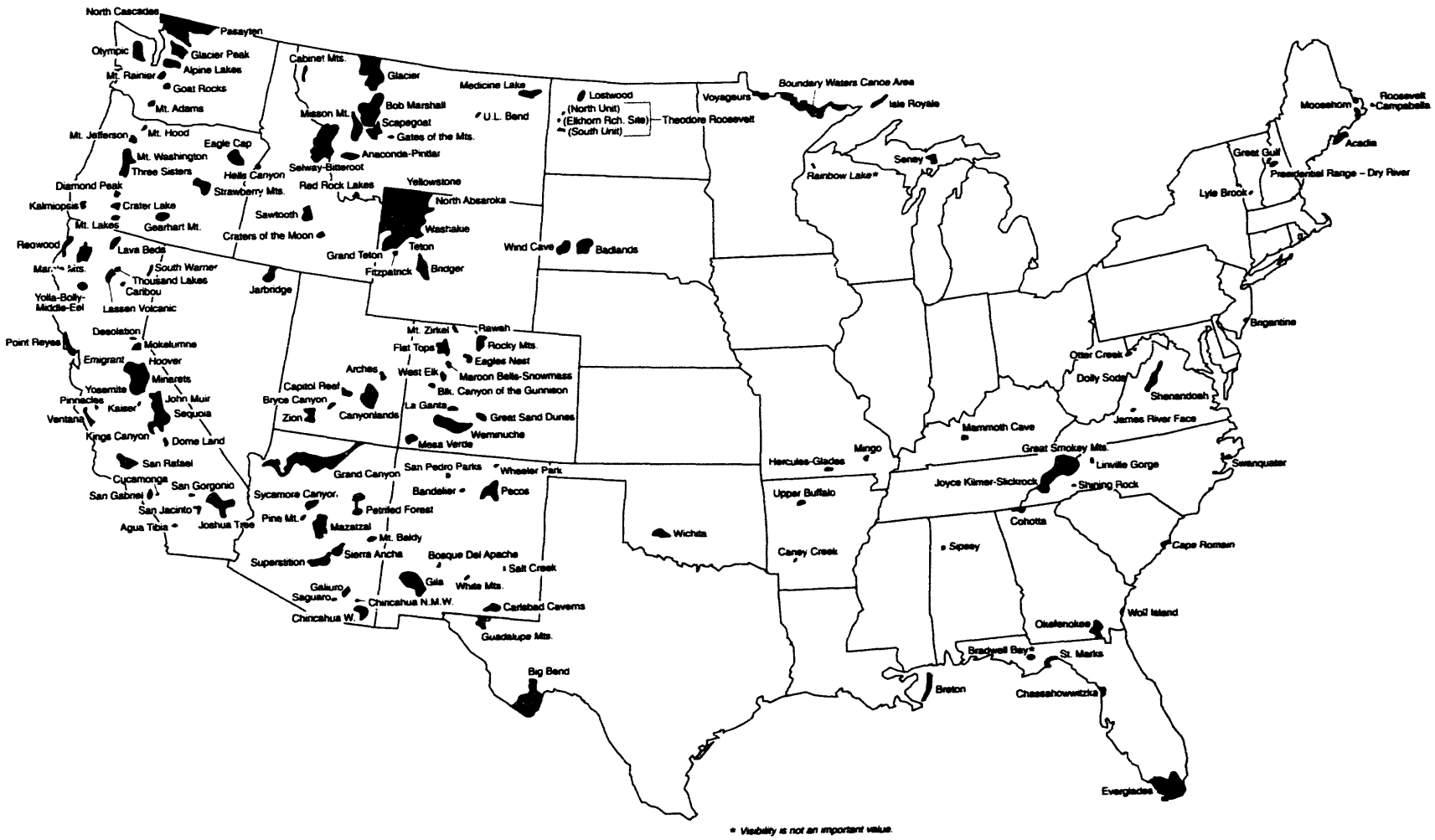


FIGURE B.11 Federal Class I Air Quality Areas in the Contiguous United States (Source: Adapted from EPA 1979)

TABLE B.6 State of Colorado Regulations on Maximum Permissible Noise Levels

	Maximum Permissible Noise Level[a] (dBA)	
Zone	7 a.m. to 7 p.m.[b]	7 p.m. to next 7 a.m.
Residential	55	50
Commercial	60	55
Light industrial	70	65
Industrial	80	75

[a] At a distance of 25 ft or more from the property line. Periodic, impulsive, or shrill noises are considered a public nuisance when such noises are at a level of 5 dBA less than those listed.

[b] For a period not to exceed 15 minutes in any one hour, the noise level may be exceeded by 10 dBA.

Source: Colorado Revised Statutes, Title 25 — Health, Article 12 — Noise Abatement.

The noise-sensitive receptors closest to the transformer substation at the Glen Canyon power plant are the residences located along the northwestern perimeter of the city of Page, approximately 1.1 mi east of the substation. If the Glen Canyon power plant were not present, these residences would have residual nighttime sound levels typical of rural communities near a lightly traveled highway (approximately 30 dBA) (Liebich and Cristoforo 1988). However, acoustic emissions from the noise sources at the Glen Canyon power plant are estimated to raise the residual background environmental noise levels in the residential area up to about 39 dBA (Chun et al. 1994).

The ambient environmental noise level at these residences is increased at times when traffic is passing on nearby roadways. An automobile can produce a momentary level of up to 77 dBA when passing along a roadway at a distance of 50 ft from a receptor. A large, heavily loaded tractor-trailer truck can create maximum levels as high as 87 dBA when passing at a distance of 50 ft (Flynn 1979; Fuller and Brown 1981). At such times, vehicular noise completely masks (makes inaudible) all other environmental background noise at these residences, including the levels attributable to the noise sources at Glen Canyon power plant.

B.1.3.2 Flaming Gorge Dam

The acoustic environment in the areas away from the major noise sources at the Flaming Gorge hydroelectric plant is that of a remote rural-to-wilderness location with typical residual sound levels of approximately 20 to 25 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the transformer substation, the residual environmental noise levels are estimated to rise to about 44 dBA (Chun et al. 1994).

The noise-sensitive receptors closest to the transformer substation at the Flaming Gorge power plant are the Arch Dam and Deer Run campgrounds — approximately 0.9 mi east and 1.1 mi west-southwest of the transformer substation, respectively. If the Flaming Gorge power plant were not present, these campgrounds would have residual nighttime sound levels typical of remote rural-to-wilderness areas (approximately 20 dBA) (Liebich and Cristoforo 1988). Acoustic emissions from the noise sources at the Flaming Gorge power plant are estimated to raise the residual background environmental noise levels at these campgrounds up to about 30 and 28 dBA, respectively (Chun et al. 1994).

The ambient environmental noise levels at the three campgrounds are increased at times when traffic is passing on nearby roadways (Section 3.2.3.1). At such times, vehicular noise completely masks all other environmental background noise at the campgrounds, including the levels attributable to the noise sources at Flaming Gorge power plant.

B.1.3.3 Aspinall Unit

The acoustic environments in the areas away from the major noise sources of the Aspinall Unit (Blue Mesa, Morrow Point, and Crystal dams) are that of a rural-to-remote-rural location with typical residual sound levels of approximately 25 to 30 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the Curecanti substation (located about 1.5 mi south of the Morrow Point power plant), which serves the three power plants, the residual environmental noise levels are estimated to rise to about 44 dBA (Chun et al. 1994).

The noise-sensitive receptor closest to the Curecanti substation is a trailer residence about 0.25 mi northwest of the substation transformer. If the Curecanti substation were not present, the area surrounding the trailer residence would have residual nighttime sound levels typical of rural-to-remote-rural locations (approximately 25 dBA) (Liebich and Cristoforo 1988). The acoustic emissions from the substation transformer are estimated to raise the residual background environmental noise levels at the trailer residence up to about 37 dBA (Chun et al. 1994).

The ambient environmental noise levels at the trailer residence are substantially increased at times when traffic is passing on nearby roadways (Section 3.2.3.1). At such times, vehicular noise completely masks all other environmental background noise at the trailer residence, including the levels attributable to the substation transformer.

B.2 ENVIRONMENTAL CONSEQUENCES

The potential consequences of Western's commitment-level alternatives and operational scenarios on air quality and the acoustic environment are discussed in Sections 4.1.2 and 4.2.2, respectively, of this EIS. Additional information regarding potential environmental consequences are presented in Tables B.7 and B.8 of this appendix. Estimated annual air pollutant emissions from the region's 17 utility systems and the percent change

TABLE B.7 Annual Emissions of SO_2, NO_x, TSP, and CO_2 from Electric Energy Generated by 17 Utility Systems under Selected Commitment-Level Alternatives for 1993, 1998, and 2008

			1993		1998		2008	
Pollutant	Supply Option	Alternative[a]	Annual Emissions (10^3 tons)	Percent Change[b]	Annual Emissions (10^3 tons)	Percent Change[b]	Annual Emissions (10^3 tons)	Percent Change[b]
SO_2	A	0	364	0.0	375	0.0	418	0.0
		2	361	-0.9	372	-0.9	415	-0.7
		4	363	-0.3	374	-0.3	418	-0.2
		5	364	-0.1	376	0.2	421	0.5
	B	0	361	0.0	373	0.0	416	0.0
		2	359	-0.6	369	-1.0	414	-0.6
		4	361	0.1	372	-0.2	415	-0.2
		5	363	0.6	375	0.5	419	0.6
	C	0	359	0.0	371	0.0	415	0.0
		2	356	-0.7	367	-1.0	411	-0.8
		4	359	-0.1	370	-0.3	413	-0.3
		5	362	0.8	373	0.5	417	0.7
NO_x	A	0	399	0.0	429	0.0	538	0.0
		2	397	-0.4	429	0.0	539	0.2
		4	396	-0.9	429	0.2	541	0.7
		5	397	-0.5	429	0.0	539	0.2
	B	0	398	0.0	429	0.0	537	0.0
		2	399	0.3	429	0.0	539	0.4
		4	396	-0.5	429	0.1	541	0.7
		5	397	-0.2	429	0.0	537	0.1
	C	0	399	0.0	427	0.0	536	0.0
		2	401	0.5	428	0.2	538	0.4
		4	395	-0.8	427	0.1	539	0.6
		5	397	-0.4	427	0.1	537	0.2

TABLE B.7 (Cont.)

Pollutant	Supply Option	Alternative[a]	1993 Annual Emissions (10^3 tons)	1993 Percent Change[b]	1998 Annual Emissions (10^3 tons)	1998 Percent Change[b]	2008 Annual Emissions (10^3 tons)	2008 Percent Change[b]
TSP	A	0	169	0.0	166	0.0	163	0.0
		2	168	-0.5	166	-0.5	162	-0.2
		4	169	-0.1	166	-0.2	163	-0.1
		5	170	0.3	167	0.3	164	0.6
	B	0	168	0.0	166	0.0	162	0.0
		2	168	-0.5	165	-0.7	162	-0.3
		4	168	-0.1	165	-0.4	162	-0.2
		5	169	0.4	167	0.3	163	0.5
	C	0	168	0.0	165	0.0	162	0.0
		2	167	-0.5	164	-0.6	161	-0.3
		4	167	-0.1	165	-0.3	161	-0.2
		5	168	0.5	165	0.3	162	0.5
CO_2	A	0	34,122	0.0	37,978	0.0	48,948	0.0
		2	34,018	-0.3	37,971	0.0	48,938	0.0
		4	33,910	-0.6	37,847	-0.3	48,852	-0.2
		5	33,974	-0.4	37,897	-0.2	49,000	0.1
	B	0	34,052	0.0	38,162	0.0	48,996	0.0
		2	34,092	0.1	38,100	-0.2	49,033	0.1
		4	33,908	-0.4	37,915	-0.6	48,816	-0.4
		5	33,997	-0.2	38,082	-0.2	49,004	0.0
	C	0	34,083	0.0	38,027	0.0	49,018	0.0
		2	34,127	0.1	38,076	0.1	49,052	0.1
		4	33,861	-0.7	37,785	-0.6	48,760	-0.5
		5	33,971	-0.3	37,883	-0.4	48,973	-0.1

[a] 0 represents the no-action alternative.

[b] Percent change from the no-action alternative.

Source: Chun et al. (1994).

TABLE B.8 Annual Emissions of SO_2, NO_x, TSP, and CO_2 from Electric Energy Generated by 17 Utility Systems under Selected Operational Scenarios for 1993, 1998, and 2008

			1993		1998		2008	
Pollutant	Alternative[a]	Supply Option	Annual Emissions (10^3 tons)	Percent Change[b]	Annual Emissions (10^3 tons)	Percent Change[b]	Annual Emissions (10^3 tons)	Percent Change[b]
SO_2	0	A	364	0.0	375	0.0	418	0.0
		B	361	-0.8	373	-0.5	416	-0.6
		C	359	-1.3	371	-1.2	415	-0.9
	2	A	361	0.0	372	0.0	415	0.0
		B	359	-0.5	369	-0.6	414	-0.4
		C	356	-1.2	367	-1.3	411	-1.0
	4	A	363	0.0	374	0.0	418	0.0
		B	361	-0.4	372	-0.5	415	-0.5
		C	359	-1.1	370	-1.2	413	-1.1
	5	A	364	0.0	376	0.0	421	0.0
		B	363	-0.3	375	-0.3	419	-0.5
		C	362	-0.7	373	-0.8	417	-0.7
NO_x	0	A	399	0.0	429	0.0	538	0.0
		B	398	-0.2	429	0.1	537	-0.2
		C	399	-0.1	427	-0.4	536	-0.3
	2	A	397	0.0	429	0.0	539	0.0
		B	399	0.5	429	0.1	539	0.0
		C	401	0.8	428	-0.1	538	-0.1
	4	A	396	0.0	429	0.0	541	0.0
		B	396	0.1	429	0.0	541	-0.1
		C	395	0.0	427	-0.5	539	-0.3
	5	A	397	0.0	429	0.0	539	0.0
		B	397	0.1	429	0.1	537	-0.3
		C	397	0.0	427	-0.3	537	-0.3

TABLE B.8 (Cont.)

Pollutant	Alternative[a]	Supply Option	1993 Annual Emissions (10^3 tons)	1993 Percent Change[b]	1998 Annual Emissions (10^3 tons)	1998 Percent Change[b]	2008 Annual Emissions (10^3 tons)	2008 Percent Change[b]
TSP	0	A	169	0.0	166	0.0	163	0.0
		B	168	-0.4	166	-0.3	162	-0.4
		C	168	-0.9	165	-0.9	162	-0.7
	2	A	168	0.0	166	0.0	162	0.0
		B	168	-0.5	165	-0.5	162	-0.4
		C	167	-1.0	164	-1.0	161	-0.7
	4	A	169	0.0	166	0.0	163	0.0
		B	168	-0.4	165	-0.5	162	-0.5
		C	167	-0.9	165	-0.9	161	-0.8
	5	A	170	0.0	167	0.0	164	0.0
		B	169	-0.4	167	-0.2	163	-0.5
		C	168	-0.8	165	-0.9	162	-0.8
CO_2	0	A	34,122	0.0	37,978	0.0	48,948	0.0
		B	34,052	-0.2	38,162	0.5	48,996	0.1
		C	34,083	-0.1	38,027	0.1	49,018	0.1
	2	A	34,018	0.0	37,971	0.0	48,938	0.0
		B	34,092	0.2	38,100	0.3	49,033	0.2
		C	34,127	0.3	38,076	0.3	49,052	0.2
	4	A	33,910	0.0	37,847	0.0	48,852	0.0
		B	33,908	0.0	37,915	0.2	48,816	-0.1
		C	33,861	-0.1	37,785	-0.2	48,760	-0.2
	5	A	33,974	0.0	37,897	0.0	49,000	0.0
		B	33,997	0.1	38,082	0.5	49,004	0.0
		C	33,971	0.0	37,883	0.0	48,973	-0.1

[a] 0 represents the no-action alternative.

[b] Percent change from supply option A.

Source: Chun et al. (1994).

from the no-action alternative are presented in Table B.7. Estimated annual air pollutant emissions from the region's utility systems under supply options A, B, and C are presented in Table B.8.

B.3 REFERENCES FOR APPENDIX B

Acoustical Society of America, 1983, *American National Standard Specification for Sound Level Meters, ANSI S1.4-1983*, New York, N.Y., Feb.

Acoustical Society of America, 1985, *American National Standard Specification for Sound Level Meters, ANSI S1.4A-1985, Amendment to ANSI S1.4A-1985, Amendment to ANSI S1.4-1983*, New York, N.Y., June.

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.

Cilek, C.M., 1993, "Annual Emissions of Nitrogen Oxides, Sulfur Dioxide, Volatile Organic Compounds, Total Suspended Particulates, and Carbon Dioxide for the Six States in the WAPA EIS Study Region and the United States for the Years 1981 through 1990, memorandum from Cilek (Argonne National Laboratory, Argonne, Ill.) to K.C. Chun (Argonne National Laboratory, Argonne, Ill.), Feb. 19.

COE (U.S. Army Corps of Engineers), 1982, *Water Control Manual for Flood Control: Hoover Dam and Lake Mead Colorado River, Nevada and Arizona*, prepared by U.S. Army Corps of Engineers, Sacramento District, for Los Angeles District, Dec.

Electrical World, 1992, *Directory of Electric Utilities*, New York, N.Y.

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*, EPA-550/9-74-004, U.S. Environmental Protection Agency, Washington, D.C., March.

EPA, 1979, *Protecting Visibility, An EPA Report to Congress*, EPA-450/5-79-008, Office of Air Quality Planning and Standards, Research Triangle Park, N.C., Oct.

EPA, 1991, "Air Quality Atlas," Air Monitoring Technical Information Center Bulletin Board System, National Air Data Branch, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

Flynn, D.R., 1979, "Regulation of New Products Noise Control," in *Handbook of Noise Control*, 2nd ed., C.M. Harris (editor), McGraw-Hill Book Co., New York, N.Y., pp. 41-1 to 41-8.

Fuller, W.R., and R. Brown, 1981, *Analysis and Abatement of Highway Construction Noise*, Research Report WR 81-89, prepared by Wyle Laboratories, Arlington, Va., for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control (EPA Report 550/9-81-314a), Washington, D.C., Oct.

Holzworth, G.C., 1972, *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States*, U.S. Environmental Protection Agency, Office of Air Programs, Division of Meteorology, Research Triangle Park, N.C., Jan.

Liebich, R.E., and M.P. Cristoforo, 1988, *The Use of Audibility Analysis to Minimize Community Noise Impact of Today's Smaller Generation Facilities Located near Residential Areas*, presented at American Power Conference 50th Annual Meeting, Chicago, Ill., April.

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.

National Oceanic and Atmospheric Administration, 1990a, *Local Climatological Data: Annual Summary with Comparative Data for Flagstaff, Ariz.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990b, *Local Climatological Data: Annual Summary with Comparative Data for Grand Junction, Colo.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990c, *Local Climatological Data: Annual Summary with Comparative Data for Las Vegas, Nev.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990d, *Local Climatological Data: Annual Summary with Comparative Data for Phoenix, Ariz.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990e, *Local Climatological Data: Annual Summary with Comparative Data for Tucson, Ariz.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990f, *Local Climatological Data: Annual Summary with Comparative Data for Winslow, Ariz.*, National Climatic Data Center, Asheville, N.C.

National Oceanic and Atmospheric Administration, 1990g, *Local Climatological Data: Annual Summary with Comparative Data for Yuma, Ariz.*, National Climatic Data Center, Asheville, N.C.

Ruffner, J.A. (editor), 1985, *Climates of the States: National Oceanic and Atmospheric Administration Narrative Summaries, Tables and Maps for Each State with Overview of State Climatologist Programs*, 3rd ed., Gale Research Co., Detroit, Mich.

Upper Colorado State-Federal Inter-Agency Group, 1971, *Upper Colorado Region Comprehensive Framework Study*, Appendix II, "The Region," prepared for the Pacific Southwest Inter-Agency Committee Water Resource Council by the Upper Colorado State-Federal Inter-Agency Group, Salt Lake City, Utah, June.

APPENDIX C:

WATER RESOURCES FOR FLAMING GORGE DAM AND THE ASPINALL UNIT

APPENDIX C:

WATER RESOURCES FOR FLAMING GORGE DAM AND THE ASPINALL UNIT

C.1 FLAMING GORGE DAM

C.1.1 Reservoir Release Patterns and Downstream Flows

Release patterns for Flaming Gorge Reservoir were developed for 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 operational scenario assumes that the monthly total reservoir releases would be the same as historical releases and that no changes would be made to the current operating constraints. The seasonally adjusted flow scenarios would comply with the Biological Opinion of the U.S. Fish and Wildlife Service (USFWS 1992), which includes high flows in the spring and limited hourly fluctuations, especially in summer and autumn releases.

The main differences in the operational scenarios are as follows. Assuming no changes in reservoir operating constraints, the maximum and minimum releases under the year-round high fluctuating flow scenario would be limited only by the water available for release, the reservoir minimum release requirement, and the power plant capacity. Ramping between maximum and minimum releases is assumed to occur in one hour. For the seasonally adjusted high fluctuating flow scenario, hourly releases would reach the maximum fluctuation feasible (as limited by the Biological Opinion), the water available for release, the minimum release requirement, and the power plant capacity; however, when ice cover is present on the Green River below the dam (assumed to be February and March), no hourly fluctuations would be allowed to protect fish. For the seasonally adjusted moderate fluctuating flow scenario, the hourly release fluctuations would be 50% of those in the seasonally adjusted high fluctuating flow scenario. For the seasonally adjusted steady flow scenario, reservoir releases would be constant throughout the day in each season, as defined by the Biological Opinion. Seasons here refer to periods of time varying from several weeks to one month.

C.1.1.1 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 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 water years (1987, 1989, and 1983, respectively). Each release pattern has a minimum release starting at midnight, ramp up

TABLE C.1 Daily Reservoir Release Patterns for a Moderate Year, 1987[a]

	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
Period	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	
Oct	800	4,700	10	2,590	800	800	0	800	800	0	800
Nov	800	4,700	17	3,720	800	4,700	9	2,220	4,170	1	2,380
Dec	800	4,700	17	3,720	800	4,700	9	2,220	4,170	1	2,380
Jan	800	4,700	12	3,240	800	4,700	9	2,220	4,170	1	2,380
Feb	800	4,700	14	3,240	2,380	2,380	24	2,380	2,380	24	2,380
Mar	800	4,700	2	1,290	2,380	2,380	24	2,380	2,380	24	2,380
Apr	800	4,700	2	1,290	800	4,700	10	2,440	4,390	1	2,600
May	800	4,700	4	1,610	800	4,700	15	2,740	4,700	7	3,390
Jun 1-21	800	4,700	2	1,290	4,700	4,700	24	4,700	4,700	24	4,700
Jun 22-30	800	4,700	2	1,290	800	4,700	17	2,770	4,700	11	3,740
Jul 1-9	800	4,700	4	1,610	800	4,700	6	1,860	3,810	1	2,020
Jul 10-31	800	4,700	4	1,610	890	2,900	1	976	1,980	1	1,060
Aug	800	4,700	3	1,450	990	3,000	1	1,080	2,080	1	1,160
Sep	800	4,700	5	1,780	1,070	3,100	1	1,160	2,160	1	1,240

[a] The annual average release is 2,230 cfs for the year-round high fluctuation, seasonally adjusted high and moderate fluctuations, and the steady release.

[b] Maximum release of 4,700 cfs assumes full reservoir conditions.

TABLE C.2 Daily Reservoir Release Patterns for a Dry Year, 1989[a]

	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
Period	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release (cfs)	On-Peak Duration (hours)	
Oct	800	2,370	1	931	800	1,270	1	820	1,050	1	839
Nov	800	2,750	1	962	800	800	0	800	800	0	800
Dec	800	2,740	1	962	800	800	0	800	800	0	800
Jan	800	2,350	1	929	800	800	0	800	800	0	800
Feb	800	1,980	1	899	800	800	0	800	800	0	800
Mar	800	1,970	1	897	800	800	0	800	800	0	800
Apr	800	3,130	1	994	870	4,700	1	1,030	2,980	1	1,200
May	800	2,350	1	929	800	4,700	9	2,260	4,210	1	2,420
Jun 1-7	800	4,700	2	1,290	4,000	4,000	24	4,000	4,000	24	4,000
Jun 8-19	800	4,700	2	1,290	800	4,700	9	2,240	4,190	1	2,400
Jun 20-30	800	4,700	2	1,290	800	800	0	800	800	0	800
Jul	800	1,580	1	865	800	2,380	1	858	1,600	1	920
Aug	800	4,700	2	1,290	950	2,400	1	1,010	1,740	1	1,070
Sep	800	1,970	1	898	1,000	2,450	1	1,060	1,780	1	1,120

[a] The annual average release is 990 cfs for the year-round high fluctuation, 1,150 cfs for the seasonally adjusted high and moderate fluctuations, and 1,150 cfs for the steady release.

[b] Maximum release of 4,700 cfs assumes full reservoir conditions.

TABLE C.3 Daily Reservoir Release Patterns for a Wet Year, 1983[a]

	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
Period	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	
Oct	800	4,700	19	4,050	800	4,700	3	1,320	3,280	1	1,490
Nov	800	4,700	17	3,720	4,700	4,700	24	4,700	4,700	24	4,700
Dec	800	4,700	12	2,910	4,700	4,700	24	4,700	4,700	24	4,700
Jan	800	4,700	12	2,910	4,700	4,700	24	4,700	4,700	24	4,700
Feb	800	4,700	9	2,420	4,700	4,700	24	4,700	4,700	24	4,700
Mar	800	4,700	9	2,420	4,700	4,700	24	4,700	4,700	24	4,700
Apr	800	4,700	11	2,750	4,700	4,700	24	4,700	4,700	24	4,700
May	800	4,700	13	3,080	4,700	4,700	24	4,700	4,700	24	4,700
Jun	8,070	8,070	24	8,070	7,470	7,470	24	7,470	7,470	24	7,470
Jul 1-19	10,100	10,100	24	10,100	800	4,700	17	2,780	4,700	10	3,670
Jul 20-31	10,100	10,100	24	10,100	800	800	0	800	800	0	800
Aug	5,010	5,010	24	5,010	800	800	0	800	800	0	800
Sep 1-15	800	4,700	17	3,720	800	3,250	1	898	2,120	1	1,000
Sep 16-30	800	4,700	17	3,720	1,470	4,410	1	1,600	3,070	1	1,720

[a] The annual average release is 4,270 cfs for the year-round high fluctuation, 3,870 cfs for the seasonally adjusted high and moderate fluctuations, and 3,870 cfs for the steady release.

[b] Maximum release of 4,700 cfs assumes full reservoir conditions.

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.

C.1.1.1.1 Year-Round High Fluctuating Flow Scenario

The maximum release for the year-round high fluctuating flow scenario would be 4,700 cfs, and the minimum release would be 800 cfs, as required by the Utah Division of Wildlife Resources (USFWS 1992). Ramping between these flow limits would occur in one hour. For average releases greater than 4,700 cfs, such as occurred in June-August 1983, a constant flow of 4,700 cfs would pass through the power plant and the remaining flow would bypass.

C.1.1.1.2 Seasonally Adjusted Fluctuating Flow Scenarios

The Biological Opinion defines allowable fluctuations for Flaming Gorge Reservoir releases in summer and autumn months and also requires shifting monthly releases to provide high flows in the spring and low flows in the summer and autumn (USFWS 1992).

Allowable Release Fluctuations for Summer and Autumn

The Biological Opinion requires that:

1. A target flow at Jensen, Utah, would be 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 as follows:

   Moderate year: July 10 through October 31

   Dry year: June 20 through October 31

   Wet year: July 20 through October 31

2. Variations of flow at Jensen for any 24-hour period would be limited to a total of 25% around the target. Variations above or below the target should be as close as possible.

3. Except for the effects of storm runoff, the flow at Jensen for wet years should stay within the range of 1,100 to 1,800 cfs, or up to 2,400 cfs after September 15.

Daily releases for Flaming Gorge Dam that comply with the above constraints are presented in Table C.4 through the end of the three water years assessed. Each daily release

TABLE C.4 Allowable Release Fluctuations for Flaming Gorge Reservoir

Year/Month	Average Yampa River Flow[a] (cfs)	Target Flow at Jensen[b] (cfs)	Daily Reservoir Release[c] (cfs)			Daily Flow at Jensen[d] (cfs)			
			Average	Base Flow	Peak Flow	Min.	% Below Target	Max.	% Above Target
1987 (Moderate)									
Jul 10-31	425	1,500	1,060	890	2,900	1,320	12.0	1,680	12.0
Aug	325	1,500	1,160	990	3,000	1,320	12.0	1,690	12.7
Sep	242	1,500	1,240	1,070	3,100	1,320	12.0	1,690	12.7
1989 (Dry)									
Jun 20-30	1,350	1,100	800	800	800	-[e]	-	-[e]	-
Jul	313	1,100	920	800	2,280	1,110	0.0	1,370	24.5
Aug	155	1,100	1,070	950	2,400	1,110	0.0	1,370	24.5
Sep	101	1,100	1,120	1,000	2,450	1,100	0.0	1,370	24.5
1983 (Wet)									
Jul 20-31	3,460	1,800	800	800	800	-[e]	-	-[e]	-
Aug	1,400	1,800	800	800	800	-[e]	-	-[e]	-
Sep 1-15	555	1,800	1,000	800	3,250	1,360	24.4	1,800	0.0
Sep 16-30	333	2,400	1,720	1,470	4,410	1,800	25.0	2,400	0.0

[a] As recorded at Deerlodge Park gage.

[b] Based on the Biological Opinion (USFWS 1992).

[c] Base and peak flows determined such that maximum and minimum flows at Jensen comply closely with the constraint of 25% fluctuations around the target flows at Jensen. The reservoir also has a minimum release requirement of 800 cfs.

[d] Flows at Jensen, Utah, computed with the SSARR model.

[e] Flows at Jensen not computed for cases where the reservoir releases would be constant at 800 cfs.

pattern is expressed in terms of a minimum and a maximum release rate with one hour on peak. The ramp up and ramp down times are both one hour. The average daily release was computed from the minimum and maximum releases and the time on peak. The minimum and maximum allowable releases for each month, or partial month when required by the Biological Opinion, were determined with the SSARR (Streamflow Synthesis and Reservoir Regulation) computer model being used by the U.S. Bureau of Reclamation (Reclamation) for the Green River below Flaming Gorge Dam (Yin 1994). The flow of the Yampa River, which is a major tributary of the Green River between Flaming Gorge Dam and Jensen, Utah, was considered in calculating flows at Jensen. The selection of the target flows shown in Table C.4 was based on the Biological Opinion constraints.

Seasonal Reservoir Releases

In addition to constraints on fluctuations for summer and autumn releases, the Biological Opinion requires shifting releases between seasons (months or partial months) to provide high flows in the spring and low flows in the summer and autumn. The criteria used in deriving the release volumes are summarized in Table C.5. These criteria strive to comply with the Biological Opinion whenever possible; other considerations include the minimum release requirement and reservoir safety. (The resulting seasonal average releases are shown as seasonally adjusted steady releases in Tables C.1 through C.3. The seasonally adjusted high and moderate fluctuating flow scenarios have the same average seasonal releases but may have fluctuations within the day.) For total annual releases (Tables C.1 through C.3), annual total power releases or total reservoir releases (power and nonpower) were not always made equal to the respective actual historical releases. The total reservoir release for the wet year is less than historical to reduce power plant bypass while still maintaining the reservoir level below the normal maximum water surface elevation. The total reservoir release for the dry year is greater than historical in an attempt to comply with the Biological Opinion. Detailed development of the seasonal releases is presented in Yin (1994).

C.1.1.2 Green River Flows

Flows in the Green River resulting from reservoir releases under the four operational scenarios were estimated for five locations below Flaming Gorge Dam: Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 3.16). The daily maximum and minimum flows in the moderate hydrologic year (1987) for year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and seasonally adjusted moderate fluctuating flows are shown in Tables C.6 through C.8. Under the seasonally adjusted steady flow scenario, the reservoir release and downstream river flow would be steady during each season (Tables C.1 through C.3). The flows at locations upstream of the Yampa River would be the same as reservoir releases, and the flows downstream of the Yampa River would be the sums of the reservoir releases and the Yampa River inflows.

TABLE C.5 Criteria for Developing Flaming Gorge Seasonally Adjusted Releases

Month	Criteria
Oct	The Biological Opinion indicates that October flow should be a continuation of summer flow, which should be 1,100 to 1,800 cfs at Jensen. The flow might be as high as 2,400 cfs at Jensen for wet years. Target flows of 1,500, 1,100, and 2,400 cfs at Jensen were assumed for moderate, dry, and wet years, respectively.
Nov-Mar	The Biological Opinion calls for relatively stable flows and indicates that the months of November through March can be used to manage reservoir storage so that spring peak and summer low flows can be provided. Therefore, average release rates were assumed to be the same for these months.
Apr-Jul	Reservoir releases would gradually increase (up to 400 cfs/d) beginning between April 1 and May 15. The release should reach 2,000 cfs during May. Release of 4,000 to 4,700 cfs (if possible) for one to six weeks begins between May 15 and June 1. This range of releases would last for one week in dry years; post-peak decline would be no more than 400 cfs/d. During moderate years, the entire spring peak would last six to eight weeks. During wet years, additional releases required to maintain reservoir levels would occur during or prior to the spring peak of the Yampa River (mid-April through June). In dry years, flows would decrease to a target flow between 1,100 and 1,800 cfs at Jensen beginning June 20 and remain at that level throughout the summer. The target flow would be reached on about July 10 in moderate years and about July 20 in wet years. Hourly fluctuations in flow would be no more than 25% around the target flow and would remain within 1,100 to 1,800 cfs.
Aug-Sep	Reservoir releases in August and September would be adjusted to maintain flows of 1,100 to 1,800 cfs at Jensen. The target flow in wet years might be increased to within the range of 1,100 to 2,400 cfs beginning September 15. The 25% fluctuation limit would remain in effect.
All	Releases through the power plant range from 800 to 4,700 cfs (if possible). The minimum release is required by an agreement with the Utah Division of Wildlife Resources (USFWS 1992), and the maximum release is based on current power plant capacity.

TABLE C.6 Daily Green River Flows in a Moderate Year, 1987, under the Year-Round High Fluctuating Flow Scenario

	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
Month	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	4,700	1,150	4,340	1,150	4,280	1,080	2,260	5,340	2,280	5,320	2,310	5,300
Nov	800	4,700	2,270	4,690	2,320	4,680	994	3,360	5,670	3,390	5,670	3,440	5,660
Dec	800	4,700	2,270	4,690	2,320	4,680	610	2,970	4,690	3,010	5,280	3,060	5,280
Jan	800	4,700	1,620	4,630	1,640	4,610	436	2,110	5,040	2,150	5,030	2,180	5,020
Feb	800	4,700	1,620	4,630	1,640	4,610	700	2,380	5,310	2,400	5,300	2,440	5,280
Mar	800	4,700	836	2,010	841	1,990	1,480	2,330	3,460	2,330	3,430	2,340	3,410
Apr	800	4,700	836	2,010	841	1,990	3,870	4,720	5,850	4,720	5,830	4,720	5,820
May	800	4,700	867	2,820	875	2,790	5,580	6,470	8,350	6,470	8,330	6,470	8,300
Jun 1-21	800	4,700	836	2,010	841	1,990	3,040	3,880	5,010	3,880	5,000	3,890	4,970
Jun 22-30	800	4,700	836	2,010	841	1,990	1,130	1,980	3,110	1,980	3,080	1,990	3,060
Jul 1-9	800	4,700	867	2,820	875	2,790	1,000	1,890	3,770	1,900	3,730	1,910	3,670
Jul 10-31	800	4,700	867	2,820	875	2,790	425	1,310	3,190	1,320	3,140	1,350	3,080
Aug	800	4,700	850	2,420	856	2,400	325	1,190	2,710	1,200	2,670	1,220	2,610
Sep	800	4,700	892	3,180	900	3,150	242	1,150	3,350	1,180	3,320	1,210	3,240

[a] Distance in river miles below Flaming Gorge Dam.

TABLE C.7 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted High Fluctuating Flow Scenario

	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
Month	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	800	800	800	800	800	1,080	1,880	1,880	1,880	1,880	1,880	1,880
Nov	800	4,700	1,070	4,190	1,080	4,120	994	2,090	5,110	2,120	5,080	2,150	5,050
Dec	800	4,700	1,070	4,190	1,080	4,120	610	1,710	4,720	1,740	4,690	1,780	4,660
Jan	800	4,700	1,070	4,190	1,080	4,120	436	1,540	4,550	1,570	4,510	1,600	4,480
Feb	2,380	2,380	2,380	2,380	2,380	2,380	700	3,080	3,080	3,080	3,080	3,080	3,080
Mar	2,380	2,380	2,380	2,380	2,380	2,380	1,480	3,860	3,860	3,860	3,860	3,860	3,860
Apr	800	4,700	1,150	4,340	1,150	4,280	3,870	5,050	8,130	5,060	8,130	5,070	8,110
May	800	4,700	1,810	4,660	1,830	4,640	5,580	7,440	10,200	7,440	10,200	7,470	10,200
Jun 1-21	4,700	4,700	4,700	4,700	4,700	4,700	3,040	7,740	7,740	7,740	7,740	7,740	7,740
Jun 22-30	800	4,700	2,270	4,690	2,320	4,680	1,130	3,500	5,810	3,530	5,810	3,580	5,800
Jul 1-9	800	4,700	925	3,490	933	3,460	1,000	1,950	4,430	1,960	4,420	1,990	4,350
Jul 10-31	890	2,900	902	1,290	903	1,280	425	1,330	1,700	1,330	1,690	1,340	1,680
Aug	990	3,000	1,000	1,390	1,000	1,390	325	1,330	1,710	1,330	1,700	1,330	1,690
Sep	1,070	3,100	1,080	1,490	1,080	1,480	242	1,320	1,720	1,330	1,710	1,330	1,690

[a] Distance in river miles below Flaming Gorge Dam.

TABLE C.8 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted Moderate Fluctuating Flow Scenario

	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
Month	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	800	800	800	800	800	1,080	1,880	1,880	1,880	1,880	1,880	1,880
Nov	2,220	4,170	2,220	2,670	2,220	2,660	994	3,220	3,650	3,220	3,650	3,220	3,640
Dec	2,220	4,170	2,220	2,670	2,220	2,660	610	2,830	3,270	2,840	3,260	2,840	3,250
Jan	2,220	4,170	2,220	2,670	2,220	2,660	436	2,660	3,100	2,660	3,090	2,660	3,080
Feb	2,380	2,380	2,380	2,380	2,380	2,380	700	3,080	3,080	3,080	3,080	3,080	3,080
Mar	2,380	2,380	2,380	2,380	2,380	2,380	1,480	3,860	3,860	3,860	3,860	3,860	3,860
Apr[b]	2,440	4,390	2,440	2,890	2,440	2,890	3,870	6,310	6,750	6,310	6,750	6,310	6,740
May[b]	2,740	4,700	2,770	4,300	2,780	4,260	5,580	8,360	9,830	8,360	9,830	8,360	9,810
Jun 1-21	4,700	4,700	4,700	4,700	4,700	4,700	3,040	7,740	7,740	7,740	7,740	7,740	7,740
Jun 22-30	2,770	4,700	2,900	4,600	2,900	4,570	1,130	4,040	5,710	4,070	5,700	4,080	5,690
Jul 1-9	1,860	3,810	1,860	2,290	1,860	2,290	1,000	2,870	3,290	2,870	3,280	2,870	3,270
Jul 10-31	976	1,980	982	1,170	982	1,170	425	1,410	1,590	1,410	1,590	1,410	1,580
Aug	1,080	2,080	1,080	1,280	1,080	1,270	325	1,410	1,600	1,410	1,590	1,410	1,590
Sep	1,160	2,160	1,160	1,360	1,160	1,360	242	1,400	1,600	1,400	1,590	1,410	1,590

[a] Distance in river miles below the Flaming Gorge Dam.

[b] Maximum and minimum flows presented are based on the average release for the month; actual daily maximum and minimum flows would differ through the month.

C.1.2 Streamflow Synthesis and Reservoir Regulation (SSARR) Modeling for the Green River

Quantitative estimates of flow as a function of time and distance from Flaming Gorge Dam were required to evaluate the effects of the hydropower operational scenarios on the Green River hydrological system. These data were needed to verify that the operational scenarios would comply with the USFWS Biological Opinion regarding operation of Flaming Gorge Dam (USFWS 1992) and to estimate flows at various points along the river during videography studies (Appendix D, Section D.2). The development of an empirical model for the Green River is discussed in Section C.1.3. Although this model is adequate for predicting flows at Jensen, Utah — the point of calibration — it does not provide any information on flow at the intermediate locations below the dam. The Streamflow Synthesis and Reservoir Regulation (SSARR) Model, developed by the North Pacific Division of the U.S. Army Corps of Engineers (COE 1987), was used to perform the required calculations. The SSARR model has two principal components: a generalized watershed model and a streamflow and reservoir regulation model. The latter model was used for this analysis.

C.1.2.1 Model Description

The streamflow and reservoir regulation component of SSARR routes flows from upstream to downstream points through channel and lake storage, and it models reservoirs under free-flow or controlled-flow modes of operation. Flows may be routed as a function of multivariable relationships involving backwater effects from tides or reservoirs. The basic routing method used in the watershed and streamflow models is referred to as a cascade-of-reservoirs technique, where the lag and attenuation of the flood wave are simulated through successive increments of lake-type storage. With SSARR, a channel or river can be visualized as a series of small lakes that represent the natural delay of runoff from upstream to downstream points. The routing characteristic of the prototype lake and the number of lake increments are specified for the model and adjusted in the calibration process (COE 1987).

Routing through watershed, river system, and reservoir components of the model relies on the law of continuity in the storage equation:

$$[(I_1 + I_2)/2 - (O_1 + O_2)/2]\ t = S_2 - S_1 \qquad \text{(C.1)}$$

where

I_1 = Inflow at the beginning of the computational period,

I_2 = Inflow at the end of the period,

O_1 = Outflow at the beginning of the period,

O_2 = Outflow at the end of the period,

S_1 = Storage at the beginning of the period,

S_2 = Storage at the end of the period, and

t = Time duration of the period.

In differential form, the inflow (I_t) is expressed as:

$$I_t = O_t + dS/dt \ . \tag{C.2}$$

In natural lakes where storage is a function of outflow at any given elevation, T_s represents the proportionality factor between storage and outflow:

$$S = T_s O \ . \tag{C.3}$$

By substitution, the following form of the equation may be derived. This form is used to compute outflow from one prototype lake increment:

$$O_2 = O_1 + t\ (I_m - O_1)/T_s + t/2) \tag{C.4}$$

where

I_m = Mean inflow, $(I_1 + I_2)/2$,

O_1 = Outflow at the beginning of the period,

t = Time duration of the period, and

T_s = Time of storage.

In the computer program, the value $t/(T_s + t/2)$ is evaluated for a specified condition and multiplied by the difference between I_m and O_1 to obtain the change in outflows. The outflow, O_2, computed from the first incremental routing is then saved and converted to initial outflow, O_1 for the next routing period (COE 1987).

Proper characterization of channel routing provides an integrated response of river system entities to hydrometeorological input. Channel routing is accomplished by using either a routing equation for incremental routing or a table that specifies time of storage-discharge relationships (COE 1987). When the following routing equation is used,

$$T_s = KTS/Q^{\,n} \ , \tag{C.5}$$

the number of routing phases, the coefficient n, and a KTS value are specified for each channel reach. The derivation of these routing parameters usually begins with values

determined from channels with similar characteristics. In the calibration process, these three parameters are adjusted to obtain the best match between the model-predicted and the observed flows (COE 1987).

C.1.2.2 Green River Model

The SSARR model was designed for the portion of the Green River that extends from Flaming Gorge Dam to Jensen, Utah. Six routing equations and two stage-discharge relationships were included in the model for this 93-mi stretch of river. Flow was computed at six locations along the river: Gates of Lodore, Hells Half Mile, Mitten Park, Jones Hole, Rainbow Park, and Jensen (Figure C.1). The stage-discharge relationships included in the model were obtained from a temporary gage installed at Mitten Park and an active U.S. Geological Survey (USGS) gage near Jensen (09261000). The stage-discharge relationships are listed in Table C.9.

A calibrated SSARR model for this segment of the Green River was obtained from Reclamation. To verify the calibration, the model-predicted flows were compared with recorded flows measured at the Jensen gage (09261000) from April 1 through September 30 of water year 1987 and water year 1988. This comparison indicated that the model was well calibrated, except during the spring months when the measured flows were much higher than the predicted flows. Figure C.2 compares the SSARR computed flows with the recorded flows at the Jensen gage. In these SSARR simulations, the recorded flows at the USGS gage near Maybell, Colorado (09251000), were used to represent the flow from the Yampa River. The same comparison is made in Figure C.3, except the recorded flows measured at the gage near Deerlodge Park, Colorado (09260050), were used to include the flow from the Yampa River; this gage is closer to the confluence of the Green River and incorporates the water contribution of the Little Snake River (Figure C.1). This adjustment to the model greatly improved the calibration near Jensen during the spring months (i.e., April through June) when the Yampa River flows discharging to the Green River are high.

Output from the calibrated SSARR model was also compared with the results of the empirical model and is summarized in Section C.1.3 of this appendix. As shown in Figure C.4, the correlation between the two models is good.

The number of routing phases specified for a channel affects the peak and timing response of the hydrograph. As the number of phases increases, with other factors held constant, the peak of the hydrograph decreases and the total time of storage increases. In the calibrated model, the number of routing phases specified for the channels in the river varied from 20 to 40, with the larger routing phase values assigned to channel segments upgradient and the smaller values downgradient of the confluence of the Yampa River. The calibrated SSARR parameters are presented in Table C.10.

The *KTS* and *n* parameters of the routing equation (C.5) were manipulated to obtain the desired time of storage per phase (T_s). The calibrated *KTS* parameters, which affect the

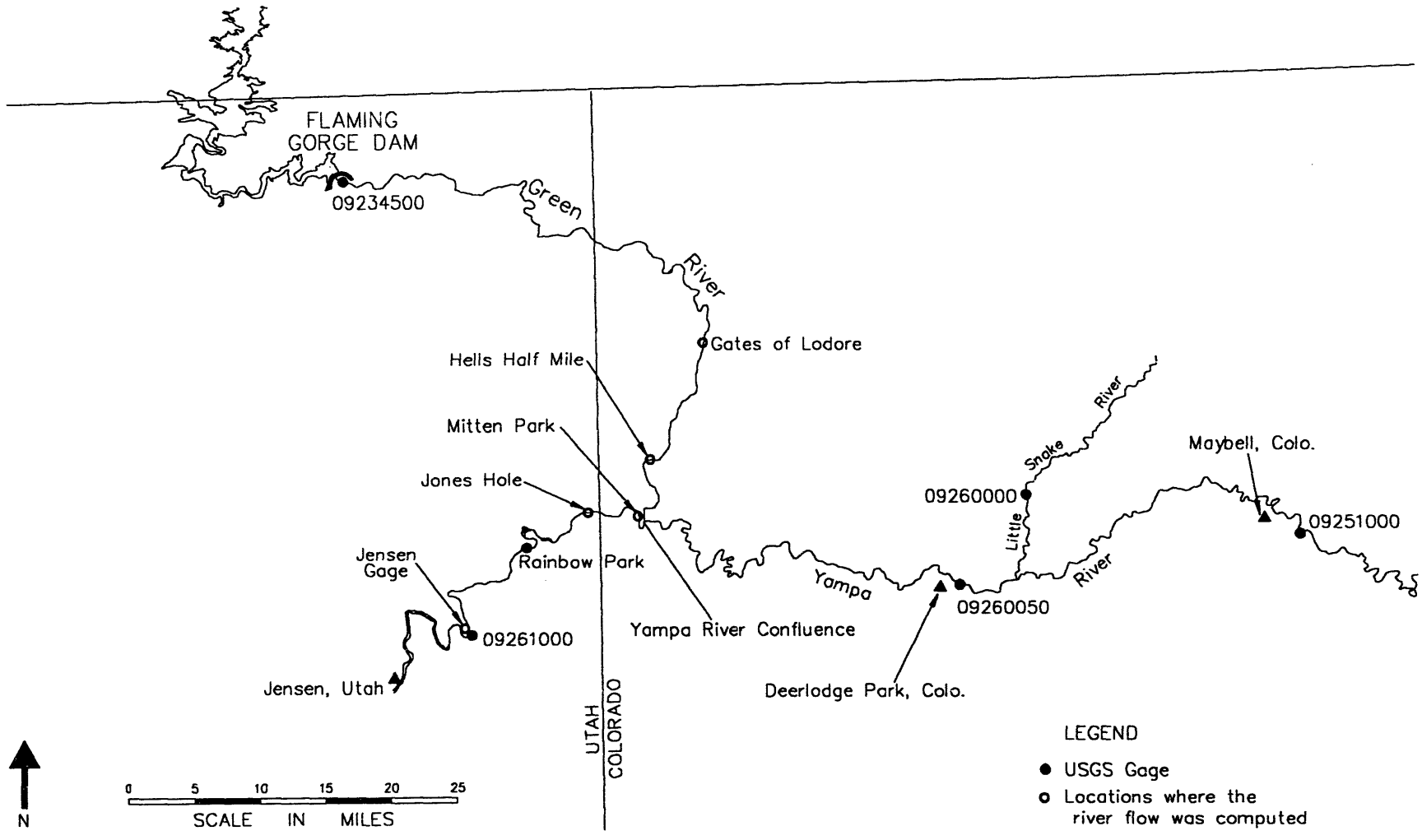


FIGURE C.1 Locations along the Green River where Flow was Computed with the SSARR Model

TABLE C.9 Stage-Discharge Relationships Used in the SSARR Model of the Green River

Mitten Park Gage		Jensen Gage[a]	
Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
1.0	452	1.90	770
1.5	1,031	1.99	842
2.0	1,609	2.00	850
2.5	2,188	2.50	1,290
3.0	2,767	3.00	1,830
3.5	3,345	3.50	2,460
4.0	3,924	4.00	3,210
4.5	4,503	4.50	4,100
5.0	5,081	5.00	5,100
5.5	5,660	5.50	6,180
6.0	6,239	6.00	7,430
6.5	6,817	6.50	8,830
7.0	7,396	7.00	10,270
7.5	7,975	7.50	11,830
8.0	8,553	8.00	13,510
8.5	9,132	8.50	15,310
9.0	9,711	9.00	17,110
9.5	10,289	9.50	18,910
10.00	10,868	10.00	20,710
10.45	11,389	10.50	22,610
		11.00	24,510
		11.50	26,510
		12.00	28,510
		12.50	30,510
		13.00	32,510
		13.50	34,760
		14.00	37,010
		14.50	39,260

[a] Gage 09261000.

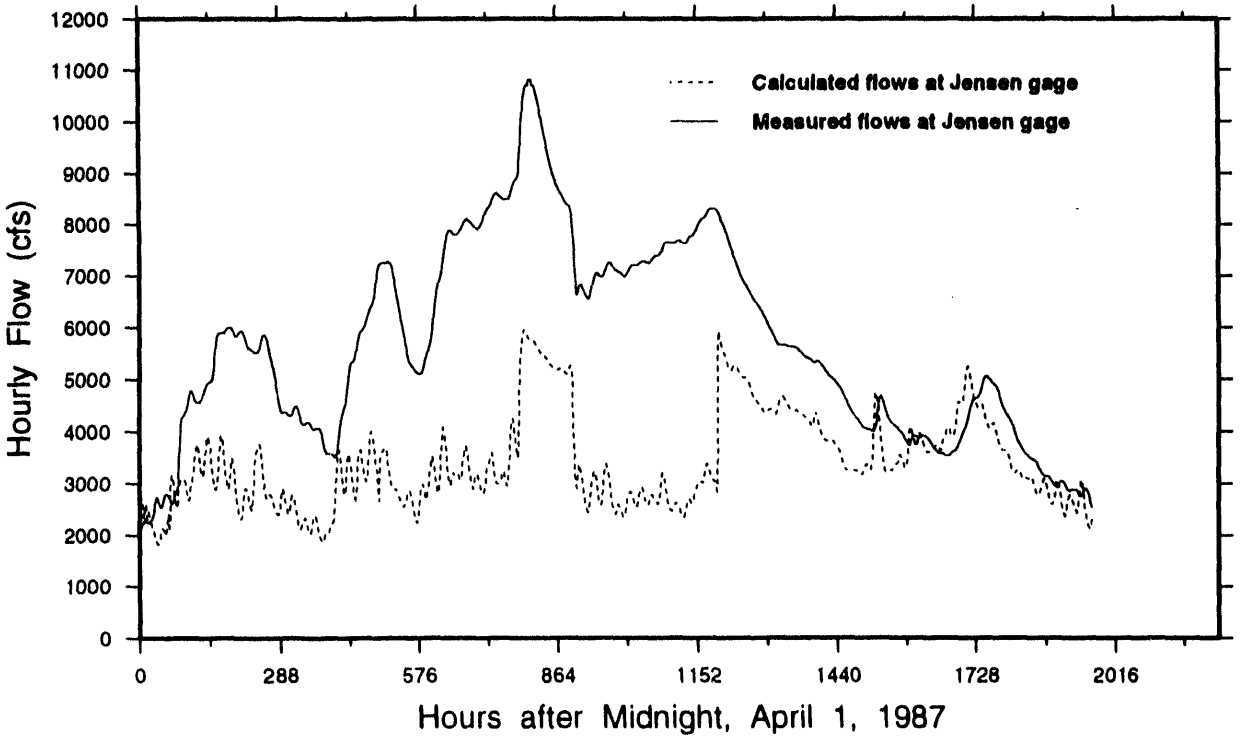


FIGURE C.2 Comparison of Model-Predicted Flows Using Data from Maybell, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987

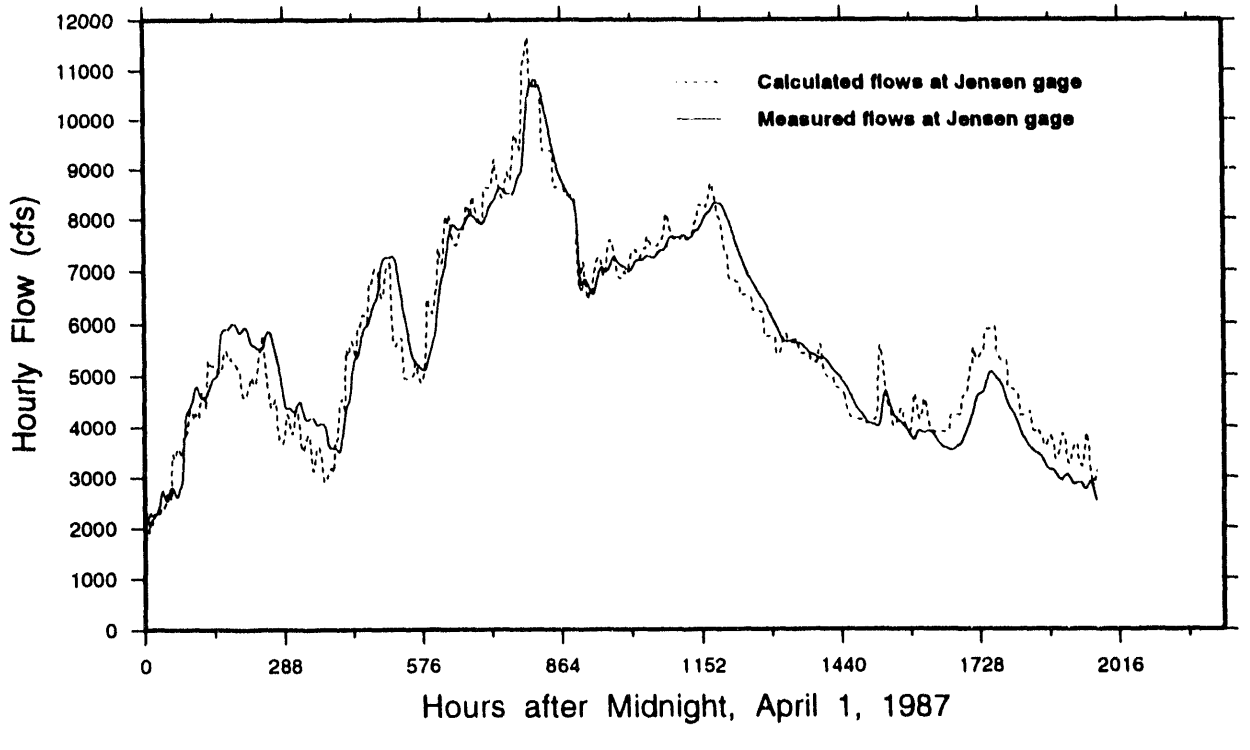


FIGURE C.3 Comparison of Model-Predicted Flows Using Data from Deer Lodge Park, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987

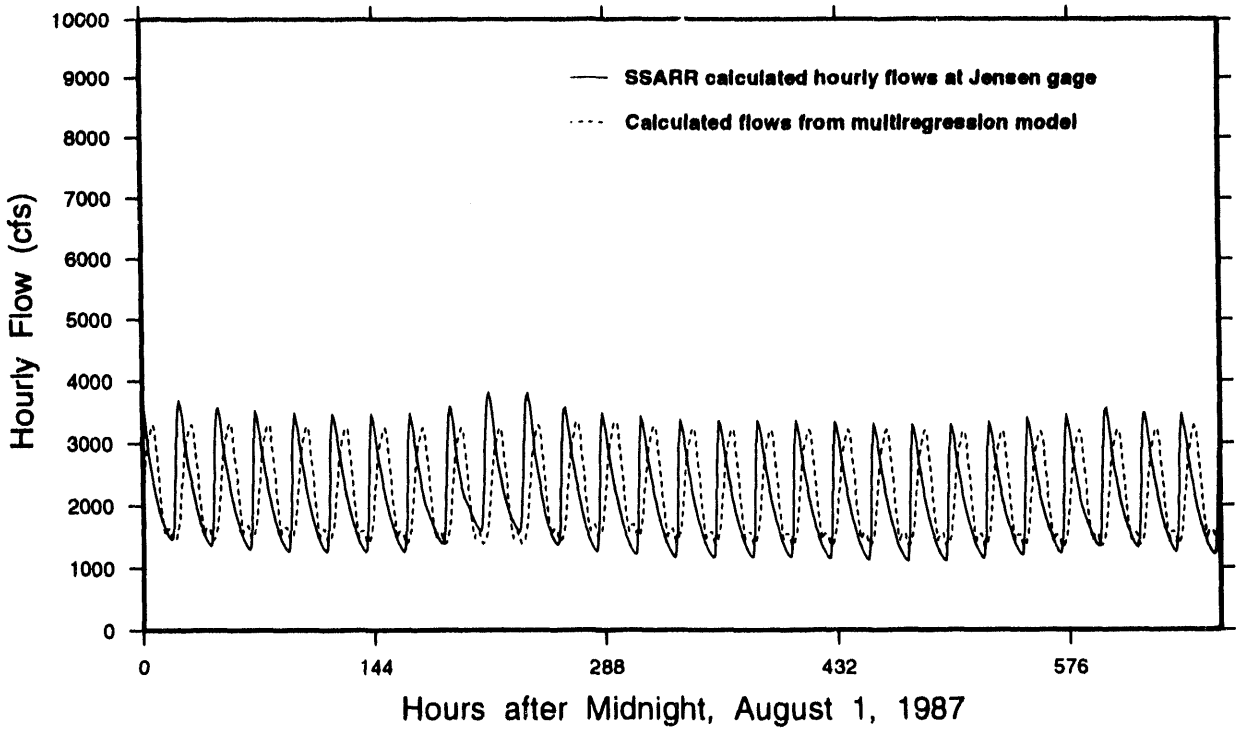


FIGURE C.4 Comparison of the SSARR Model Results with the Empirical Model Results

TABLE C.10 Calibrated Parameters Used in the SSARR Modeling for the Green River

	Parameter Value		
River Segment	Number of Routing Phases	*n* Coefficient	*KTS*
Flaming Gorge Dam to Lodore	30	20	300
Lodore to Hells Half Mile	40	50	300
Hells Half Mile to confluence of the Green and Yampa rivers and Mitten Park	40	50	300
Mitten Park to Jones Hole	20	50	300
Jones Hole to Rainbow Park	25	40	300
Rainbow Park to Jensen USGS gage	20	37	290

time of storage linearly, were 300 for all river segments except for the channel between Rainbow Park and Jensen; the calibrated *KTS* value for this segment was 290.

The *n* coefficient relates flow to time of storage exponentially, with smaller values of *n* yielding much greater times of storage for a given *KTS*. As shown in Equation C.5, the *n* coefficient is related to time of storage inversely, assuming *n* is positive. The range of the *n* coefficient was between 20 and 50, with the highest values corresponding to segments near the confluence of the Yampa River. The smallest calibrated *n* coefficients are assigned to channels directly downstream of the dam and upstream of the Jensen gage (Table C.10).

The sensitivity analysis evaluated the number of routing phases and the *n* and *KTS* of the routing Equation C.5. The model was more sensitive to changes in the coefficient *n*, relative to the other two parameters. This sensitivity result was expected because *n* represents the exponential in the routing equation.

C.1.3 Multiple Regression Model for the Green River

A multiple regression empirical model was developed to estimate the flow of the Green River near Jensen as a function of releases from Flaming Gorge Reservoir and of flow from the Yampa River. This empirical model was also used to verify the results obtained with the SSARR model (COE 1987).

No hourly discharge data were available for the Jensen gage for water year 1983, a wet year, so no models were developed for that time period. The moderate water year 1987 and dry water year 1989 were each divided into quarters for easier manipulation and because there are differences in Yampa River flows between these points. Each quarter was modeled separately. Flow could not be modeled for the second quarter (winter) of water year 1989 because the gages at Jensen, Utah, and Deerlodge Park, Colorado, were frozen and the data are therefore erroneous.

The model was calibrated by making repeated runs on a data set, with each run using different combinations of dam-release lags. The final result showed that the flow at Jensen depends on only a few dam release lags and on one or two lags of the Yampa River. The coefficients of the dam releases form a distribution about some central dam-release lag (Figures C.5 and C.6). The primary travel time of the release wave can be determined from the coefficients of the lags; the primary travel time is the lag with the largest coefficient.

Comparison plots were created from the mean daily values for the Jensen gage and the Flaming Gorge releases. These plots were used for comparing both the full and adjusted discharge at Jensen to identify the travel time from Flaming Gorge Dam to Jensen and to evaluate the flow of the Green River at the Jensen gage. The monthly plots for full discharge at Jensen show that, during low-flow periods (July through February), it takes one to two days for a water wave to travel from Flaming Gorge Dam to Jensen. It was also determined that the Yampa River has a small influence on the total discharge at Jensen for

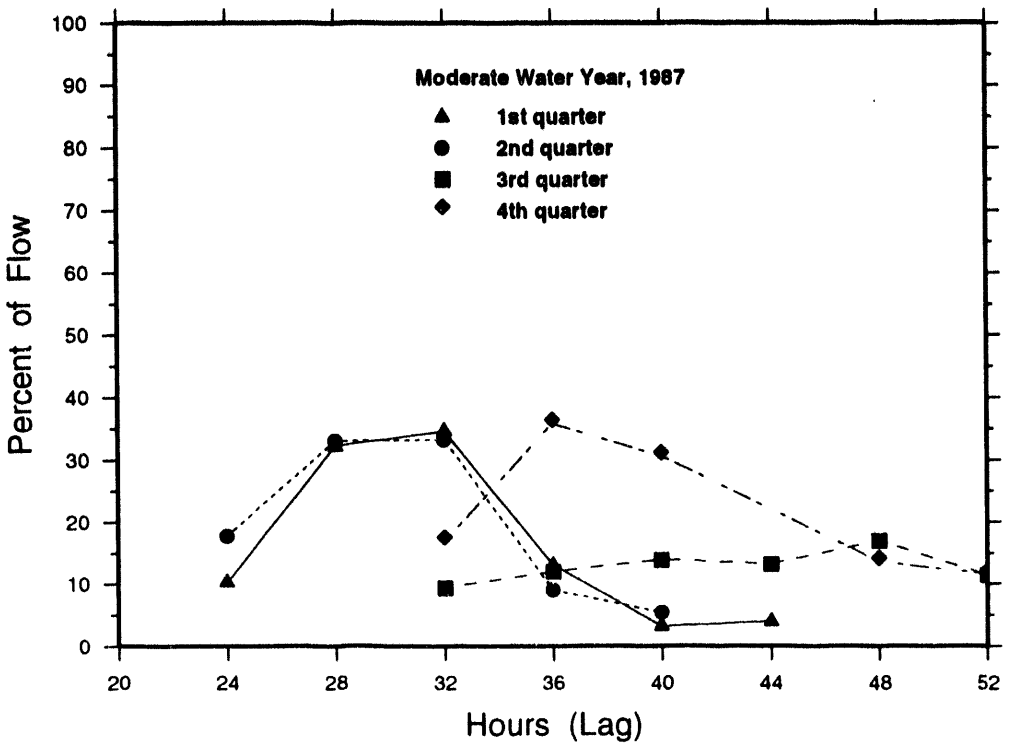


FIGURE C.5 Lag Distributions for a Moderate Year, 1987

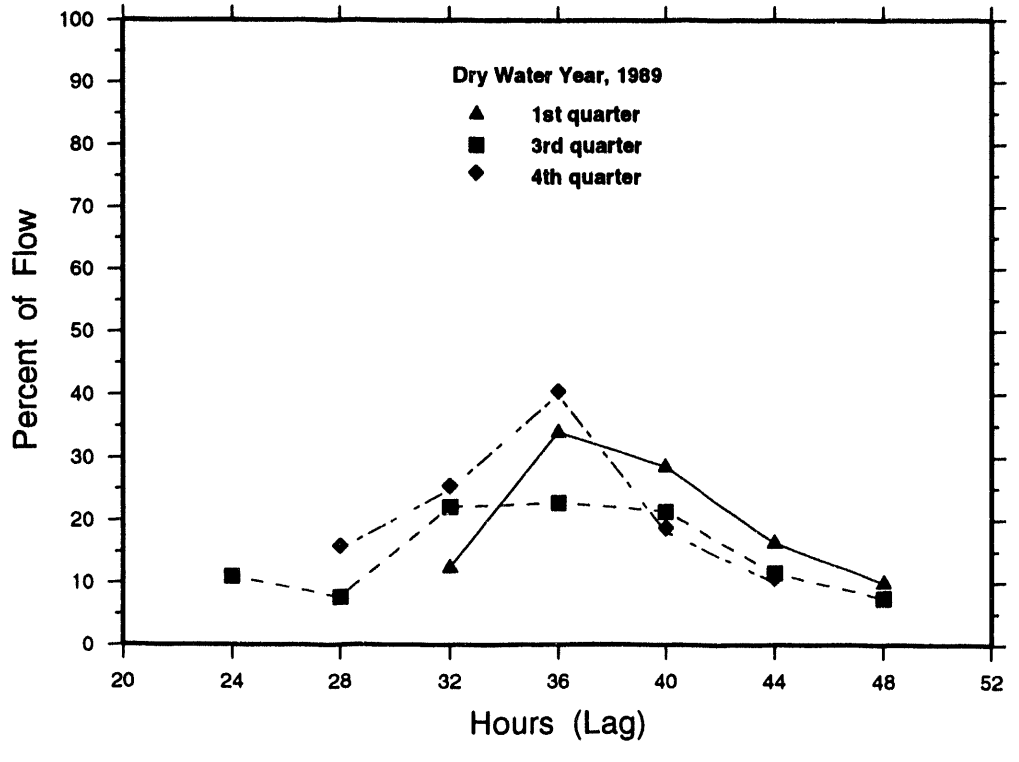


FIGURE C.6 Lag Distributions for a Dry Year, 1989

these periods. During high-flow periods (April through June), the dam releases are completely masked by flows in the Yampa River.

To determine the impact of the Yampa River on the flow at Jensen, the Yampa River flow at Deerlodge Park was subtracted from the flow at Jensen The difference in flow for a user-specified lag time was calculated by Fortran from mean daily values. The adjusted discharge was then plotted with the dam releases. During periods of high flow, the Yampa River accounted for about 50% of the discharge of the Green River at Jensen; during periods of low flow, the influence of the Yampa River was less than 30%.

The dam release data for the operational scenarios and three water years were used to calculate the coefficient of variation (C_v) and the index of variability (I_v). These statistics were then used to compare the stability of the dam operational scenarios with historical releases. The comparison indicated that, with large values of C_v and I_v, the river is more susceptible to bank erosion and aggradation. The results of the historical flow calculations are discussed in Section 3.3.2.2 of this Power Marketing Environmental Impact Statement (EIS). Table C.11 presents values of C_v and I_v for the four operational scenarios. The equations for C_v and I_v are as follows (Gordon et al. 1992):

$$C_v = \frac{s}{\bar{x}} \tag{C.6}$$

and

$$I_v = \left[\frac{\sum_i (\log x_i - \overline{\log x})^2}{n - 1} \right]^{1/2} \tag{C.7}$$

where s is the standard deviation of the dam releases, $\bar{x}$ is the mean dam release, x_i is the ith dam release, and n is the total number of dam releases.

C.1.4 Sediment Transport Modeling for the Browns Park Reach of the Green River

A mathematical model was developed to evaluate total sediment load because no gaging station is present within the alluvial reach of the Green River through Browns Park. This model was applied to the hydropower operational scenarios to assess their potential impacts on the river.

TABLE C.11 Summary of Coefficient of Variation and Index of Variability for the Operational Scenarios at Flaming Gorge Dam[a]

	Coefficient of Variation (C_v)					
	Moderate Year (1987)		Dry Year (1989)		Wet Year (1983)	
Operational Scenario	Value	% Diff.	Value	% Diff.	Value	% Diff.
Year-round high fluctuating flows	0.8414	0	0.6841	0	0.6563	0
Seasonally adjusted high fluctuating flows	0.7343	-13	0.8640	26	0.5118	-22
Seasonally adjusted moderate fluctuating flows	0.4875	-42	0.6057	-11	0.4918	-25
Seasonally adjusted steady flows	0.4411	-48	0.5609	-18	0.4860	-26

	Index of Variability (I_v)					
	Moderate Year (1987)		Dry Year (1989)		Wet Year (1983)	
Operational Scenario	Value	% Diff.	Value	% Diff.	Value	% Diff.
Year-round high fluctuating flows	0.8540	0	0.3632	0	0.9215	0
Seasonally adjusted high fluctuating flows	0.7507	-12	0.4695	29	0.7920	-14
Seasonally adjusted moderate fluctuating flows	0.5058	-41	0.4112	13	0.7136	-23
Seasonally adjusted steady flows	0.4811	-44	0.3954	9	0.6982	-24

[a] % Diff. is the percent difference from year-round high fluctuating flows.

C.1.4.1 Mathematical Model

Total sediment load for a reach was calculated with the Engelund-Hansen method (Engelund and Hansen 1967). This model requires a minimum amount of site-specific information, and it has been demonstrated to give satisfactory results for similar flow systems (Simons and Sentürk 1992; Andrews 1986).

The functional form for the total sediment load, Q_s, is given by the expression

$$Q_s = 0.05\, \gamma_s\, U^2 \sqrt{\frac{d_{50}}{g\left(\frac{\gamma_s}{\gamma} - 1\right)}} \left(\frac{\tau_0}{(\gamma_s - \gamma)\, d_{50}}\right)^{3/2}, \qquad \text{(C.8)}$$

where

U = water velocity = volumetric flow of water (Q) per channel area,

d_{50} = mean size of the sediment,

g = gravitational constant,

γ_s = specific weight of sand sediment = $\rho_s g$ and ρ_s = density of the sediment,

γ = specific weight of water = ρg and ρ = density of water, and

τ_0 = bed shear stress given by the following:

$$\tau_0 = \gamma\, D\, S \qquad \text{(C.9)}$$

where

D = depth of the water, and

S = bed slope of the reach.

In the above relationship, the wide-channel approximation is made, that is, the hydraulic radius of the channel is set approximately equal to the depth of water (Garde and Ranga Raju 1985).

C.1.4.2 Site-Specific Values

The following values were used in the sediment transport calculations for this EIS:

d_{50} = 0.4 mm (Andrews 1986),

γ_s = 2.65 × γ,

γ = 62.4 lb/ft^3,

U = water velocity obtained from the HEC-2 flow model results (Yin 1994) for a given Q and a cross section near Swinging Bridge in Browns Park,

D = depth of water obtained from HEC-2 flow model results (Yin 1994) for a given Q and a cross section near Swinging Bridge in Browns Park, and

S = 0.0004356 (value obtained from USGS 7-1/2 minute map of the Green River.

Because of the lack of site-specific data, both the bed slope and channel cross section were estimated from USGS 7-1/2 minute maps.

C.1.4.3 Model Results

The cumulative sediment load from the alluvial reach of the Green River in the Browns Park area is shown in Figures C.7, C.8, and C.9 for moderate, dry, and wet years, respectively. The sand load was calculated for year-round high fluctuating flows, seasonally adjusted high fluctuating flows, seasonally adjusted moderate fluctuating flows, and seasonally adjusted steady flows. The fraction of total load as a function of discharge is shown in Figures C.10, C.11, and C.12 for the same water years. Historical sediment loads are discussed in Section 3.2.1.2 and illustrated in Figure 3.17.

C.2 ASPINALL UNIT

C.2.1 Release Patterns and Reservoir Elevations

The Aspinall Unit reservoir release patterns and reservoir elevations are discussed in Section 4.2.3.3.1 for two hydropower operational scenarios. For Blue Mesa and Morrow Point reservoirs, the first scenario allows seasonally adjusted high fluctuating flows whereas the second scenario allows only seasonally adjusted steady flows (no hourly fluctuations within a day). Crystal Reservoir would release only seasonally adjusted steady flows within each day under both operational scenarios.

Both operational scenarios are based on USFWS research flows for the Aspinall Unit. Monthly research flows below Crystal Dam were developed by Reclamation for representative moderate (1987), dry (1989), and wet (1983) water years (Harris 1992).

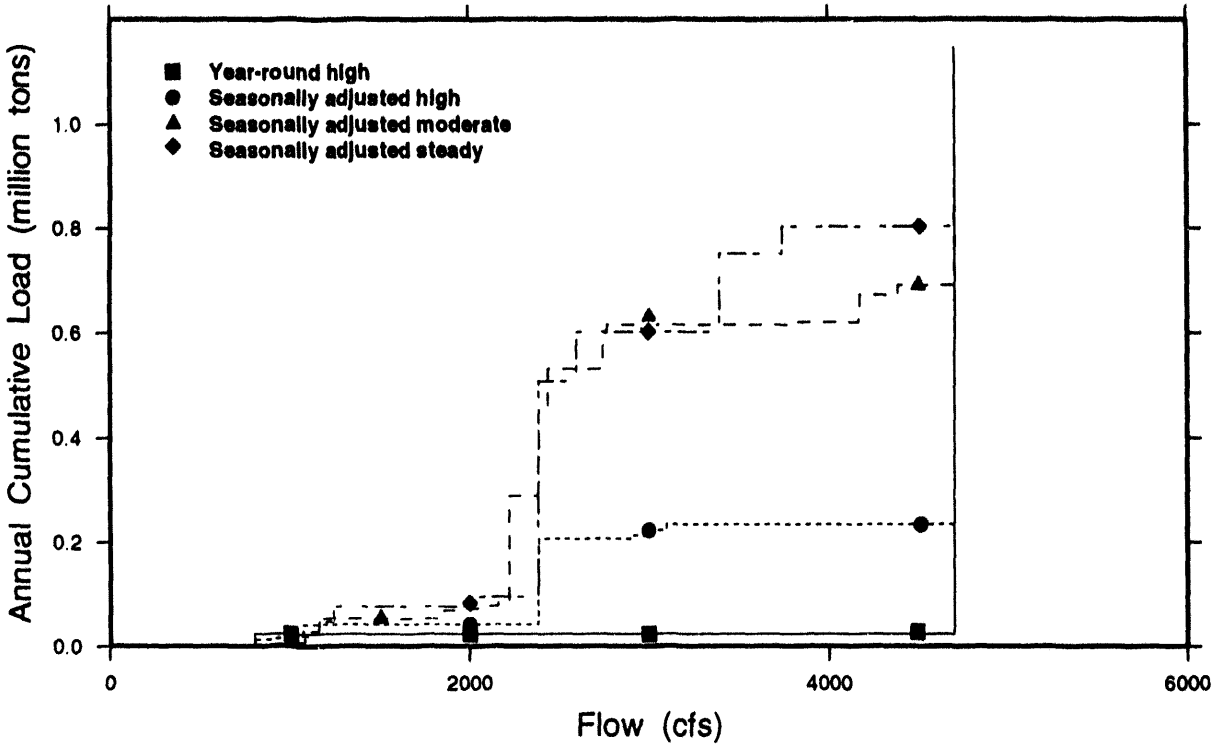


FIGURE C.7 Total Sediment Load for the Green River during a Moderate Year, 1987

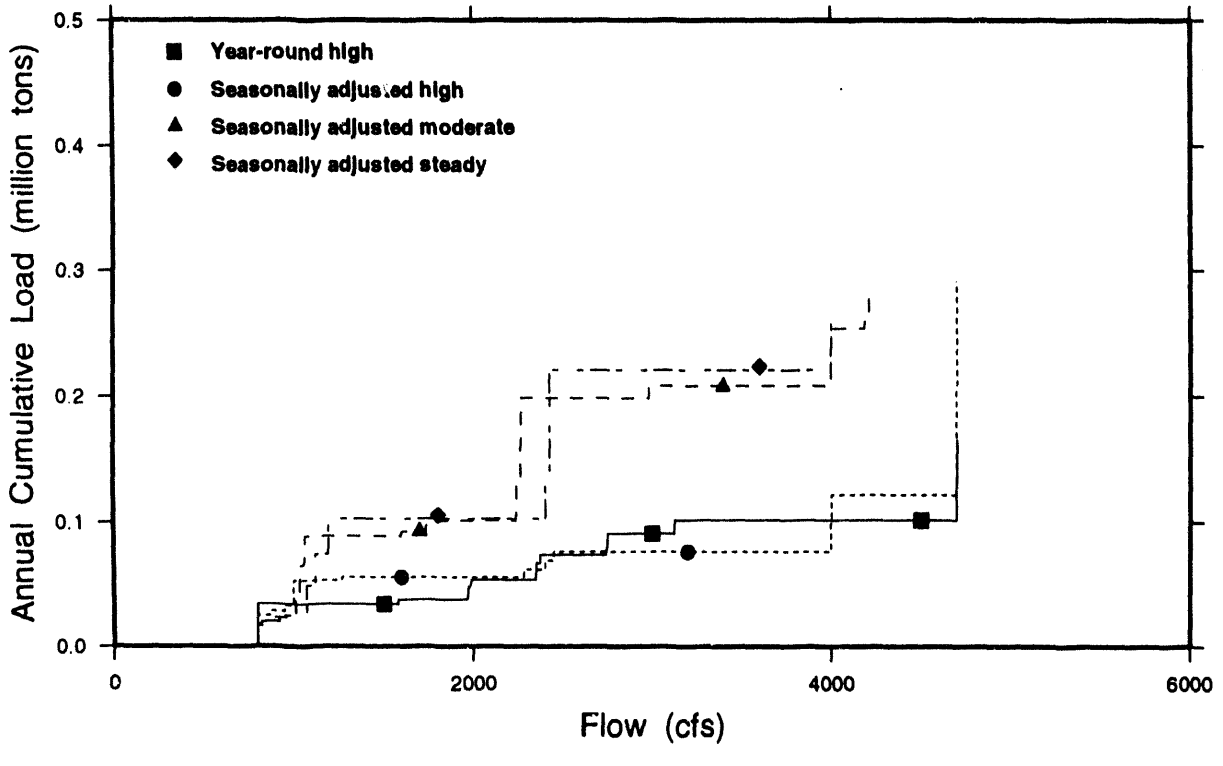


FIGURE C.8 Total Sediment Load for the Green River during a Dry Year, 1989

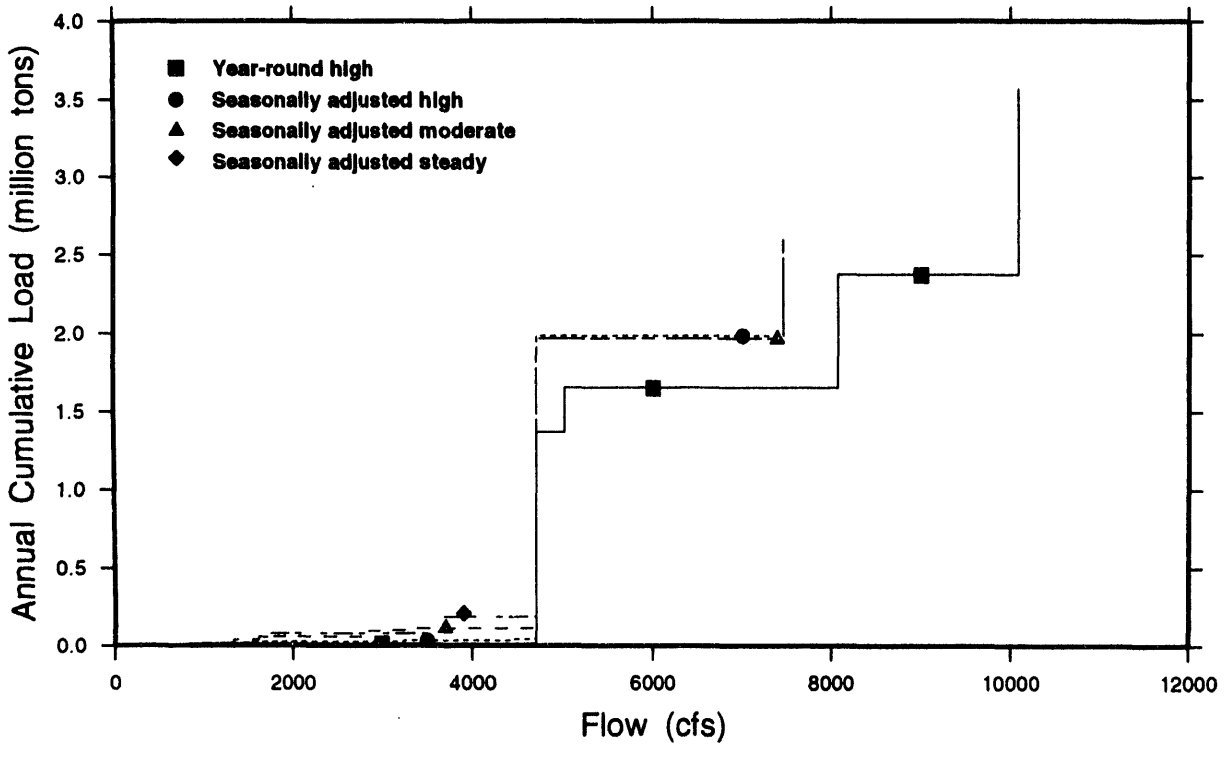


FIGURE C.9 Total Sediment Load for the Green River during a Wet Year, 1983

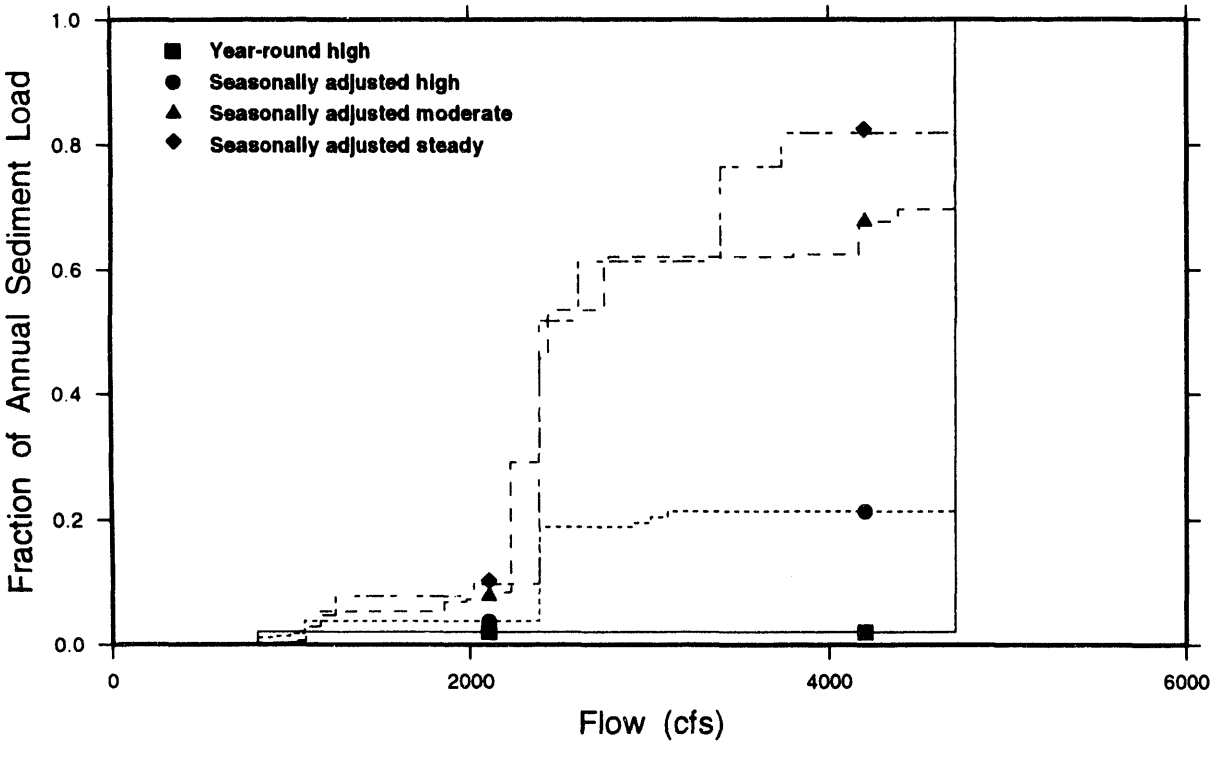


FIGURE C.10 Fraction of Annual Sediment Load for the Green River during a Moderate Year, 1987

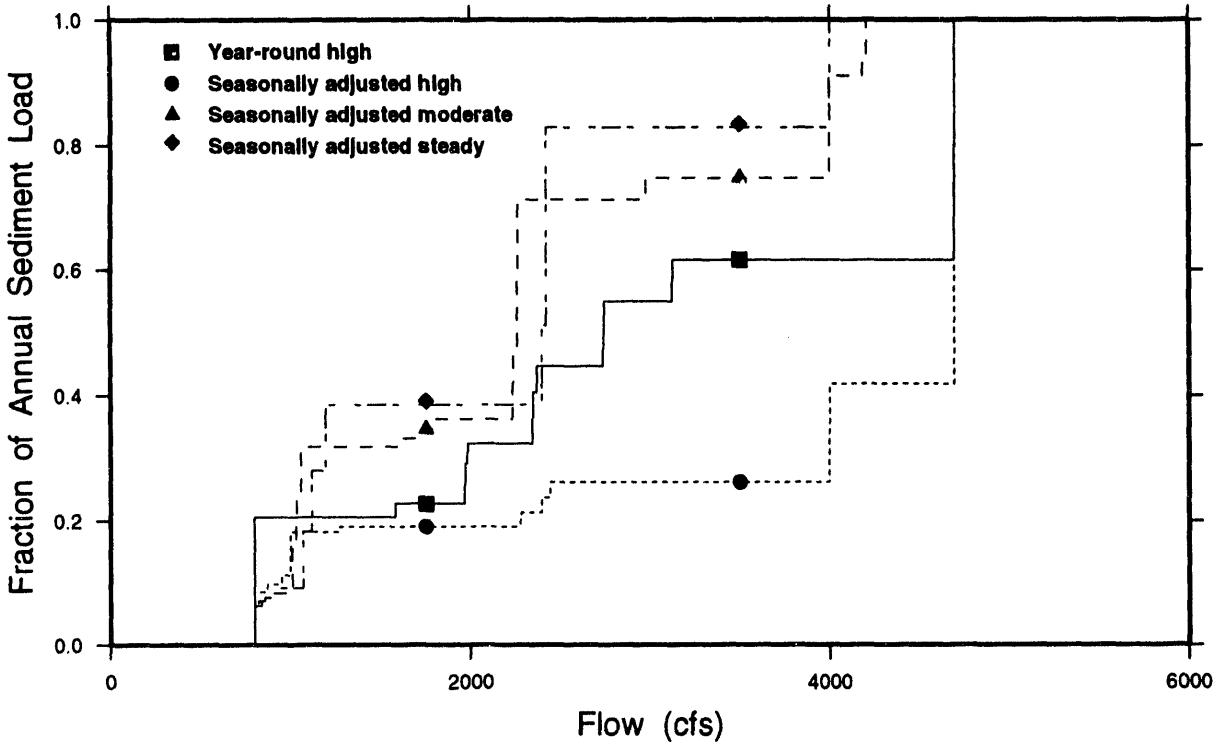


FIGURE C.11 Fraction of Annual Sediment Load for the Green River during a Dry Year, 1989

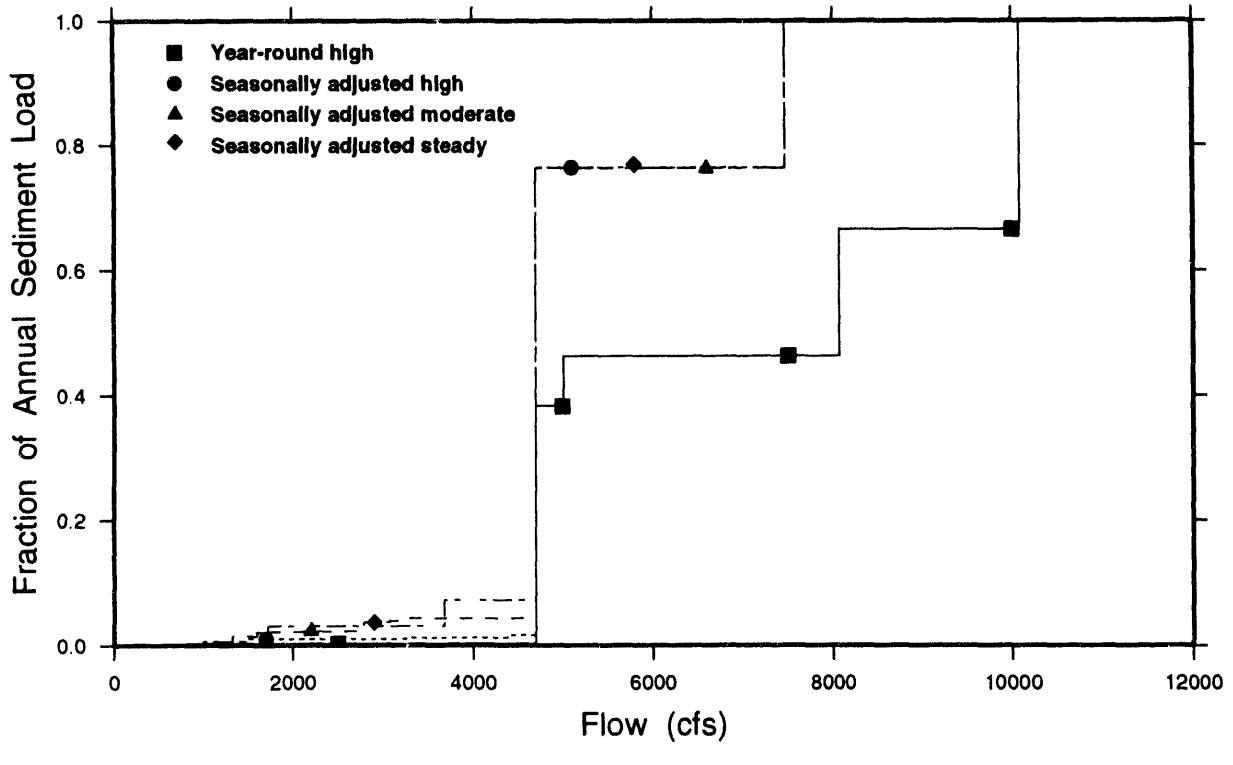


FIGURE C.12 Fraction of Annual Sediment Load for the Green River during a Wet Year, 1983

C.2.1.1 Release Patterns

Reservoir release patterns for an average day in each month are summarized in Tables C.12, C.13, and C.14 for the three Aspinall Unit reservoirs. These release patterns were based on the USFWS research flows, and the feasibility of the research flows was confirmed by monthly reservoir operational models for the three representative water years. The model used historical inflows to Blue Mesa Reservoir and side inflows to Morrow Point and Crystal reservoirs (Tables C.15, C.16, and C.17); initial reservoir storages were also historical, except for the 1987 initial storage for Blue Mesa. An initial storage of 660,000 acre-feet, lower than the historical 742,000 acre-feet, was necessary for the proposed Crystal research flows to be feasible. Reservoir operations upstream of Blue Mesa could be modified to provide the lower initial storage.

The feasibility of the operational scenarios on both daily and hourly bases was assessed by developing daily and hourly reservoir operational models to test the reservoir operations by simulating the linked operations of the three Aspinall Unit reservoirs. The daily operational model was validated by simulating historical reservoir operations for 1987, 1989, and 1983. Calculated end-of-month water surface elevations for all three reservoirs were found to deviate generally less than 1 ft from those reported by Reclamation. The model was then used to simulate the seasonally adjusted steady flow scenario. Steady releases from all three reservoirs were feasible for 1987 and 1989, without violating restrictions on short-term water surface fluctuations for Crystal Reservoir. However, shifting Crystal daily releases, but maintaining the average monthly releases, was necessary for 1983.

The hourly operational model is an extension of the daily model and reproduces end-of-day results for the daily model. The hourly model was used to test the feasibility of fluctuating hourly flows for the seasonally adjusted high fluctuating flow scenario. The maximum fluctuations feasible may be limited by the operating constraints for Crystal Reservoir. In wet seasons (April through July), the reservoir surface elevation should not change by more than 0.5 ft in any 24-hour period if the elevation is lower than 6,748 ft. If the elevation is at or above 6,748 ft, the elevation should not change by more than 4 ft in any 24-hour period and by not more than 6 ft in any 48-hour period. In dry seasons (August through March), the reservoir surface elevation should not change by more than 0.5 ft in any 24-hour period if the elevation is lower than 6,733 ft. If the elevation is at least 6,733 ft, the elevation should not change by more than 10 ft in any 24-hour period and by not more than 15 ft in any 48-hour period.

Results from the hourly operational model indicate that the maximum release fluctuations for Morrow Point Reservoir from April through July should be limited to those shown in Table C.18 to comply with constraints on Crystal Reservoir elevation fluctuations. For other months, the fluctuations may be up to power plant capacity. For Blue Mesa Reservoir, the release fluctuations may be up to its power plant capacity (3,700 cfs) in any month when available head permits.

TABLE C.12 Daily Release Patterns for Blue Mesa Reservoir[a]

	Release Patterns for Moderate Year, 1987				Release Patterns for Dry Year, 1989				Release Patterns for Wet Year, 1983			
	High Fluctuating Release				High Fluctuating Release				High Fluctuating Release			
Month	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)
Oct	0	3,700	9	1,570	0	3,700	3	650	0	3,700	7	1,320
Nov	0	3,700	6	1,200	0	3,700	<1	180	0	3,700	8	1,400
Dec	0	3,700	5	1,050	0	3,600	<1	150	0	3,700	8	1,500
Jan	0	3,700	2	500	0	3,700	<1	200	0	3,700	8	1,540
Feb	0	3,700	2	510	0	3,700	<1	250	0	3,700	8	1,470
Mar	0	3,700	2	500	0	3,700	<1	200	0	3,700	8	1,450
Apr	0	3,700	9	1,600	0	3,700	3	760	2,260	3,700	15	3,220
May	0	3,700	14	2,370	0	3,700	4	900	0	3,700	13	2,200
Jun	1,750	3,700	15	3,050	0	3,700	6	1,150	0	3,700	14	2,330
Jul	0	3,700	14	2,350	0	3,700	7	1,300	0	3,700	9	1,550
Aug	0	3,700	10	1,750	0	3,700	7	1,300	0	3,700	6	1,100
Sep	0	3,700	10	1,750	0	3,700	7	1,300	0	3,700	8	1,500

[a] The average annual releases would be 1,520 cfs for the moderate year, 1,710 cfs for the wet year, and 697 cfs for the dry year.

[b] Maximum release of 3,700 cfs assumes full reservoir condition.

TABLE C.13 Daily Release Patterns for Morrow Point Reservoir[a]

	Release Patterns for Moderate Year, 1987				Release Patterns for Dry Year, 1989				Release Patterns for Wet Year, 1983			
	High Fluctuating Release				High Fluctuating Release				High Fluctuating Release			
Month	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)
Oct	0	5,300	6	1,700	0	5,300	2	720	0	5,300	5	1,410
Nov	0	5,300	4	1,280	0	4,800	<1	200	0	5,300	5	1,510
Dec	0	5,300	3	1,100	0	4,800	<1	200	0	5,300	5	1,520
Jan	0	5,300	1	570	0	5,270	<1	220	0	5,300	5	1,520
Feb	0	5,300	1	580	0	5,300	<1	270	0	5,300	5	1,540
Mar	0	5,300	1	650	0	5,300	<1	260	0	5,300	5	1,540
Apr	557	2,680	15	1,970	0	2,120	9	970	1,930	4,050	15	3,340
May	1,830	3,420	15	2,890	0	2,120	11	1,090	1,700	3,300	15	2,760
Jun	2,440	3,770	15	3,320	0	2,120	12	1,220	2,120	3,710	15	3,180
Jul	1,070	3,190	17	2,480	0	2,120	14	1,350	780	2,370	15	1,840
Aug	0	5,300	7	1,770	0	5,300	5	1,400	0	5,300	4	1,300
Sep	0	5,300	7	1,820	0	5,300	4	1,300	0	5,300	5	1,510

[a] The annual average releases would be 1,680 cfs for the moderate year, 1,910 cfs for the wet year, and 769 cfs for the dry year.

[b] Maximum release of 5,300 cfs assumes full reservoir condition.

TABLE C.14 Daily Releases for Crystal Reservoir

	Daily Release (cfs)		
Month	Moderate Year, 1987	Dry Year, 1989	Wet Year, 1983
Oct	1,920	960	1,600
Nov	1,430	303	1,600
Dec	1,280	293	1,600
Jan	683	293	1,600
Feb	702	306	1,600
Mar	748	293	1,600
Apr	2,250	1,190	3,500
May	3,580	1,330	3,500
Jun	3,830	1,410	4,600
Jul	2,640	1,420	2,500
Aug	1,920	1,460	1,650
Sep	1,920	1,400	1,650
Annual	1,910	891	2,250

C.2.1.1.1 Seasonally Adjusted Steady Flows

The seasonally adjusted steady flow scenario would have a steady release during each month from Blue Mesa and Morrow Point reservoirs. Varying daily releases would be necessary from Crystal Reservoir for April through July during a wet year (e.g., 1983), but a steady flow would be maintained throughout each day. The release rates are shown in Tables C.15, C.16, and C.17 for moderate, dry, and wet water years, respectively.

C.2.1.1.2 Seasonally Adjusted High Fluctuating Flows

The seasonally adjusted high fluctuating flow scenario can be considered a variation of the seasonally adjusted steady flow scenario. Reservoir release volumes would be the same as the steady flow case during each day, but hourly fluctuations within the day would be allowed. Blue Mesa releases would fluctuate up to 100% of power plant capacity (3,700 cfs) any day except for those months that base releases would be required so that the peaking period could be limited to 15 hours per day. Morrow Point releases would fluctuate up to 100% of power plant capacity (5,300 cfs) for the dry season (August through March) when available head permits and up to 25 to 40%, depending on the year and month, during the wet season (April through July) because of more stringent constraints on the fluctuation of Crystal Reservoir surface elevations. Ramping up and ramping down were assumed to occur in one hour. Ramping up was assumed to start on the hour at a certain hour such that the approximate center of the on-peak period would be at 4:00 p.m. If the peaking period were

TABLE C.15 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Moderate Year, 1987

Reservoir/ Month	Inflow		Side Inflow (cfs)	Release			Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change	
	acre-feet	cfs		Power (cfs)	Other (cfs)	Total (cfs)				ft	ft/d
Blue Mesa[a]											
Oct	62,539	1,017	0	1,570	0	1,570	8.8	625,462	7,495.61	-4.25	-0.14
Nov	51,278	862	0	1,200	0	1,200	4.2	605,086	7,493.05	-2.56	-0.09
Dec	30,550	497	0	1,050	0	1,050	2.5	570,920	7,488.69	-4.37	-0.14
Jan	27,811	452	0	500	0	500	2.0	567,864	7,488.29	-0.40	-0.01
Feb	28,728	517	0	510	0	510	2.6	568,124	7,488.33	0.03	0.00
Mar	55,524	903	0	500	0	500	4.9	592,603	7,491.47	3.14	0.10
Apr	125,807	2,114	0	1,600	0	1,600	7.8	622,739	7,495.27	3.80	0.13
May	271,476	4,415	0	2,370	0	2,370	14.6	747,592	7,510.23	14.96	0.48
Jun	255,805	4,299	0	3,050	0	3,050	22.8	820,553	7,518.42	8.19	0.27
Jul	97,192	1,581	0	2,350	0	2,350	24.6	771,736	7,512.98	-5.43	-0.18
Aug	64,634	1,051	0	1,750	0	1,750	18.6	727,623	7,507.91	-5.07	-0.16
Sep	44,320	745	0	1,750	0	1,750	15.2	666,907	7,500.70	-7.21	-0.24
Morrow Point[b]											
Oct	96,535	1,570	94	1,700	0	1,700	0.0	112,632	7,154.30	-2.75	-0.09
Nov	71,405	1,200	61	1,280	0	1,280	0.0	111,489	7,152.86	-1.44	-0.05
Dec	64,562	1,050	69	1,100	0	1,100	0.0	112,627	7,154.29	1.44	0.05
Jan	30,744	500	61	570	0	570	0.0	112,061	7,153.58	-0.71	-0.02
Feb	28,324	510	82	580	0	580	0.0	112,744	7,154.44	0.86	0.03
Mar	30,744	500	98	650	0	650	0.0	109,528	7,150.36	-4.08	-0.13
Apr	95,207	1,600	373	1,970	0	1,970	0.0	109,707	7,150.59	0.23	0.01
May	145,726	2,370	534	2,890	0	2,890	2.1	110,439	7,151.52	0.94	0.03
Jun	181,488	3,050	311	3,325	0	3,325	14.3	111,730	7,153.16	1.64	0.05
Jul	144,496	2,350	74	2,480	0	2,480	13.6	107,420	7,147.63	-5.53	-0.18
Aug	107,603	1,750	58	1,770	0	1,770	1.4	109,688	7,150.56	2.93	0.09
Sep	104,132	1,750	44	1,820	0	1,820	0.0	108,124	7,148.55	-2.02	-0.07

TABLE C.15 (Cont.)

Reservoir/ Month	Inflow acre-feet	Inflow cfs	Side Inflow (cfs)	Release Power (cfs)	Release Other (cfs)	Release Total (cfs)	Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change ft	Elevation Change ft/d
***Crystal*[c]**											
Oct	104,529	1,700	210	1,763	156	1,919	0.0	15,276	6,747.04	-1.96	-0.06
Nov	76,165	1,280	135	1,429	0	1,429	0.0	14,443	6,744.02	-3.02	-0.10
Dec	67,636	1,100	152	1,285	0	1,285	0.0	12,413	6,736.29	-7.73	-0.25
Jan	35,048	570	135	683	0	683	0.0	13,766	6,741.50	5.21	0.17
Feb	32,212	580	123	702	0	702	0.0	13,822	6,741.71	0.21	0.01
Mar	39,967	650	147	748	0	748	0.0	16,835	6,752.48	10.77	0.35
Apr	117,223	1,970	275	1,763	489	2,252	0.0	16,418	6,751.05	-1.43	-0.05
May	177,699	2,890	680	1,763	1,815	3,578	0.0	15,926	6,749.34	-1.71	-0.06
Jun	197,851	3,325	507	1,763	2,069	3,832	0.0	15,926	6,749.34	0.00	0.00
Jul	152,489	2,480	164	1,763	872	2,635	0.0	16,480	6,751.26	1.92	0.06
Aug	108,833	1,770	130	1,763	156	1,919	0.0	15,311	6,747.16	-4.10	-0.13
Sep	108,297	1,820	97	1,763	153	1,916	0.0	15,395	6,747.46	0.30	0.01

[a] Starting conditions: storage, 660,000 acre-feet; elevation, 7,499.86 ft. Totals (acre-feet): inflow, 1,115,664; release, 1,100,965; evaporation, 7,793.

[b] Starting conditions: storage, 114,833 acre-feet; elevation, 7,157.05 ft. Totals (acre-feet): inflow, 1,100,965; side inflow, 112,178; release, 1,217,950; evaporation, 1,902.

[c] Starting conditions: storage, 15,829 acre-feet; elevation, 6,749.00 ft. Totals (acre-feet): inflow, 1,217,950; side inflow, 166,679; release, 1,385,063; evaporation, 0.

TABLE C.16 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Dry Year, 1989

Reservoir/ Month	Inflow		Side Inflow (cfs)	Release			Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change	
	acre-feet	cfs		Power (cfs)	Other (cfs)	Total (cfs)				ft	ft/d
Blue Mesa[a]											
Oct	30,258	492	0	650	0	650	6.4	439,014	7,470.52	-1.48	-0.05
Nov	26,684	448	0	180	0	180	3.2	454,796	7,472.82	2.30	0.08
Dec	23,654	385	0	150	0	150	2.0	469,104	7,474.88	2.05	0.07
Jan	27,006	439	0	200	0	200	2.0	483,690	7,476.94	2.06	0.07
Feb	23,941	431	0	250	0	250	2.8	493,591	7,478.32	1.38	0.05
Mar	44,848	729	0	200	0	200	6.2	525,760	7,482.73	4.40	0.14
Apr	96,499	1,622	0	760	0	760	10.8	576,394	7,489.39	6.67	0.22
May	124,997	2,033	0	900	0	900	16.0	645,068	7,498.03	8.64	0.28
Jun	123,561	2,077	0	1,150	0	1,150	21.4	698,926	7,504.53	6.50	0.22
Jul	59,496	968	0	1,300	0	1,300	22.2	677,123	7,501.93	-2.60	-0.08
Aug	56,234	915	0	1,300	0	1,300	17.2	652,366	7,498.93	-3.00	-0.10
Sep	27,920	469	0	1,300	0	1,300	13.6	602,121	7,492.68	-6.25	-0.21
Morrow Point[b]											
Oct	39,967	650	38	720	0	720	0.0	112,021	7,153.53	-2.47	-0.08
Nov	10,711	180	37	200	0	200	0.0	113,033	7,154.80	1.27	0.04
Dec	9,223	150	37	200	0	200	0.0	112,234	7,153.80	-1.01	-0.03
Jan	12,298	200	(15)	220	0	220	0.0	110,082	7,151.07	-2.73	-0.09
Feb	13,884	250	24	270	0	270	0.0	110,304	7,151.35	0.28	0.01
Mar	12,298	200	66	260	0	260	0.0	110,673	7,151.82	0.47	0.02
Apr	45,223	760	207	970	0	970	0.0	110,494	7,151.59	-0.23	-0.01
May	55,339	900	192	1,090	0	1,090	2.1	110,488	7,151.58	-0.01	0.00
Jun	68,430	1,150	102	1,225	0	1,225	14.3	111,244	7,152.55	0.96	0.03
Jul	79,934	1,300	37	1,350	0	1,350	13.8	109,596	7,150.44	-2.10	-0.07
Aug	79,934	1,300	88	1,400	0	1,400	1.4	108,772	7,149.38	-1.06	-0.03
Sep	77,355	1,300	63	1,300	0	1,300	0.0	112,521	7,154.16	4.78	0.16

TABLE C.16 (Cont.)

Reservoir/ Month	Inflow acre-feet	Inflow cfs	Side Inflow (cfs)	Release Power (cfs)	Release Other (cfs)	Release Total (cfs)	Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change ft	Elevation Change ft/d
Crystal											
Oct	44,271	720	186	960	0	960	0.0	13,657	6,741.09	-11.87	-0.38
Nov	11,901	200	98	303	0	303	0.0	13,359	6,739.96	-1.13	-0.04
Dec	12,298	200	92	293	0	293	0.0	13,298	6,739.72	-0.23	-0.01
Jan	13,527	220	73	293	0	293	0.0	13,298	6,739.72	0.00	0.00
Feb	14,995	270	46	306	0	306	0.0	13,853	6,741.83	2.10	0.08
Mar	15,987	260	99	293	0	293	0.0	17,911	6,756.08	14.25	0.46
Apr	57,719	970	224	1,193	0	1,193	0.0	17,971	6,756.27	0.20	0.01
May	67,021	1,090	244	1,334	0	1,334	0.0	17,971	6,756.27	0.00	0.00
Jun	72,893	1,225	183	1,412	0	1,412	0.0	17,733	6,755.49	-0.78	-0.03
Jul	83,008	1,350	64	1,415	0	1,415	0.0	17,671	6,755.29	-0.20	-0.01
Aug	86,083	1,400	43	1,464	0	1,464	0.0	16,380	6,750.92	-4.37	-0.14
Sep	77,355	1,300	66	1,395	0	1,395	0.0	14,654	6,744.79	-6.13	-0.20

[a] Starting conditions: storage, 449,116 acre-feet; elevation, 7,472.00 ft. Totals (acre-feet): inflow, 665,098; release, 504,595; evaporation, 7,498.

[b] Starting conditions: storage, 113,989 acre-feet; elevation, 7,156.00 ft. Totals (acre-feet): inflow, 504,595; side inflow, 52,909; release, 557,058; evaporation, 1,915.

[c] Starting conditions: storage, 16,977 acre-feet; elevation, 6,752.96 ft. Totals (acre-feet): inflow, 557,058; side inflow, 85,783; release, 645,163; evaporation, 0.

TABLE C.17 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Wet Year, 1983

Reservoir/ Month	Inflow		Side Inflow (cfs)	Release			Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change	
	acre-feet	cfs		Power (cfs)	Other (cfs)	Total (cfs)				ft	ft/d
Blue Mesa[a]											
Oct	64,331	1,046	0	1,320	0	1,320	8.9	721,799	7,507.23	-2.02	-0.07
Nov	36,661	616	0	1,400	0	1,400	4.2	674,905	7,501.66	-5.56	-0.19
Dec	29,191	475	0	1,500	0	1,500	2.7	611,698	7,493.89	-7.78	-0.25
Jan	29,301	477	0	1,540	0	1,540	2.0	546,185	7,485.45	-8.43	-0.27
Feb	25,993	468	0	1,470	0	1,470	3.3	490,355	7,477.87	-7.58	-0.27
Mar	42,347	689	0	1,450	0	1,450	5.9	443,183	7,471.13	-6.74	-0.22
Apr	58,197	978	0	3,220	0	3,220	9.5	309,211	7,449.49	-21.65	-0.72
May	164,542	2,676	0	2,200	0	2,200	12.0	337,743	7,454.48	4.99	0.16
Jun	398,810	6,702	0	2,330	0	2,330	22.8	596,551	7,491.97	37.49	1.25
Jul	218,498	3,554	0	1,550	0	1,550	25.2	718,194	7,506.81	14.84	0.48
Aug	123,580	2,010	0	1,100	0	1,100	19.7	772,927	7,513.12	6.31	0.20
Sep	58,040	975	0	1,500	0	1,500	15.8	740,770	7,509.43	-3.68	-0.12
Morrow Point[b]											
Oct	81,164	1,320	81	1,410	0	1,410	0.0	112,214	7,153.77	-0.70	-0.02
Nov	83,306	1,400	37	1,510	0	1,510	0.0	107,870	7,148.22	-5.55	-0.19
Dec	92,231	1,500	37	1,520	0	1,520	0.0	108,915	7,149.57	1.35	0.04
Jan	94,691	1,540	35	1,520	0	1,520	0.0	112,297	7,153.88	4.31	0.14
Feb	81,640	1,470	46	1,540	0	1,540	0.0	110,964	7,152.19	-1.69	-0.06
Mar	89,157	1,450	68	1,535	0	1,535	0.0	109,919	7,150.86	-1.33	-0.04
Apr	191,603	3,220	141	3,345	0	3,345	0.0	110,871	7,152.07	1.21	0.04
May	135,273	2,200	581	2,765	0	2,765	2.1	111,725	7,153.16	1.08	0.03
Jun	138,645	2,330	855	3,180	0	3,180	14.3	111,172	7,152.45	-0.70	-0.02
Jul	95,306	1,550	298	1,840	0	1,840	13.6	110,828	7,152.02	-0.44	-0.01
Aug	67,636	1,100	152	1,300	0	1,300	1.4	107,790	7,148.12	-3.90	-0.13
Sep	89,256	1,500	60	1,510	0	1,510	0.0	110,765	7,151.94	3.82	0.13

TABLE C.17 (Cont.)

Reservoir/ Month	Inflow acre-feet	Inflow cfs	Side Inflow (cfs)	Release Power (cfs)	Release Other (cfs)	Release Total (cfs)	Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change ft	Elevation Change ft/d
Crystal[c]											
Oct	86,697	1,410	180	1,600	0	1,600	0.0	1,488	6,747.79	-2.17	-0.07
Nov	89,851	1,510	83	1,600	0	1,600	0.0	15,072	6,746.30	-1.49	-0.05
Dec	93,461	1,520	83	1,600	0	1,600	0.0	15,256	6,746.97	0.66	0.02
Jan	93,461	1,520	78	1,600	0	1,600	0.0	15,133	6,746.53	-0.44	-0.01
Feb	85,527	1,540	70	1,600	0	1,600	0.0	15,688	6,748.50	1.98	0.07
Mar	94,383	1,535	102	1,600	0	1,600	0.0	17,963	6,756.25	7.75	0.25
Apr	199,041	3,345	153	1,763	1,737	3,500	0.0	17,844	6,755.86	-0.39	-0.01
May	170,013	2,765	739	1,763	1,737	3,500	0.0	18,090	6,756.67	0.81	0.03
Jun	189,223	3,180	1,395	1,763	2,837	4,600	0.0	16,603	6,751.69	-4.98	-0.17
Jul	113,137	1,840	663	1,763	737	2,500	0.0	16,787	6,752.32	0.63	0.02
Aug	79,934	1,300	339	1,650	0	1,650	0.0	16,111	6,749.99	-2.33	-0.08
Sep	89,851	1,510	133	1,650	0	1,650	0.0	15,694	6,748.53	-1.46	-0.05

[a] Starting conditions: storage, 739,179 acre-feet; elevation, 7,509.25 ft. Totals (acre-feet): inflow, 1,249,491; release, 1,239,907; evaporation, 7,993.

[b] Starting conditions: storage, 112,767 acre-feet; elevation, 7,154.47 ft. Totals (acre-feet): inflow, 1,239,907; side inflow, 144,575; release, 1,384,581; evaporation, 1,902.

[c] Starting conditions: storage, 16,103 acre-feet; elevation, 6,749.96 ft. Totals (acre-feet): inflow, 1,384,581; side inflow, 243,142; release, 1,628,131; evaporation, 0.

TABLE C.18 Maximum Allowable Fluctuations for Morrow Point Reservoir Releases

	Maximum Fluctuation as Percent of 5,300-cfs Power Plant Capacity		
Month	Moderate Year, 1987	Dry Year, 1989	Wet Year, 1983
April	40	40	40
May	30	40	30
June	25	40	30
July	40	40	30

greater than 15 hours (8:00 a.m. to 11:00 p.m.), a base flow would be added. However, if adding a base flow resulted in a peak release greater than the power plant capacity, the maximum fluctuation would be reduced so that the peak release did not exceed the power plant capacity.

C.2.1.2 Reservoir Surface Elevations

End-of-month reservoir elevations and daily elevation changes within each month are shown in Tables C.15, C.16, and C.17 for the seasonally adjusted steady flow scenarios for water years 1987 (moderate), 1989 (dry), and 1983 (wet), respectively. Hourly storage changes and maximum elevation fluctuations during the first day of each month for the seasonally adjusted high fluctuating flow scenario are presented in Table C.19 for water year 1987 (moderate). For each month, the maximum daily fluctuations in elevation for subsequent days would be about the same as the first day.

C.2.2 Reservoir Fluctuation Calculations

To determine fluctuations in daily reservoir pool elevations, a 24-hour reservoir routing model was developed to route the Aspinall unit releases (Tables C.20, C.21, and C.22) through Blue Mesa, Morrow Point, and Crystal reservoirs. The model used is diagrammed in Figure C.13. Mathematically, the model is as follows:

$$BM_{storage_{i+1}} = BM_{storage_i} + BM_{inflow_i} + BM_{sideflow_i} - BM_{release_i} \quad (i=1,24) \qquad (C.10)$$

$$MP_{storage_{i+1}} = MP_{storage_i} + MP_{sideflow_i} + BM_{release_i} - MP_{release_i} \quad (i=1,24) \qquad (C.11)$$

TABLE C.19 Maximum and Minimum Reservoir Surface Elevations on the First Day of the Month under the Seasonally Adjusted High Fluctuating Flow Scenario at the Aspinall Unit for a Moderate Year, 1987

Reservoir/Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Blue Mesa												
Starting storage (acre-feet)	660,000	625,462	605,086	570,920	567,864	568,124	592,603	622,739	747,592	820,553	771,736	727,623
Inflow (cfs)	1,017	862	497	452	517	903	2,114	4,415	4,299	1,581	1,051	745
End-of-hour storage (acre-feet)												
1:00 a.m.	660,084	625,533	605,127	570,957	567,907	568,199	592,778	623,103	747,803	820,684	771,823	727,685
2:00 a.m	660,168	625,604	605,168	570,995	567,949	568,273	592,952	623,466	748,013	820,814	771,910	727,746
3:00 a.m.	660,252	625,676	605,209	571,032	567,992	568,348	593,127	623,830	748,224	820,945	771,997	727,808
4:00 a.m.	660,336	625,747	605,250	571,069	568,035	568,423	593,302	624,194	748,435	821,076	772,083	727,869
5:00 a.m.	660,420	625,818	605,291	571,107	568,078	568,497	593,477	624,557	748,645	821,206	772,170	727,931
6:00 a.m.	660,504	625,889	605,332	571,144	568,120	568,572	593,651	624,921	748,856	821,337	772,257	727,992
7:00 a.m.	660,588	625,961	605,374	571,181	568,163	568,646	593,826	625,285	749,067	821,468	772,344	728,054
8:00 a.m.	660,672	626,032	605,415	571,219	568,206	568,721	594,001	625,343	749,116	821,293	772,431	728,116
9:00 a.m.	660,756	626,103	605,456	571,256	568,249	568,796	594,175	625,400	749,166	821,117	772,518	728,177
10:00 a.m.	660,840	626,174	605,497	571,294	568,291	568,870	594,350	625,458	749,215	820,942	772,605	728,239
11:00 a.m.	660,619	626,246	605,538	571,331	568,334	568,945	594,219	625,516	749,265	820,767	772,386	727,994
12:00 Noon	660,397	626,317	605,579	571,368	568,377	569,020	594,088	625,574	749,314	820,592	772,167	727,750
1:00 p.m.	660,175	626,082	605,314	571,406	568,419	569,094	593,957	625,632	749,364	820,417	771,948	727,506
2:00 p.m.	659,954	625,848	605,049	571,443	568,462	569,169	593,826	625,690	749,413	820,242	771,729	727,262
3:00 p.m.	659,732	625,613	604,785	571,175	568,199	568,938	593,695	625,748	749,463	820,067	771,510	727,018
4:00 p.m.	659,510	625,379	604,520	570,906	567,936	568,706	593,564	625,806	749,512	819,892	771,291	726,773
5:00 p.m.	659,288	625,144	604,255	570,638	567,673	568,475	593,433	625,864	749,562	819,716	771,072	726,529
6:00 p.m.	659,067	624,910	603,991	570,601	567,622	568,476	593,302	625,921	749,611	819,541	770,853	726,285
7:00 p.m.	658,845	624,675	603,784	570,638	567,664	568,550	593,170	625,979	749,661	819,366	770,634	726,041
8:00 p.m.	658,623	624,507	603,825	570,675	567,707	568,625	593,039	626,037	749,710	819,191	770,415	725,797
9:00 p.m.	658,651	624,578	603,866	570,713	567,750	568,699	593,098	626,095	749,760	819,016	770,196	725,552
10:00 p.m.	658,735	624,649	603,907	570,750	567,792	568,774	593,273	626,153	749,809	818,841	770,176	725,506
11:00 p.m.	658,819	624,720	603,948	570,787	567,835	568,849	593,448	626,403	749,859	818,897	770,263	725,568
12:00 Midnight	658,903	624,792	603,989	570,825	567,878	568,923	593,623	626,766	750,069	819,028	770,350	725,630
Storage (acre-feet)												
Maximum	660,840	626,317	605,579	571,443	568,462	569,169	594,350	626,766	750,069	821,468	772,605	728,239
Minimum	658,623	624,507	603,784	570,601	567,622	568,124	592,603	622,739	747,592	818,841	770,176	725,506
Elevation (ft)												
Maximum	7,499.96	7,495.72	7,493.12	7,488.76	7,488.37	7,488.46	7,491.69	7,495.77	7,510.51	7,518.52	7,513.08	7,507.98
Minimum	7,499.69	7,495.49	7,492.89	7,488.65	7,488.26	7,488.33	7,491.47	7,495.27	7,510.23	7,518.23	7,512.81	7,507.66
Difference	0.27	0.23	0.23	0.11	0.11	0.14	0.22	0.50	0.28	0.29	0.27	0.32

TABLE C.19 (Cont.)

Reservoir/Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Morrow Point												
Starting storage (acre-ft)	114,833	112,632	111,489	112,627	112,061	112,744	109,528	109,707	110,439	111,730	107,420	109,688
Side inflow (cfs)	94	61	69	61	82	98	373	534	311	74	58	44
End-of-hour storage (acre-feet)												
1:00 a.m.	114,841	112,637	111,495	112,632	112,068	112,752	109,513	109,600	110,408	111,648	107,425	109,692
2:00 a.m.	114,849	112,642	111,500	112,637	112,075	112,760	109,498	109,493	110,376	111,566	107,430	109,695
3:00 a.m.	114,856	112,647	111,506	112,642	112,081	112,768	109,482	109,386	110,345	111,484	107,434	109,699
4:00 a.m.	114,864	112,652	111,512	112,647	112,088	112,776	109,467	109,279	110,313	111,402	107,439	109,703
5:00 a.m.	114,872	112,657	111,518	112,652	112,095	112,784	109,452	109,171	110,282	111,320	107,444	109,706
6:00 a.m.	114,880	112,662	111,523	112,657	112,102	112,793	109,437	109,064	110,250	111,238	107,449	109,710
7:00 a.m.	114,887	112,667	111,529	112,662	112,108	112,801	109,422	108,957	110,219	111,156	107,454	109,713
8:00 a.m.	114,895	112,672	111,535	112,667	112,115	112,809	109,231	109,025	110,239	111,204	107,458	109,717
9:00 a.m.	114,903	112,677	111,540	112,672	112,122	112,817	109,041	109,092	110,259	111,253	107,463	109,721
10:00 a.m.	114,911	112,682	111,546	112,677	112,129	112,825	108,851	109,159	110,279	111,301	107,468	109,724
11:00 a.m.	115,224	112,687	111,552	112,682	112,136	112,833	108,966	109,226	110,300	111,350	107,779	110,034
12:00 Noon	115,538	112,692	111,557	112,687	112,142	112,841	109,081	109,294	110,320	111,398	107,651	109,905
1:00 p.m.	115,413	113,003	111,869	112,693	112,149	112,849	109,197	109,361	110,340	111,447	107,524	109,777
2:00 p.m.	115,289	112,876	111,742	112,698	112,156	112,857	109,312	109,428	110,360	111,496	107,396	109,648
3:00 p.m.	115,164	112,749	111,616	112,570	112,030	112,733	109,428	109,495	110,380	111,544	107,269	109,519
4:00 p.m.	115,040	112,622	111,489	112,443	111,905	112,609	109,543	109,563	110,401	111,593	107,141	109,391
5:00 p.m.	114,915	112,495	111,363	112,499	111,943	112,510	109,658	109,630	110,421	111,641	107,014	109,262
6:00 p.m.	114,791	112,367	111,245	112,579	112,044	112,592	109,774	109,697	110,441	111,690	106,886	109,134
7:00 p.m.	114,667	112,329	111,498	112,584	112,051	112,600	109,889	109,765	110,461	111,738	106,759	109,005
8:00 p.m.	114,674	112,574	111,504	112,589	112,058	112,608	110,005	109,832	110,481	111,787	107,063	109,209
9:00 p.m.	114,738	112,579	111,510	112,594	112,064	112,617	109,930	109,899	110,502	111,835	107,374	109,518
10:00 p.m.	114,746	112,584	111,515	112,599	112,071	112,625	109,740	109,966	110,522	111,884	107,486	109,629
11:00 p.m.	114,754	112,589	111,521	112,604	112,078	112,633	109,549	109,842	110,542	111,701	107,491	109,633
12:00 Midnight	114,762	112,594	111,527	112,609	112,085	112,641	109,534	109,735	110,510	111,619	107,495	109,636
Storage (acre-feet)												
Maximum	115,538	113,003	111,869	112,698	112,156	112,857	110,005	109,966	110,542	111,884	107,779	110,034
Minimum	114,667	112,329	111,245	112,443	111,905	112,510	108,851	108,957	110,219	111,156	106,759	109,005
Elevation (feet)												
Maximum	7,157.92	7,154.77	7,153.34	7,154.38	7,153.70	7,154.58	7,150.97	7,150.92	7,151.65	7,153.36	7,148.10	7,151.00
Minimum	7,156.84	7,153.92	7,152.55	7,154.06	7,153.38	7,154.15	7,149.49	7,149.62	7,151.24	7,152.43	7,146.77	7,149.68
Difference	1.08	0.85	0.79	0.32	0.32	0.44	1.48	1.30	0.41	0.92	1.33	1.32

TABLE C.19 (Cont.)

Reservoir/Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Crystal												
Starting storage (acre-feet)	15,829	15,276	14,443	12,413	13,766	13,822	16,835	16,418	15,926	15,926	16,480	15,311
Side inflow (cfs)	210	135	152	135	123	147	275	680	507	164	130	97
Steady release (cfs)	1,919	1,429	1,285	683	702	748	2,252	3,578	3,832	2,635	1,919	1,916
End-of-hour storage (acre-feet)												
1:00 a.m.	15,688	15,169	14,349	12,368	13,718	13,772	16,718	16,330	15,853	15,810	16,332	15,161
2:00 a.m.	15,547	15,062	14,256	12,322	13,670	13,723	16,600	16,241	15,780	15,694	16,184	15,010
3:00 a.m.	15,405	14,955	14,162	12,277	13,622	13,673	16,483	16,153	15,707	15,578	16,036	14,860
4:00 a.m.	15,264	14,848	14,068	12,232	13,575	13,623	16,365	16,065	15,634	15,462	15,889	14,710
5:00 a.m.	15,123	14,741	13,975	12,187	13,527	13,574	16,248	15,977	15,561	15,346	15,741	14,559
6:00 a.m.	14,982	14,634	13,881	12,141	13,479	13,524	16,131	15,888	15,488	15,230	15,593	14,409
7:00 a.m.	14,840	14,527	13,788	12,096	13,431	13,474	16,013	15,800	15,415	15,114	15,445	14,259
8:00 a.m.	14,699	14,420	13,694	12,051	13,383	13,425	16,071	15,843	15,451	15,173	15,297	14,108
9.00 a.m.	14,558	14,314	13,600	12,005	13,335	13,375	16,129	15,886	15,488	15,232	15,149	13,958
10:00 a.m.	14,417	14,207	13,507	11,960	13,287	13,325	16,187	15,930	15,524	15,291	15,001	13,808
11:00 a.m.	14,275	14,100	13,413	11,915	13,240	13,276	16,245	15,973	15,561	15,350	14,854	13,657
12:00 Noon	14,134	13,993	13,319	11,870	13,192	13,226	16,302	16,016	15,597	15,409	15,144	13,945
1:00 p.m.	14,431	13,886	13,226	11,824	13,144	13,176	16,360	16,059	15,634	15,468	15,434	14,233
2:00 p.m.	14,728	14,217	13,570	11,779	13,096	13,127	16,418	16,102	15,670	15,528	15,724	14,520
3:00 p.m.	15,024	14,548	13,914	12,172	13,486	13,515	16,476	16,145	15,707	15,587	16,014	14,808
4:00 p.m.	15,321	14,879	14,259	12,564	13,876	13,903	16,534	16,188	15,743	15,646	16,304	15,096
5:00 p.m.	15,618	15,210	14,603	12,774	14,103	14,267	16,592	16,232	15,780	15,705	16,595	15,383
6:00 p.m.	15,915	15,541	14,939	12,728	14,055	14,217	16,649	16,275	15,816	15,764	16,885	15,671
7:00 p.m.	16,212	15,783	14,846	12,683	14,007	14,168	16,707	16,318	15,853	15,823	17,175	15,959
8:00 p.m.	16,376	15,676	14,752	12,638	13,959	14,118	16,765	16,361	15,889	15,882	17,034	15,914
9:00 p.m.	16,235	15,569	14,658	12,593	13,912	14,068	16,823	16,404	15,926	15,942	16,886	15,764
10:00 p.m.	16,094	15,462	14,565	12,547	13,864	14,019	16,881	16,447	15,963	16,001	16,738	15,614
11:00 p.m.	15,952	15,355	14,471	12,502	13,816	13,969	16,938	16,490	15,999	16,060	16,590	15,463
12:00 Midnight	15,811	15,248	14,378	12,457	13,768	13,919	16,821	16,402	15,926	15,944	16,442	15,313
Storage (acre-feet)												
Maximum	16,376	15,783	14,939	12,774	14,103	14,267	16,938	16,490	15,999	16,060	17,175	15,959
Minimum	14,134	13,886	13,226	11,779	13,096	13,127	16,013	15,800	15,415	15,114	14,854	13,657
Elevation (feet)												
Maximum	6,750.91	6,748.84	6,745.83	6,737.70	6,742.76	6,743.37	6,752.83	6,751.30	6,749.60	6,749.81	6,753.63	6,749.46
Minimum	6,742.88	6,741.95	6,739.45	6,733.75	6,738.95	6,739.07	6,749.65	6,748.90	6,747.53	6,746.46	6,745.52	6,741.09
Difference	8.03	6.89	6.38	3.95	3.81	4.30	3.18	2.40	2.06	3.35	8.11	8.37

TABLE C.20 Bureau of Reclamation Coefficient Tables Used to Calculate Reservoir Elevations

Reservoir	E_b	A	B	C
Blue Mesa	7350.	(14174.00)	1668.82	12.59
	7380.	47203.00	2415.18	14.80
	7400.	101405.00	3000.20	22.13
	7420.	170210.00	2899.79	27.75
	7450.	312210.00	5572.05	29.43
	7470.	435478.00	6767.88	25.68
	7490.	501135.00	7776.96	22.50
	7510.	745605.00	8680.00	26.80
	7519.	829523.00	0.00	0.00
Morrow Point	6770.	0.00	0.00	0.05
	6780.	5.00	1.00	0.15
	6790.	30.00	4.00	0.20
	6800.	90.00	8.00	0.25
	6810.	195.00	13.00	0.40
	6820.	365.00	21.00	0.50
	6830.	625.00	30.70	0.63
	6850.	1490.00	56.00	0.80
	6860.	2131.07	71.39	0.55
	6880.	3781.61	93.09	0.73
	6900.	5931.25	125.13	1.23
	6920.	8911.77	175.79	0.74
	6960.	17120.46	235.21	1.28
	7038.	39833.16	402.63	1.44
Crystal	6670.	0.00	134.00	0.65
	6680.	1405.00	147.00	0.75
	6690.	2950.00	162.00	0.80
	6720.	4650.00	178.00	0.95
	6710.	6525.54	196.00	1.03
	6730.	10870.54	237.70	1.23
	6750.	16115.00	287.00	1.40
	6769.	22044.00	-[a]	0.00

[a] Value missing from table provided by Reclamation.

Source: Bureau of Reclamation, Salt Lake City, Utah Office, April 1992; reformatted from electronic transmittal.

TABLE C.21 Elevation Changes in a Moderate Year, 1987[a]

Reservoir/ Month	Elevation[b] (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	
Blue Mesa					
Oct	7498.1	7498.2	0.2	0.1	49
Nov	7494.8	7495.0	0.2	0.1	37
Dec	7492.6	7492.8	0.2	0.1	61
Jan	7488.6	7488.7	0.1	0.1	11
Feb	7488.2	7488.3	0.1	0.1	1
Mar	7488.3	7488.4	0.1	0.0	82
Apr	7491.4	7491.6	0.2	0.1	65
May	7494.7	7495.1	0.4	0.0	100
Jun	7504.9	7505.0	0.1	0.0	100
Jul	7509.5	7509.6	0.1	0.1	58
Aug	7506.4	7506.6	0.2	0.1	57
Sep	7503.3	7503.5	0.2	0.1	73
Morrow Point					
Oct	7156.8	7157.9	1.1	1.0	8
Nov	7153.9	7154.7	0.8	0.8	5
Dec	7152.5	7153.3	0.8	0.8	5
Jan	7154.0	7154.3	0.3	0.3	6
Feb	7153.3	7153.6	0.3	0.3	9
Mar	7154.1	7154.5	0.3	0.2	30
Apr	7149.4	7150.9	0.6	0.6	0
May	7149.6	7151.0	1.4	1.3	9
Jun	7151.2	7151.6	0.4	0.4	22
Jul	7152.4	7153.3	0.9	0.8	15
Aug	7146.7	7148.0	1.3	1.2	7
Sep	7149.6	7150.9	1.3	1.2	5
Crystal					
Oct	6742.8	6750.9	8.1	8.0	1
Nov	6741.9	6748.8	6.9	6.8	1
Dec	6739.4	6745.8	6.4	6.1	4
Jan	6733.7	6737.6	3.9	3.7	4
Feb	6738.9	6742.7	3.8	3.8	0
Mar	6739.0	6743.3	4.3	3.9	9
Apr	6749.6	6752.8	3.2	3.2	1
May	6748.8	6750.9	2.1	1.7	18
Jun	6747.5	6749.5	2.0	2.0	0
Jul	6746.4	6749.7	3.3	3.2	2
Aug	6745.4	6753.6	8.2	8.0	2
Sep	6741.0	6749.4	8.4	8.4	0

[a] All elevations are for the first day of the month and are reported to the nearest 0.1 ft.

[b] Maximum and minimum reservoir elevations on the first day of the month.

TABLE C.22 Elevation Changes in a Dry Year, 1989[a]

Reservoir/ Month	Elevation[b] (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	
Blue Mesa					
Oct	7471.9	7472.0	0.1	0.1	29
Nov	7470.5	7470.6	0.1	0.0	100
Dec	7472.8	7472.8	0.0	0.0	100
Jan	7474.8	7474.9	0.1	0.0	93
Feb	7476.9	7477.0	0.1	0.0	72
Mar	7478.3	7478.4	0.1	0.0	100
Apr	7482.7	7482.9	0.2	0.0	100
May	7489.3	7489.6	0.3	0.0	100
Jun	7496.8	7497.0	0.2	0.0	100
Jul	7501.3	7501.4	0.1	0.1	35
Aug	7499.5	7499.7	0.2	0.1	40
Sep	7497.3	7497.5	0.2	0.1	73
Morrow Point					
Oct	7155.8	7156.4	0.6	0.5	15
Nov	7153.4	7153.5	0.1	0.1	37
Dec	7154.7	7154.8	0.1	0.1	26
Jan	7153.5	7153.7	0.2	0.1	46
Feb	7150.9	7151.0	0.1	0.1	6
Mar	7151.2	7151.4	0.2	0.2	9
Apr	7151.4	7152.3	0.9	0.9	0
May	7150.9	7152.0	0.1	0.1	0
Jun	7151.0	7152.2	1.2	1.1	5
Jul	7151.9	7153.2	1.3	1.3	2
Aug	7149.9	7150.9	1.0	1.0	3
Sep	7149.3	7150.2	0.9	0.7	17
Crystal					
Oct	6749.8	6753.8	4.0	0.4	9
Nov	6740.1	6741.5	1.4	1.4	3
Dec	6738.9	6740.4	1.5	1.5	1
Jan	6738.6	6740.2	1.6	1.6	0
Feb	6738.4	6740.3	1.9	1.8	4
Mar	6740.9	6742.7	1.8	1.3	27
Apr	6753.4	6756.8	3.4	3.4	0
May	6753.5	6756.9	3.4	3.4	0
Jun	6753.2	6756.1	2.9	2.9	1
Jul	6752.4	6755.6	3.2	3.2	0
Aug	6750.5	6757.0	6.5	6.4	2
Sep	6745.8	6752.6	6.8	6.6	3

[a] All elevations are for the first day of the month and are reported to the nearest 0.1 ft.

[b] Maximum and minimum reservoir elevations at the first day of the month.

$$CR_{storage_{i+1}} = CR_{storage_i} + CR_{sideflow_i} + MP_{release_i} - CR_{outflow_i} \quad (i=1,24) \qquad (C.12)$$

where

BM = Blue Mesa Reservoir,

MP = Morrow Point Reservoir,

CR = Crystal Reservoir,

$storage_i$ = the reservoir storage at the beginning of the ith hour,

$sideflow_i$ = is the sideflow into the reservoir during the ith hour,

$release_i$ = the flow through the dam during the ith hour,

$inflow_i$ = the steady inflow into Blue Mesa during the ith hour, and

$outflow_i$ = the steady outflow from Crystal during the ith hour.

Equations C.10, C.11, and C.12 are coupled with the release terms. The outflow from Blue Mesa Dam during one hour is the inflow to Morrow Point Reservoir during the same hour, whereas the outflow from the dam at Morrow Point is the inflow to Crystal Reservoir. The model input values for initial storage, inflow, sideflow, and outflow were obtained from Aspinall Unit research-flow release patterns (Section C.2.1). The storage value for the beginning of the first hour of a month was taken as the reservoir storage at the end of the preceding month. Sideflows, inflow into Blue Mesa Reservoir, and outflow from Crystal Reservoir were assumed to be constant during the modeled 24-hour period. The dam outflows from Blue Mesa Reservoir and Morrow Point Reservoir were taken as the hourly flows corresponding to the research release patterns. Flow from Crystal Reservoir was assumed to be constant for each day at a rate set by the research release patterns. For this model, evapotranspiration was assumed to be negligible.

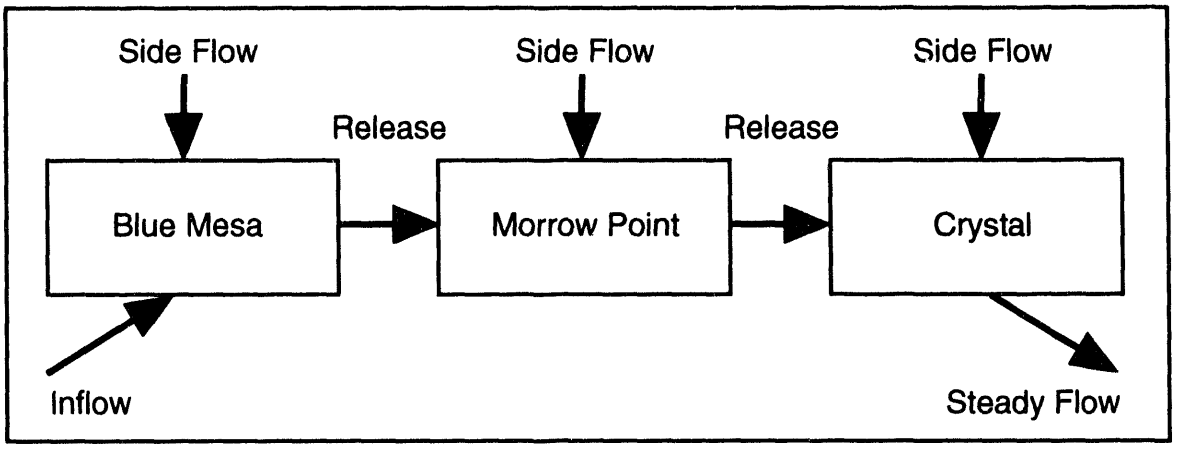


FIGURE C.13 Diagram of the Reservoir Routing Model Used to Determine Reservoir Pool Elevation Changes due to the Aspinall Unit Research-Flow Hydrographs

Hourly time steps were used to compute reservoir storage at the end of each hour for a day. The minimum and maximum storage values that occur during this day were used to compute the maximum change in reservoir storage; the storage values at the end of the first hour and at the end of the 24th hour were used to compute the storage change that would occur because of steady operations (i.e., the change that would occur if there were no fluctuations in flow due to power generation).

Reservoir elevations corresponding to the maximum and minimum storage values were determined with a table-lookup function. This lookup function always rounds up (e.g., 0.21 becomes 0.3). The storage-elevation table used by this lookup function was generated in 0.1-ft increments from the Reclamation equation:

$$S_{lf} = A_{lf} + B_{lf}\,(\underline{E_{lf}} - E_f^B)^2 + C_{lf}\,(\underline{E_{lf}} - E_f^B)^2 \qquad \text{(C.13)}$$

where A_{lf}, B_{lf}, and C_{lf} are estimated coefficients from Reclamation for various reservoir levels at facility f; E_{lf} is the elevation for level l at facility f; and E_f^B is the base elevation level at facility f. The values for A, B, and C are given in Table C.20.

The daily maximum elevation change in a reservoir was computed from the elevations corresponding to the maximum and minimum storage values for the reservoir. The daily cumulative change was calculated by using the difference in storage from the beginning to the end of the day (end of the first hour to the end of the 24th hour). The percent maximum elevation change that would occur if reservoir operations were constant was determined by taking a ratio of the cumulative storage change to the maximum storage change. The value reported as resulting from Western power generation operations in Tables C.21, C.22, and C.23 is subject to roundoff error due to the use of elevation values that were only calculated to the nearest 0.1 ft, the type of lookup function used, and the use of this ratio.

TABLE C.23 Elevation Changes in a Wet Year, 1983[a]

Reservoir/ Month	Elevation[b] (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	
Blue Mesa					
Oct	7504.2	7504.4	0.2	0.1	30
Nov	7502.9	7503.1	0.2	0.1	68
Dec	7499.2	7499.4	0.2	0.0	78
Jan	7493.3	7493.6	0.3	0.1	79
Feb	7485.1	7485.4	0.3	0.1	78
Mar	7477.6	7477.9	0.3	0.1	65
Apr	7470.4	7471.1	0.7	0.0	100
May	7450.0	7450.2	0.2	0.1	60
Jun	7454.5	7455.9	1.4	0.0	100
Jul	7491.9	7492.3	0.4	0.0	100
Aug	7502.8	7502.9	0.1	0.0	98
Sep	7506.5	7506.6	0.1	0.1	48
Morrow Point					
Oct	7153.9	7154.9	1.0	1.0	2
Nov	7153.1	7154.1	1.0	0.8	20
Dec	7147.5	7148.6	1.1	1.0	13
Jan	7148.9	7150.0	1.1	1.0	13
Feb	7153.2	7154.3	1.1	1.0	5
Mar	7151.6	7152.7	1.1	1.1	4
Apr	7150.9	7151.3	0.4	0.4	11
May	7151.5	7152.9	1.4	0.9	34
Jun	7152.3	7153.6	1.3	1.3	1
Jul	7151.5	7153.2	1.7	1.7	1
Aug	7151.8	7152.7	0.9	0.8	14
Sep	7147.6	7148.6	1.0	0.9	12
Crystal					
Oct	6744.9	6751.9	3.0	3.0	1
Nov	6742.2	6749.9	7.7	7.6	1
Dec	6740.7	6748.5	7.8	7.8	0
Jan	6741.4	6749.1	7.6	7.6	0
Feb	6740.9	6748.8	7.9	7.8	1
Mar	6743.0	6750.8	7.8	7.6	3
Apr	6753.4	6756.5	3.1	3.1	0
May	6752.5	6755.3	2.0	1.2	42
Jun	6754.5	6756.7	2.2	2.0	7
Jul	6749.5	6751.9	2.0	2.0	1
Aug	6747.3	6754.0	6.7	6.6	1
Sep	6744.5	6752.0	7.5	7.4	1

[a] All elevations are for the first day of the month and are reported to the nearest 0.1 ft.

[b] Maximum and minimum reservoir elevations at the first day of the month.

C.3 REFERENCES FOR APPENDIX C

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.

COE (U.S. Army Corps of Engineers), 1987, *User Manual SSARR Model Streamflow Synthesis and Reservoir Regulation*, U.S. Army Corps of Engineers, North Pacific Division, Portland, Ore.

Engelund, F., and E. Hansen, 1972, *A Monograph on Sediment Transport in Alluvial Streams*, 3rd ed. Rev., Teknisk Forlag, Copenhagen, Denmark.

Garde, R.J., and K.G. Ranga Raju, 1985, *Mechanics of Sediment Transportation and Alluvial Stream Problems*, John Wiley and Sons, New York, N.Y.

Gordon, N.D., et al., 1992, *Stream Hydrology: An Introduction for Ecologists*, John Wiley and Sons, New York.

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.

Simons, D.B., and F. Sentürk, 1992, *Sediment Transport Technology: Water and Sediment Dynamics*, Water Resources Publications, Littleton, Colo.

USFWS (U.S. Fish and Wildlife Service), 1992, *Final Biological Opinion on the Operation of Flaming Gorge Dam*, Fish and Wildlife Service, Mountain-Prairie Region, Denver, Colo., Nov. 25.

Yin, S.C.L., 1994, *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, Argonne, Ill.

APPENDIX D:

ECOLOGICAL RESOURCES

APPENDIX D:

ECOLOGICAL RESOURCES

Appendix D contains supplementary materials supporting the ecological resource discussions in Sections 3.4 and 4.2.4. Included are more detailed discussions of impact assessment approaches and wetland resources. Section D.1 lists scientific names and habitat information on all species mentioned in the text, and Section D.2 discusses the approaches used to assess impacts to the ecological resources at Flaming Gorge Dam and the Aspinall Unit. A wetlands assessment is presented in Section D.3; explanations of Federal and state categories of threatened and endangered species and correspondence received from Federal agencies regarding these species are presented in Section D.4. References cited in this appendix are listed in Section D.5.

D.1 LISTS OF SPECIES NAMES

Tables D.1 through D.6 provide information on common and scientific names, habitats, and abundance of species mentioned in Sections 3.4 and Section 4.2.4.

D.2 ECOLOGICAL IMPACT ASSESSMENT METHODOLOGIES FOR FLAMING GORGE DAM AND THE ASPINALL UNIT

The impact assessment for Glen Canyon Dam presented in Section 4.2.4.1 was derived from the Glen Canyon Dam EIS (Reclamation 1993). That assessment was based on extensive research conducted as part of the Glen Canyon Environmental Studies begun in 1982. Similar research has not been conducted for either Flaming Gorge Dam or the Aspinall Unit, and assessment of impacts at those facilities required a different approach involving data collection and analysis. Data gathering was focused on collecting existing data from state and Federal agencies, as well as collecting field data to support the assessment. Aerial videography of the Green River during different flows and of the Aspinall Unit reservoirs was performed for this EIS to catalog and quantify resources that could be affected by hydropower operations and, in the case of Flaming Gorge Dam, to determine the relationship of these resources to different flows. Details of the approaches used are presented in the remainder of this section.

D.2.1 Flaming Gorge Dam

D.2.1.1 Multispectral Aerial Videography

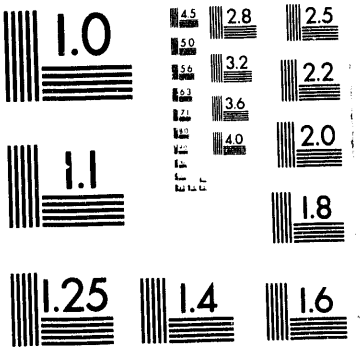
Multispectral aerial videography was obtained under different flow conditions for selected segments of the Green River between Flaming Gorge Dam and the gaging station

TABLE D.1 Fish Species in the Lower Colorado River between Glen Canyon Dam and Lake Mead

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Clupeidae			
Threadfin shad	*Dorosoma petenense*	Introduced	Rare; common in Lakes Mead and Powell; prefers pelagic zones of reservoirs.
Salmonidae			
Apache trout	*Oncorhynchus apache*	Introduced	Federally threatened, accidental; did not become established; prefers small headwater streams at high elevations.
Cutthroat trout	*O. clarki*	Introduced	Rare; once common, now fished out; prefers cold, clear headwater streams.
Coho salmon	*O. kisutch*	Introduced	Accidental; did not become established; prefers pelagic zones of reservoirs.
Rainbow trout	*O. mykiss*	Introduced	Abundant; most abundant trout species below the dam; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Brown trout	*Salmo trutta*	Introduced	Common; abundant in some reaches and tributaries; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Brook trout	*Salvelinus fontinalis*	Introduced	Common, especially from dam to Lees Ferry; prefers clear headwater areas and lakes with gravel substrate.
Cyprinidae			
Red shiner	*Cyprinella lutrensis*	Introduced	Rare; accidental, isolated escapees from reservoirs or introduction; prefers backwaters, side channels, and inundated areas with silt, sand, or gravel substrates and shorelines with emergent vegetation.
Common carp	*Cyprinus carpio*	Introduced	Common, but numbers declining; prefers low-water-velocity habitats with silt, sand, or boulder substrate.

TABLE D.1 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Cyprinidae (Cont.)			
Utah chub	Gila atraria	Introduced	Accidental; one record from Lees Ferry; prefers littoral and pelagic zones of reservoirs.
Humpback chub	*G. cypha*	Native	Federally endangered; large population in the Little Colorado River; prefers eddy/run interfaces in deep canyon areas with swift currents and boulder/rubble substrates.
Bonytail chub	*G. elegans*	Native	Federally endangered; extirpated between dam and Lake Mead.
Roundtail chub	*G. robusta*	Native	Federal Category 2; extirpated between dam and Lake Mead; prefers large river channels with boulders and overhanging cliffs; usually in riffles, shallow runs, or eddy/run interfaces.
Virgin spinedace	*Lepidomeda mollispinis*	Introduced	Accidental; one record from Paria River in 1972; prefers gravel- and sand-bottomed flowing pools and runs of fast and usually clear creeks and small rivers.
Golden shiner	*Notemigonus crysoleucas*	Introduced	Rare or accidental; few records; prefers quiet, vegetated waters on lakes, ponds, swamps, backwaters, and pools of creeks and small to medium rivers.
Fathead minnow	*Pimephales promelas*	Introduced	Common or abundant locally in tributaries; in mainstream most abundant in downstream reaches; prefers backwaters and pools with silt/sand substrate.
Woundfin	*Plagopterus argentissimus*	Introduced	Federally endangered; accidental; introduced into Paria River in 1972; did not become established.
Colorado squawfish	*Ptychocheilus lucius*	Native	Federally endangered; extirpated between dam and Lake Mead.
Redside shiner	*Richardsonius balteatus*	Introduced	Accidental; isolated escapee from reservoirs; prefers littoral zones of reservoirs or river backwaters and pools with slow current.
Speckled dace	*Rhinichthys osculus*	Native	Common; associated with tributaries; abundant in lower reaches of the mainstream; prefers shallow, swift runs and riffles with gravel substrate.


1.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.8
1.1
1.25
1.4
1.6

2 of 2

TABLE D.1 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Catostomidae			
Bluehead sucker	*Catostomus discobolus*	Native	Common; rare or absent above Nankoweap Basin; prefers deep riffles and shallow runs with gravel or cobble substrate.
Flannelmouth sucker	*Catostomus latipinnis*	Native	Federal Category 2; common; rare or absent above Nankoweap Basin; prefers runs, shorelines, and eddies of mainstem rivers.
Razorback sucker	*Xyrauchen texanus*	Native	Federally endangered; very rare between dam and Lake Mead; prefers backwaters, quiet eddies, and deep runs of large river channels.
Ictaluridae			
Black bullhead	*Ameiurus melas*	Introduced	Rare; occasionally found in tributaries; prefers backwaters with silt/gravel substrate.
Channel catfish	*Ictalurus punctatus*	Introduced	Common; widespread, but locally most common in warm tributaries; prefers deep pools, eddies, shorelines, and runs with silt/gravel/boulder substrate or backwaters with silt/sand substrate.
Centrarchidae			
Green sunfish	*Lepomis cyanellus*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers slow-moving stream areas or weed beds of warmwater reservoirs and lakes.
Bluegill	*L. macrochirus*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers shallow, warm lakes and ponds or slow-moving areas of streams with abundant aquatic vegetation.
Largemouth bass	*Micropterus salmoides*	Introduced	Rare; not established; occasional escapee from Lake Mead; prefers clear, quiet waters with aquatic vegetation or littoral zones of reservoirs and lakes.

TABLE D.1 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Percidae			
Walleye	*Stizostedion vitreum*	Introduced	Accidental; one record from Lees Ferry, probable escapee from Lake Powell; prefers large streams, rivers, or lakes with moderately deep water.
Cyprinodontidae			
Western plains killifish	*Fundulus zebrinus*	Introduced	Common; rare or absent above Little Colorado River; locally abundant in some tributaries; prefers shallow backwaters with silt/sand substrate.
Poeciliidae			
Mosquitofish	*Gambusia affinis*	Introduced	Accidental; prefers vegetated drainage ditches, backwaters, and oxbows containing aquatic vegetation.
Percichthyidae			
Striped bass	*Morone saxatilis*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers pelagic zones of reservoirs.

[a] All common and scientific names are from the American Fisheries Society's *Common and Scientific Names of Fishes* (AFS 1991).

[b] Native = a species or subspecies naturally occurring in the Colorado River below Glen Canyon Dam; Introduced = a species or subspecies that has been introduced into the Colorado River below Glen Canyon Dam.

[c] Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Accidental = one or two specimen records, isolated releases of bait, relatively unsuccessful introductions, or occasional individuals entering from Lake Powell or Lake Mead; Extirpated = formerly present in the Grand Canyon but now locally extinct.

Sources: AFS (1991); Maddux et al. (1987); Carothers and Brown (1991); Minckley (1991); Reclamation (1993).

TABLE D.2 Fish Species in the Green River from Flaming Gorge Dam to Jensen, Utah

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Salmonidae			
Cutthroat trout	*Oncorhynchus clarki*	Introduced and native	Common from dam to Little Hole; decreases to Echo Park; stocked in tailwaters; prefers cold, clear headwater streams; includes the Colorado River, Snake River, and Bear Lake subspecies.
Rainbow trout	*O. mykiss*	Introduced	Abundant from dam to Browns Park; common from Browns Park to Echo Park; rare below Echo Park; stocked in tailwaters; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Kokanee salmon	*O. nerka*	Introduced	Rare; probable escapees from reservoir where stocked; prefers pelagic zones of reservoirs.
Mountain whitefish	*Prosopium williamsoni*	Native	Rare or incidental below dam; common in the upper Yampa River; prefers runs with swift water and gravel/rubble substrate.
Brook trout	*Salvelinus fontinalis*	Introduced	Common from tailrace; decreases in abundance to Echo Park; stocked in tailwaters; prefers clear headwater areas and lakes with gravel substrate.
Brown trout	*Salmo trutta*	Introduced	Rare in tailrace; becomes more common downstream in Browns Park area; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Cyprinidae			
Red shiner	*Cyprinella lutrensis*	Introduced	Abundant from Lodore to Jensen; rare above Lodore; common in lower Yampa River; prefers backwaters, side channels, and inundated areas with silt, sand, or gravel substrates and shorelines with emergent vegetation.
Common carp	*Cyprinus carpio*	Introduced	Rare above Browns Park; common from Browns Park to Echo Park; abundant from Echo Park to Jensen; prefers low-water-velocity habitats with silt, sand, or boulder substrates.
Utah chub	*Gila atraria*	Introduced	Rare from the dam to Echo Park; incidental in the lower Yampa; prefers littoral and pelagic zones of reservoirs.

TABLE D.2 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Cyprinidae (Cont.)			
Humpback chub	*G. cypha*	Native	Federally endangered; rare from Lodore to Jensen; rare in the lower Yampa; prefers eddy/run interfaces in deep canyon areas with swift currents and boulder/rubble substrate.
Bonytail chub	*G. elegans*	Native	Federally endangered; historically present in the upper Green River and at the confluence of the Green and Yampa rivers; last verified specimen from the upper Green River Basin collected in 1979 from the lower Yampa River; prefers eddies and runs in canyon areas with swift current and steep walls.
Roundtail chub	*G. robusta*	Native	Federal Category 2; abundant from Browns Park to Island Park; abundant in Yampa; prefers large river channels with boulders and overhanging cliffs; usually in riffles, shallow runs, or eddy/run interfaces.
Sand shiner	*Notropis stramieneus*	Introduced	Common around Echo Park and lower Yampa River; rare below Echo Park; prefers shallow runs and backwaters with silt/sand substrate.
Fathead minnow	*Pimephales promelas*	Introduced	Rare from dam to Browns Park; common from Browns Park to Jensen; prefers backwaters and pools with silt/sand substrate.
Colorado squawfish	*Ptychocheilus lucius*	Native	Federally endangered; absent above Lodore; rare from Lodore to Jensen; rare in the lower Yampa; adults prefer deep runs, eddies, and large backwaters with silt/boulder substrate; juveniles and young-of-the-year prefer backwaters with silt/sand substrate.
Redside shiner	*Richardsonius balteatus*	Introduced	Rare from dam to Lodore; common around Echo Park and Yampa River; prefers littoral zones of reservoirs or river backwaters and pools with slow current.
Speckled dace	*Rhinichthys osculus*	Native	Rare from dam to Echo Park; common from Echo Park to Jensen; prefers shallow, swift runs and riffles with gravel substrate.
Creek chub	*Semotilus atromaculatus*	Introduced	Rare between Browns Park and Jensen; common around Echo Park; prefers riffles, runs, and pools with rubble/cobble substrate.

TABLE D.2 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Catostomidae			
Utah sucker	*Catostomus ardens*	Introduced	Rare; prefers reservoirs and areas of slow to rapid current in streams.
White sucker	*C. commersoni*	Introduced	Rare or incidental; common in the Yampa River; prefers gravel/cobble substrate; prefers creeks and small to medium rivers but also occurs in a wide range of habitats from headwater streams to large lakes.
Bluehead sucker	*C. discobolus*	Native	Rare above Lodore; common from Lodore to Jensen; prefers deep riffles and shallow runs with gravel or cobble substrates.
Flannelmouth sucker	*C. latipinnis*	Native	Federal Category 2; rare above Lodore; common from Lodore to Jensen; prefers runs, shorelines, and eddies of mainstem rivers.
Mountain sucker	*C. platyrhynchus*	Native	Rare around Echo Park; prefers cool, clear streams with gravel/cobble substrate.
Razorback sucker	*Xyrauchen texanus*	Native	Federally Endangered; rare from Lodore to Jensen; spawns in lower Yampa; prefers backwaters, quiet eddies, and deep runs of large river channels.
Ictaluridae			
Black bullhead	*Ameiurus melas*	Introduced	Absent or incidental from dam to Split Mountain; incidental in upper Yampa River; rare or incidental in the Green River below Split Mountain; prefers backwaters with silt/gravel substrate.
Channel catfish	*Ictalurus punctatus*	Introduced	Rare from dam to Echo Park; common from Echo Park to Jensen; prefers deep pools, eddies, shorelines, and runs with silt/gravel/boulder substrate or backwaters with silt/sand substrate.
Centrarchidae			
Green sunfish	*Lepomis cyanellus*	Introduced	Rare from Echo Park to Jensen; rare in the lower Yampa River; prefers slow-moving stream areas or weed beds of warmwater reservoirs and lakes.

TABLE D.2 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Centrarchidae (Cont.)			
Bluegill	*L. macrochirus*	Introduced	Incidental at Echo Park; prefers shallow, warm lakes and ponds or slow-moving areas of streams with abundant aquatic vegetation.
Smallmouth bass	*Micropterus dolomieui*	Introduced	Rare from Echo Park to Jensen; prefers clear, fast-flowing runs and flowing pools with gravel/rubble substrate.
Largemouth bass	*M. salmoides*	Introduced	Incidental in the lower Yampa River; prefers clear, quiet waters with aquatic vegetation or littoral zones of reservoirs and lakes.
Percidae			
Walleye	*Stizostedion vitreum*	Introduced	Rare from Echo Park to Jensen; incidental in lower Yampa River; prefers large streams, rivers, or lakes with moderately deep water.
Esocidae			
Northern pike	*Esox lucius*	Introduced	Incidental; rare in the Yampa; prefers pools with silt, gravel, or sand/rubble substrate and shallow vegetated areas of lakes.
Cottidae			
Mottled sculpin	*Cottus bairdi*	Native	Rare from dam to Browns Park and below Echo Park; common around Echo Park and lower Yampa River; prefers riffles and deep runs with gravel, rubble, or boulder substrate.

[a] All common and scientific names are from the American Fisheries Society's *Common and Scientific Names of Fishes* (AFS 1991).

[b] Native = a species or subspecies naturally occurring in the Upper Green River Basin; Introduced = a species or subspecies that has been introduced into the Upper Green River Basin.

[c] Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Incidental = occurring in very low numbers and known only from a few collections.

Sources: AFS (1991); Tyus et al. (1982); Haines and Tyus (1990); Karp and Tyus (1990).

TABLE D.3 Fish Species in the Aspinall Unit Reservoirs, Gunnison River, Colorado

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Salmonidae			
Cutthroat trout	*Oncorhynchus clarki*	Native	Rare or incidental; restricted to the reservoirs; prefer cold, clear headwater streams.
Coho salmon	*O. kisutch*	Introduced	Common; restricted to the reservoirs; stocked; prefers pelagic zones of reservoirs.
Rainbow trout	*O. mykiss*	Introduced	Abundant; stocked in reservoirs and the upper Gunnison River; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Kokanee salmon	*O. nerka*	Introduced	Abundant; stocked in reservoirs and the upper Gunnison River; prefers pelagic zones of reservoirs.
Brown trout	*Salmo trutta*	Introduced	Common in the reservoirs and the river; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Brook trout	*Salvelinus fontinalis*	Introduced	Rare or incidental; restricted to the reservoirs; stocked; prefers cold, clear headwater streams and lakes with gravel substrate.
Lake trout	*S. namaycush*	Introduced	Rare; restricted to the reservoirs; prefers deep, cold water in reservoirs.
Cyprinidae			
Fathead minnow	*Pimephales promelas*	Introduced	Rare or incidental; prefers shallow nearshore areas with silt/sand substrate.
Speckled dace	*Rhinichthys osculus*	Native	Rare to common; prefers shallow, nearshore areas with gravel substrate.
Catostomidae			
Longnose sucker	*Catostomus catostomus*	Introduced	Common; prefers clear, cold water with gravel substrate.
White sucker	*C. commersoni*	Introduced	Common; prefers gravel/cobble substrate; prefers creeks and small to medium rivers but also occurs in a wide range of habitats from headwater streams to large lakes.

TABLE D.3 (Cont.)

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Catostomidae (Cont.)			
Bluehead sucker	*C. discobolus*	Native	Rare; prefers deep riffles and shallow runs with gravel and cobble substrates; in the reservoirs occurs along nearshore areas with gravel or cobble substrate.
Flannelmouth sucker	*C. latipinnis*	Native	Federal Category 2; rare; prefers nearshore areas with gravel or cobble substrate.
Esocidae			
Northern pike	*Esox lucius*	Introduced	Incidental; one record from Blue Mesa Reservoir; in reservoirs prefers shallow, vegetated areas with silt/gravel or sand/rubble substrate.
Cottidae			
Mottled sculpin	*Cottus bairdi*	Native	Rare to common; in lakes and reservoirs prefers shallow margins with gravel, rubble, or boulder substrate.

[a] All common and scientific names are from the American Fisheries Society's *Common and Scientific Names of Fishes* (AFS 1991).

[b] Native = a species or subspecies naturally occurring in the upper reaches of the Gunnison River and the Aspinall Reservoirs; Introduced = a species or subspecies that has been introduced into the upper reaches of the Gunnison River and the Aspinall Reservoirs.

[c] Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Incidental = occurring in very low numbers and known only from a few collections.

Sources: AFS (1991); Van Buren and Burkhard (1981); Stanford and Ward (1982); Tyus et al. (1982); Woodling (1985); Hebein (1992); Rose (1992).

TABLE D.4 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species below Glen Canyon Dam, Arizona

Common Name	Scientific Name	Habitat
Plants		
Apache plume	*Fallugia paradoxa*	Woody riparian
Arrowweed	*Pluchea sericea*	Woody riparian
Bulrush	*Scirpus validus*	Marsh
Catclaw acacia	*Acacia greggii*	Woody riparian
Cattail	*Typha domingensis, T. latifolia*	Marsh
Common reed	*Phragmites australis*	Marsh
Desert broom	*Baccharis* spp.	Woody riparian
Grand Canyon flaveria	*Flaveria macdougallii*	Upland
Horsetail	*Equisetum hyemale*	Marsh
Netleaf hackberry	*Celtis reticulata*	Woody riparian
Plantain	*Plantago* spp.	Marsh
Redbud	*Cercis occidentalis*	Woody riparian
Rush	*Juncus* spp.	Marsh
Scouring rush	*Equisetum laevigatum*	Marsh
Sedge	*Carex* spp.	Marsh
Spikerush	*Eleocharis* spp.	Marsh
Tamarisk	*Tamarix ramosissima*	Woody riparian
Western honey mesquite	*Prosopis glandulosa*	Woody riparian
Willow	*Salix* spp.	Woody riparian
Invertebrates		
Kanab ambersnail	*Oxyloma haydeni kanabensis*	Marsh
Amphibians and Reptiles		
Red-spotted toad	*Bufo punctatus*	Marsh, woody riparian
Chuckwalla	*Sauromalus obesus*	Upland, woody riparian

TABLE D.4 (Cont.)

Common Name	Scientific Name	Habitat
Amphibians and Reptiles (Cont.)		
Side-blotched lizard	*Uta stansburiana*	Upland, woody riparian, marsh, open shoreline
Birds		
American coot	*Fulica americana*	Marsh, open water
Bald eagle	*Haliaeetus leucocephalus*	Open water, woody riparian
Bell's vireo	*Vireo bellii*	Woody riparian
Belted kingfisher	*Ceryle alcyon*	Open water, woody riparian
Black-chinned hummingbird	*Archilochus alexandri*	Woody riparian
Black-crowned night heron	*Nycticorax nycticorax*	Open water, open shoreline, marsh, woody riparian
Bufflehead	*Bucephala albeola*	Open water, marsh
Canada goose	*Branta canadensis*	Open water, open shoreline, marsh, woody riparian
Common yellowthroat	*Geothlypis trichas*	Marsh, woody riparian
Common merganser	*Mergus merganser*	Open water, marsh
Common goldeneye	*Bucephala clangula*	Open water, marsh
Great blue heron	*Ardea herodias*	Open water, open shoreline, marsh, woody riparian
Green-winged teal	*Anas crecca*	Open water, marsh
Killdeer	*Charadrius vociferus*	Marsh, open shoreline
Loggerhead shrike	*Lanius ludovicianus*	Upland, woody riparian
Mallard	*Anas platyrhynchos*	Open water, marsh
Mexican spotted owl	*Strix occidentalis lucida*	Upland, woody riparian
Northern goshawk	*Accipiter gentilis*	Upland, woody riparian
Osprey	*Pandion haliaetus*	Open water, woody riparian
Peregrine falcon	*Falco peregrinus*	Open water, marsh, woody riparian, upland

TABLE D.4 (Cont.)

Common Name	Scientific Name	Habitat
Birds (Cont.)		
Ruddy duck	*Oxyura jamaicensis*	Open water, marsh
Snowy egret	*Egretta thula*	Open water, open shoreline, marsh, woody riparian
Southwestern willow flycatcher	*Empidonax traillii extimus*	Woody riparian, marsh
Spotted sandpiper	*Actitis macularia*	Marsh, open shoreline
Violet-green swallow	*Tachycineta thalassina*	Open water, marsh, woody riparian, upland
White-faced ibis	*Plegadis chihi*	Marsh, open shoreline, open water
White-throated swift	*Aeronautes saxatalis*	Open water, marsh, woody riparian, upland
Yellow-breasted chat	*Icteria virens*	Woody riparian
Mammals		
Bighorn sheep	*Ovis canadensis*	Upland, woody riparian
Brush mouse	*Peromyscus boylii*	Upland, woody riparian, marsh
Mule deer	*Odocoileus hemionus*	Upland, woody riparian
Pinyon mouse	*Peromyscus truei*	Upland, woody riparian
Southwestern river otter	*Lutra canadensis sonora*	Open water, woody riparian, marsh, open shoreline
Spotted bat	*Euderma maculatum*	Upland, open water, woody riparian, marsh

TABLE D.5 Common Names, Scientific Names, and Habitats of Terrestrial Pant and Animal Species below Flaming Gorge Dam, Utah and Colorado

Common Name	Scientific Name	Habitat
Plants		
Box elder	*Acer negundo*	Woody riparian
Bulrush	*Scirpus* spp.	Marsh
Cattail	*Typha latifolia*	Marsh
Common reed	*Phragmites australis*	Marsh
Coyote willow	*Salix exigua*	Woody riparian
Dogbane	*Apocynum cannabinum*	Woody riparian
Douglas-fir	*Pseudotsuga menziesii*	Upland
Field horsetail	*Equisetum arvense*	Marsh
Fremont cottonwood	*Populus fremontii*	Woody riparian
Giant whitetop	*Lepidium latifolium*	Woody riparian
Golden aster	*Heterotheca* spp.	Woody riparian
Ownbey thistle	*Cirsium ownbeyi*	Woody riparian
Pinyon pine	*Pinus edulis*	Upland
Ponderosa pine	*Pinus ponderosa*	Upland
Rabbitbrush	*Chrysothamnus* spp.	Woody riparian
Rush	*Juncus* spp.	Marsh
Russian olive	*Elaeagnus angustifolia*	Woody riparian
Sagebrush	*Artemisia* spp.	Upland
Scouring rush	*Equisetum* spp.	Woody riparian, marsh
Sedge	*Carex* spp.	Marsh
Shore buttercup	*Ranunculus cymbalaria*	Marsh
Silverweed	*Potentilla anserina*	Marsh
Smooth cliff-brake	*Pellaea glabella*	Cliffs
Sow thistle	*Sonchus* spp.	Marsh, woody riparian
Spikerush	*Eleocharis palustris*	Marsh

TABLE D.5 (Cont.)

Common Name	Scientific Name	Habitat
Plants (Cont.)		
Squawbush	*Rhus trilobata*	Woody riparian
Sweet clover	*Melilotus* spp.	Woody riparian
Tamarisk	*Tamarix ramosissima*	Woody riparian
Thistle	*Cirsium* spp.	Woody riparian
Utah juniper	*Juniperus osteosperma*	Upland
Ute ladies-tresses	*Spiranthes diluvialis*	Woody riparian
Western goldenrod	*Solidago occidentalis*	Woody riparian, marsh
Western mugwort	*Artemisia ludoviciana*	Woody riparian
Wild licorice	*Glycyrrhiza lepidota*	Woody riparian
Wyoming big sagebrush	*Artemisia tridentata*	Upland
Amphibians and Reptiles		
Woodhouse's toad	*Bufo woodhousei*	Marsh, open shoreline, woody riparian
Fence lizard	*Sceloporus undulatus*	Upland, woody riparian, marsh, open shoreline
Gopher snake	*Pituophis melanoleucus*	Upland, woody riparian
Utah milk snake	*Lampropeltis triangulum taylori*	Upland, woody riparian
Western smooth green snake	*Opheodrys vernalis blanchardi*	Upland, woody riparian
Birds		
American widgeon	*Anas americana*	Open water, marsh
American redstart	*Setophaga ruticilla*	Woody riparian
American coot	*Fulica americana*	Marsh, open water
Bald eagle	*Haliaeetus leucocephalus*	Open water, woody riparian
Black-chinned hummingbird	*Archilochus alexandri*	Woody riparian

TABLE D.5 (Cont.)

Common Name	Scientific Name	Habitat
Birds (Cont.)		
Canada goose	*Branta canadensis*	Open water, open shoreline, marsh, woody riparian
Common goldeneye	*Bucephala clangula*	Open water, marsh
Gadwall	*Anas strepera*	Open water, marsh
Great blue heron	*Ardea herodias*	Open water, open shoreline, marsh, woody riparian
Greater sandhill crane	*Grus canadensis tabida*	Marsh, open shoreline, open water
Green-winged teal	*Anas crecca*	Open water, marsh
Killdeer	*Charadrius vociferus*	Open shoreline, marsh
Lazuli bunting	*Passerina amoena*	Upland, woody riparian
Lewis's woodpecker	*Melanerpes lewis*	Upland, woody riparian
Loggerhead shrike	*Lanius ludovicianus*	Upland, woody riparian
Long-billed curlew	*Numenius americanus*	Marsh, open shoreline, open water
Mallard	*Anas platyrhynchos*	Open water, marsh
Mexican spotted owl	*Strix occidentalis lucida*	Upland, woody riparian
Northern goshawk	*Accipiter gentilis*	Upland, woody riparian
Osprey	*Pandion haliaetus*	Open water, woody riparian
Peregrine falcon	*Falco peregrinus*	Open water, marsh, woody riparian, upland
Red-tailed hawk	*Buteo jamaicensis*	Upland, woody riparian
Redhead	*Aythya americana*	Open water, marsh
Spotted sandpiper	*Actitis macularia*	Open shoreline, marsh
Swainson's hawk	*Buteo swainsoni*	Upland, woody riparian
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	Woody riparian

TABLE D.5 (Cont.)

Common Name	Scientific Name	Habitat
Birds (Cont.)		
Willow flycatcher	*Empidonax traillii*	Woody riparian, marsh
Wilson's warbler	*Wilsonia pusilla*	Woody riparian
Yellow-breasted chat	*Icteria virens*	Woody riparian
Mammals		
Bighorn sheep	*Ovis canadensis*	Upland, woody riparian
Coyote	*Canis latrans*	Upland, woody riparian
Deer mouse	*Peromyscus maniculatus*	Upland, woody riparian, marsh
Dwarf shrew	*Sorex nanus*	Upland, woody riparian, marsh
Elk	*Cervus elaphus*	Upland, woody riparian
Moose	*Alces alces*	Woody riparian
Mule deer	*Odocoileus hemionus*	Upland, woody riparian
Pronghorn	*Antilocapra americana*	Upland, woody riparian
Ringtail	*Bassariscus astutus*	Upland, woody riparian
River otter	*Lutra canadensis*	Open water, open shoreline, marsh, woody riparian
Spotted bat	*Euderma maculatum*	Upland, open water, woody riparian, marsh

TABLE D.6 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species in the Vicinity of the Aspinall Unit Reservoirs, Gunnison River, Colorado

Common Name	Scientific Name	Habitat
Plants		
Aspen	*Populus tremuloides*	Upland
Bebb willow	*Salix bebbiana*	Woody riparian
Black sagebrush	*Artemisia nova*	Upland
Black Canyon gilia	*Gilia penstemonoides*	Cliffs
Blue grama	*Bouteloua gracilis*	Upland
Bottlebrush squirreltail	*Sitanion hystrix*	Upland
Box elder	*Acer negundo*	Woody riparian
Colorado desert-parsley	*Lomatium concinnum*	Upland
Coyote willow	*Salix exigua*	Woody riparian
Douglas-fir	*Pseudotsuga menziesii*	Upland
Gambel oak	*Quercus gambelii*	Upland
Geyer willow	*Salix geyeriana*	Woody riparian
Gunnison milkvetch	*Astragalus anisus*	Upland
Hanging garden sullivantia	*Sullivantia purpusii*	Cliffs
Horsetail	*Equisetum* spp.	Marsh
Mountain big sagebrush	*Artemisia tridentata*	Upland
Narrowleaf cottonwood	*Populus angustifolia*	Woody riparian
Needlegrass	*Stipa* spp.	Upland
Pacific willow	*Salix lasiandra*	Woody riparian
Pinyon pine	*Pinus edulis*	Upland
Rocky Mountain juniper	*Juniperus scopulorum*	Upland
Rocky Mountain thistle	*Cirsium perplexans*	Upland
Sandberg bluegrass	*Poa sandbergii*	Upland
Sedge	*Carex* spp.	Marsh
Serviceberry	*Amelanchier* spp.	Upland
Sierra corydalis	*Corydalis caseana brandegei*	Upland

TABLE D.6 (Cont.)

Common Name	Scientific Name	Habitat
Plants (Cont.)		
Spikerush	*Eleocharis* spp.	Marsh
Sweetclover	*Melilotus* spp.	Woody riparian
Thinleaf alder	*Alnus tenuifolia*	Woody riparian
Wheatgrass	*Agropyron* spp.	Upland
White fir	*Abies concolor*	Upland
Amphibians and Reptiles		
Leopard frog	*Rana pipiens*	Open water, open shoreline, marsh
Woodhouse's toad	*Bufo woodhousei*	Open shoreline, marsh, woody riparian
Milk snake	*Lampropeltis triangulum*	Upland, woody riparian
Birds		
American widgeon	*Anas americana*	Open water, marsh
Bald eagle	*Haliaeetus leucocephalus*	Open water, woody riparian
Blue-winged teal	*Anas discors*	Open water, marsh
Canada goose	*Branta canadensis*	Open water, open shoreline, marsh, woody riparian
Common goldeneye	*Bucephala clangula*	Open water, marsh
Golden eagle	*Aquila chrysaetos*	Upland
Great blue heron	*Ardea herodias*	Open water, open shoreline, marsh, woody riparian
Greater sandhill crane	*Grus canadensis tabida*	Marsh, open water, open shoreline
Green-winged teal	*Anas crecca*	Open water, marsh
Killdeer	*Charadrius vociferus*	Open shoreline, marsh
Lazuli bunting	*Passerina amoena*	Upland, woody riparian

TABLE D.6 (Cont.)

Common Name	Scientific Name	Habitat
Birds (Cont.)		
Loggerhead shrike	*Lanius ludovicianus*	Upland, woody riparian
Mallard	*Anas platyrhynchos*	Open water, marsh
Northern goshawk	*Accipiter gentilis*	Upland, woody riparian
Northern pintail	*Anas acuta*	Open water, marsh
Northern shoveler	*Anas clypeata*	Open water, marsh
Peregrine falcon	*Falco peregrinus*	Open water, marsh, woody riparian, upland
Prairie falcon	*Falco mexicanus*	Upland
Red-tailed hawk	*Buteo jamaicensis*	Upland, woody riparian
Song sparrow	*Melospiza melodia*	Woody riparian, marsh
Spotted sandpiper	*Actitis macularia*	Open shoreline, marsh
White-faced ibis	*Plegadis chihi*	Marsh, open shoreline, open water
Whooping crane	*Grus americana*	Marsh, open water, open shoreline
Yellow warbler	*Dendroica petechia*	Woody riparian, marsh
Mammals		
Beaver	*Castor canadensis*	Open water, woody riparian
Bighorn sheep	*Ovis canadensis*	Upland, woody riparian
Dusky shrew	*Sorex obscurus*	Upland, woody riparian, marsh
Elk	*Cervus elaphus*	Upland, woody riparian
Least chipmunk	*Eutamias minimus*	Upland, woody riparian
Mountain vole	*Microtus montanus*	Upland, woody riparian
Mule deer	*Odocoileus hemionus*	Upland, woody riparian
River otter	*Lutra canadensis*	Open water, open shoreline, woody riparian, marsh
Spotted bat	*Euderma maculatum*	Upland, open water, woody riparian, marsh

near Jensen, Utah (Figure D.1). A low-flying fixed-wing aircraft was used to collect videography information in red, green, and infrared bands, similar to data collected by Landsat multispectral scanner satellites. Data were collected between May 15, 1992, and June 5, 1992, in order to correspond with the descending portion of peak flows requested by the U.S. Fish and Wildlife Service (USFWS 1992). Videotape was obtained at flows ranging from 780 to 3,960 cfs in the portion of the Green River between Flaming Gorge Dam and the confluence of the Green and Yampa rivers and ranging from 3,980 to 7,960 cfs in the portion of the Green River below the Yampa River (Table D.7).

After videography was collected, images were catalogued in order to identify river segments that had been videotaped at three or four different flow levels, including the highest and lowest flows obtained. The number of flows at which a particular site was successfully videotaped depended, in part, on weather conditions (e.g., cloud cover) during data collection

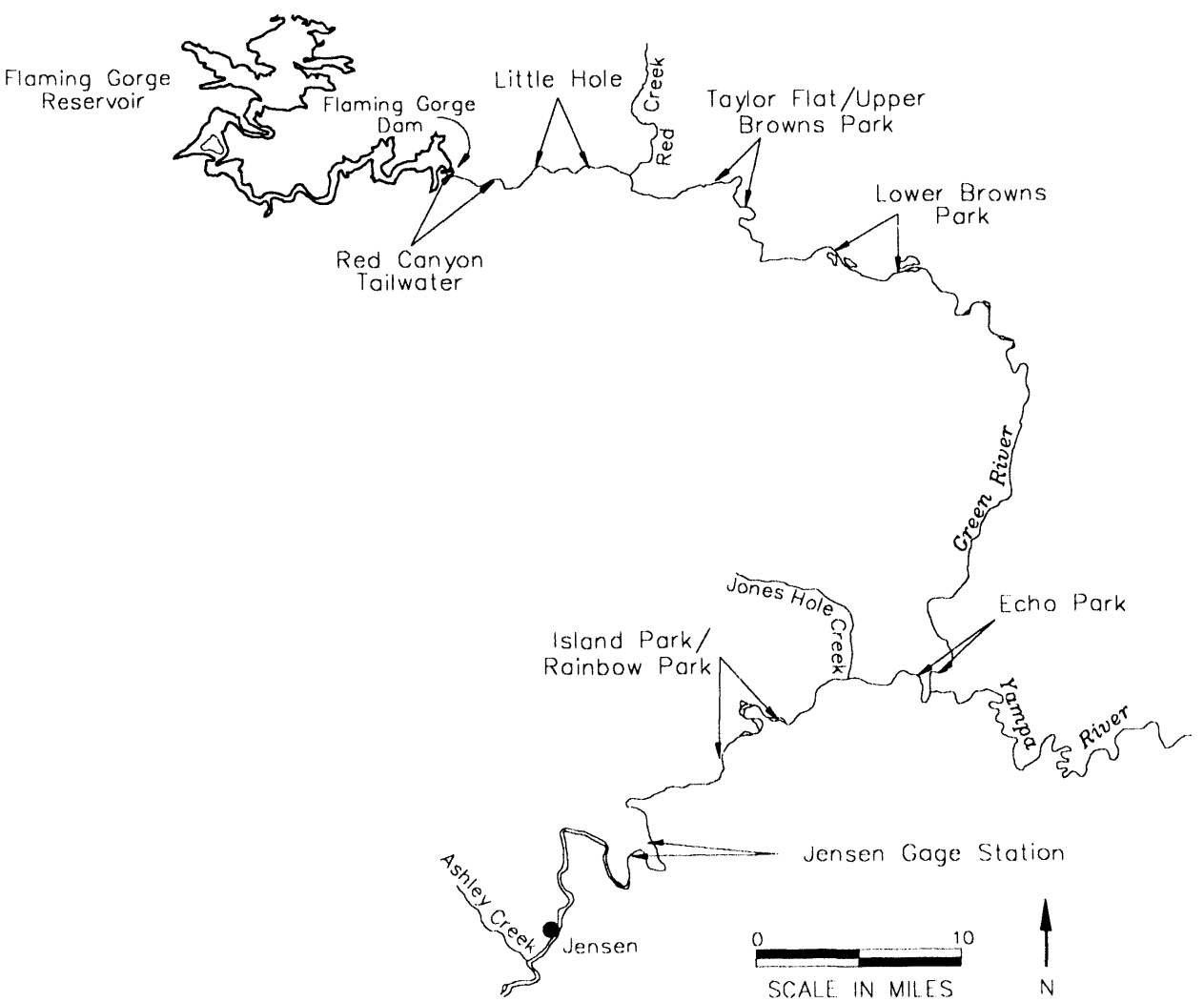


FIGURE D.1 Location of Aerial Videography Sites Used in Ecological Impact Assessment of the Green River Downstream of Flaming Gorge Dam

TABLE D.7 Approximate River Flows during Multispectral Aerial Videography on the Green River

	Flows (cfs) on Date of Videography			
Videography Sites[a]	5/15/92	5/17/92	5/20/92	6/5/92
Red Canyon Tailwaters	3,823	2,427	1,442	778
Little Hole	3,961	2,493	N/A[b]	795
Taylor Flat/Upper Browns Park	3,953	2,578	1,544	813
Lower Browns Park	3,942	2,679	1,602	815
Echo Park	7,950	7,211	6,394	4,052
Island Park/Rainbow Park	7,714	7,412	6,468	3,976
Jensen Gage Station	7,963	7,556	N/A	4,472

[a] See Figure D.1 for location of videography sites.

[b] Videography not available.

flights. After these segments were identified (Table D.7), the appropriate images were captured and transferred to a computer format by using commercially available hardware and software.

Argonne National Laboratory ecologists examined the images and identified and digitized selected features. The features quantified in all images from each river segment included the area of the riparian zone, the surface area of the river, and the number and size of backwater areas. The relationships between discharge and these habitat features were used to predict habitat conditions under each of the hydropower operational scenarios (Hlohowskyj and Hayse 1994; LaGory and Van Lonkhuyzen 1994).

D.2.1.2 Methodology for Assessment of Impacts to Aquatic Ecology

Evaluation of impacts to the aquatic ecology of the Green River was restricted to the area between Flaming Gorge Dam and the U.S. Geological Survey (USGS) gage station near Jensen, Utah. A Biological Opinion issued by the USFWS (1992) has placed restrictions on operations of the dam that limit impacts in areas downstream of the gage. The portion of the Green River between the dam and Jensen can be divided into two distinct regions in terms of the fish they support: (1) the region upstream of the Yampa River, which is dominated by trout species, and (2) the region downstream of the Yampa River, which is dominated by native species (including four Federal endangered species) and introduced species (not including trout) (see Section 3.4.2.1.1 for additional information). The impacts to trout, native fish, and endangered fish downstream of Flaming Gorge Dam were evaluated for the four hydropower operational scenarios for the dam: year-round high fluctuations, seasonally adjusted high fluctuations, seasonally adjusted moderate fluctuations, and seasonally

adjusted steady flow. The factors evaluated were changes that would occur to seasonal discharge levels and patterns, daily fluctuations, desiccation periods, aquatic habitats, and the aquatic food base that supports these fish. The evaluation methods and assumptions are summarized below; greater detail is provided in Hlohowskyj and Hayse (1994).

D.2.1.2.1 Green River Upstream of the Yampa River

Discharge Levels, Daily Fluctuations, and Seasonal Patterns

Information about discharge levels, daily fluctuations in flow, and seasonal hydrological patterns in the upper portion of the Green River was obtained from descriptions of the operational scenarios and hydrological modeling (Section 4.2.3.2.1). For evaluation of impacts to biota, the assumption was made that the areas of concern in the Green River upstream of the Yampa River would experience daily fluctuations in discharge similar to the fluctuations in releases from Flaming Gorge Dam. Dam release patterns for each of the operational scenarios are presented in Section 4.2.3.2.1.

Aquatic Habitats in the Upper Portion of the Green River

Aerial videography (Section D.2.1.1) of the upper portion of the Green River was used to determine the relationship between the inundated area and flow. Videographic information was used with data on the daily minimum and maximum flows under each of the operational scenarios to delineate the aquatic habitat into (1) a permanently wetted zone, (2) a seasonally wetted zone, and (3) a fluctuation zone. The permanently wetted zone is that area that would be inundated throughout the year and is determined by the minimum flow that would occur in a given year. This zone was assumed to provide the most suitable conditions for a rich aquatic food base and was assumed to include the most suitable sites for successful reproduction by trout and other fish species. In the upper portion of the Green River, algae production is supported at all depths, because the high degree of water clarity allows sunlight to penetrate to the bottom in all areas. The seasonally wetted zone is the area that would be inundated throughout the day for some portion of the year, but would become exposed during other periods of the year. Such areas were generally considered to be less productive and less suitable for successful reproduction by fish than the permanently wetted area. The fluctuation zone refers to the portion of the aquatic habitat that is subjected to daily flooding and exposure. Such areas would typically be less productive than seasonally wetted areas, with the level of production depending on the number of hours of exposure.

Impacts to the Aquatic Food Base

The principal components of the aquatic food base in the Green River downstream of Flaming Gorge Dam are the green alga cladophora, the amphipod gammarus, and periphytic diatoms. A large proportion of the diet of trout in the upper portion of the Green

River is composed of cladophora and the amphipods and other invertebrates supported by cladophora. Cladophora and its attached diatoms are the most important primary producers within the aquatic food base, and cladophora serves as an indicator of productivity in the upper portion of the Green River.

Since cladophora production decreases as the length of daily exposure to the air increases (Usher et al. 1987), it was assumed that the production of cladophora would be highest in permanently wetted zones and lowest in fluctuation zones with daily exposures of 1 to 12 hours. Areas with exposure times greater than 12 hours were considered unsuitable for sustaining a cladophora-based community. The production of cladophora and associated biota in the seasonally wetted zone was assumed to be intermediate to production in the other two zones. In addition, the time of the year and the number of consecutive days that seasonally wetted areas were present were considered in evaluating the potential for food production; inundation during cold periods and inundation for less than a month would probably not be conducive to high levels of cladophora production.

Impacts to Trout

In the Green River, successful reproduction by trout is limited primarily by the availability of suitable spawning sites and successful hatching of eggs once they are spawned. The critical period for successful reproduction extends from the spawning of eggs through the emergence of the fry. Areas of aquatic habitat that are exposed to the air between spawning and the emergence of young trout are of little value for reproduction, and the presence of such areas could reduce overall success of spawning by wasting the efforts of reproductively mature females that use those areas. The critical periods for successful reproduction extend from early October to late May for trout that spawn in the fall (brown and rainbow trout), and from March through mid-July for trout that spawn in the spring (rainbow and brook trout) (Modde et al. 1991). All the operational scenarios provide the same amount of permanently wetted zone, and it was assumed that the number of available spawning sites in this zone would be similar. If the seasonally wetted zone was inundated throughout the period of spawning and egg development for trout, that zone was considered capable of providing additional habitat for reproduction. The assumption also was made that smaller fluctuations would provide a more constant environment for developing eggs than large fluctuations, since the quality of a redd site can be affected by water velocity.

An important factor for maintenance of the trout fishery downstream of Flaming Gorge Dam is the overwinter survival of the fish that are stocked each spring. The current management practice is to stock hatchery-reared trout that are about 6 in. long, with the goal of having those fish reach 12 in. by the end of the year. It has been demonstrated that trout smaller than 12 in. at the end of the year are more likely to die during the winter than larger trout (Modde et al. 1991). Therefore, increasing growth rates during the warmer period of the year could increase the proportion of the trout population that survives the winter. To survive the winter, many trout depend upon energy reserves accrued during warmer periods of the year. Excessive activity during the winter can result in mortality if it causes these energy reserves to fall below critical levels. Since fluctuations in flow have been observed to

increase the movements of trout, the potential for overwinter mortality would increase with increasing fluctuations.

D.2.1.2.2 Green River Downstream of the Yampa River

Discharge Levels, Daily Fluctuations, and Seasonal Patterns

Information about discharge levels, daily fluctuations in flow, and seasonal hydrological patterns in the lower portion of the Green River also was obtained from descriptions of the operational scenarios and hydrological modeling (Section 4.2.3.2.1). These predictions of discharge levels and patterns in the lower portion of the river took into account the average seasonal inflow from the Yampa River. The major areas of interest downstream of the Yampa River (i.e., Island Park, Rainbow Park, and the area near the Jensen gaging station) were presumed to experience similar flow regimes because of their distance from the dam and the similarity of topography. Hydrological models predicted that under any of the operational scenarios, flows would not differ by more than about ±80 cfs among these sites during any part of the year. The predicted annual patterns of flow for the Rainbow Park and Jensen gage stations are provided in Section 4.2.3.2.1.

Backwater Habitats in the Lower Portion of the Green River

Backwaters constitute one of the most important resources for the native fish (including endangered species) that inhabit the Green River downstream of the Yampa River. Backwaters are defined as areas of little or no current that are either narrowly connected (connected backwaters) or unconnected (isolated backwaters) from the main channel. Water temperatures are commonly warmer in backwaters than in the main channel during spring, summer, and fall. Juveniles of many native fish species in the Green River rely upon backwaters as nursery areas after hatching. Young fish inhabiting backwater areas that are flooded and drained regularly can be subjected to thermal shock from the inflow of cooler water during flooding or they can be drawn into the main channel during backwater draining. Once in the main channel, young fish are subject to colder water temperatures, which reduce growth rates, and to increased predation by larger fish inhabiting the main channel. In addition, backwaters that are not flooded and drained regularly can attain a greater biomass of food organisms, thus benefitting feeding by younger fish (Grabowski and Hiebert 1989). Investigations by Pucherelli et al. (1990) and aerial videography collected specifically to evaluate impacts of the operational scenarios presented in this document (Section D.2.1.1) were used to quantify the relationships between flows and the number and surface area of backwaters in the lower Green River. These relationships were then used to predict effects of the operational scenarios on backwaters. Although no link has been demonstrated between backwater area and the quality of backwaters as nursery habitats for fish, the stability of backwater areas is thought to play an important role in nursery habitat quality (USFWS 1992; Reclamation 1993). The greater the magnitude and frequency of daily fluctuation in backwater size, the less suitable the backwater as a nursery habitat. For the analyses in the

EIS, the assumption was made that predicted daily change in backwater area is an indicator of backwater habitat quality. Thus, a large fluctuation in backwater area on a daily basis is assumed to result in low backwater habitat quality, while smaller daily fluctuations reflect a higher quality. Other factors important in determining backwater quality include water temperature, depth, and substrate type. These factors were not evaluated in these analyses.

Impacts to Native Fish Species

The impacts of hydropower operations on native fish species in the Green River were assessed by evaluating potential effects on reproduction and the survival of larval, juvenile, and adult fish.

Reproduction of native fish is restricted primarily to areas downstream of Echo Park, presumably because of the cold water temperatures upstream of that point. A large proportion of fish larvae collected from the Green River between the Yampa River and Jensen were those of native species (Haines and Tyus 1990). Therefore, production of larvae in the Green River does not appear to be the limiting factor in recruitment of young to adult populations of native fish, and this production would be expected to remain about the same under all the operational scenarios, especially for species that spawn in the Yampa River.

After hatching, the larvae of many of the native fish enter the main channel of the Green River and are transported downstream. At downstream sites, many of the larvae move into backwaters, where they grow until winter. The survival of young fish in backwaters depends on a number of factors, including the quality of backwaters and the magnitude and frequency of flooding and draining that occurs during the nursery period, a period that is critical to the continued existence of endangered fish species in the Green River (USFWS 1992). Since the nursery period for most of the native fish in the river is from July through December, backwater habitat quality (as a function of stability) during this period was used as an indicator of the survival of larval and juvenile fish. The assumptions were made that lower backwater habitat quality during this period would reduce survival, while the presence of higher quality backwater habitats would improve survival.

Increasing backwater habitat stability was also assumed to enhance populations of introduced fish, which may compete with native fish for food resources or prey on larval and juvenile native fish (Kaeding and Osmundson 1988; Haines and Tyus 1990; Karp and Tyus 1990; Tyus and Beard 1990; Minckley et al., 1991; Reclamation 1993). Slow-water habitats such as backwaters are used by juveniles and adults of a number of introduced fish species present in the upper Green River (Table D.2), including the common carp, fathead minnow, sand shiner, redside shiner, and black bullhead. Tyus et al. (1982) discuss species distributions within the Green River, and Pflieger (1975), Smith (1979), and Woodling (1985) discuss habitat preferences. Quiet water habitats are also preferred by the green sunfish, bluegill, and northern pike. The two former species are omnivorous forms that will feed on larval fish, while the latter species eats fish exclusively. For the assessment in this EIS, it was assumed that as backwater habitats become more stable under the seasonally adjusted

flow scenarios, the quality of these habitats should increase for introduced fish as well as for the native species.

Survival of adult and juvenile fish during the winter can also be decreased by fluctuations in flow. In order to survive the winter, many fish species depend upon energy reserves accrued during warmer periods of the year. Excessive activity during the winter can kill fish if that activity causes these energy reserves to fall below critical levels. Since fluctuations in flow increase the movements of some Green River fish (Valdez and Masslich 1989), the potential for overwinter (December through March) survival was assumed to decrease as fluctuations in flow increased.

D.2.1.3 Methodology for Assessment of Impacts to Riparian Vegetation

This section describes the approach used to identify the types of impacts to riparian vegetation that would result from shifts in flow regimes for the Flaming Gorge Dam hydropower operational scenarios. Aerial videography was obtained for the Green River to determine riparian areas inundated at different flows (as described in Section D.2.1.1). Three-band (red, green, infrared) videography was collected during May and June 1992. Images were obtained at four locations along the river (approximately 1 mi of river length at each) between the dam and the Yampa River. Riparian area (defined here as the area of vegetation and substrate between upland vegetation and low water [800 cfs flows]) and water surface areas were identified, and acreage was calculated. Changes in the amount of riparian area inundated at different flows were calculated in units of acres per mile (LaGory and Van Lonkhuyzen 1994).

Shifts in river stages corresponding to different flow releases were calculated for the Green River below Flaming Gorge Dam (Section 4.2.4.2.2). Stage changes were used to determine which types of plant communities would be affected by different water levels and to what extent they would be inundated.

Species composition and elevation data were obtained along 38 transects on the Green River between Flaming Gorge Dam and Split Mountain Canyon (82 mi below the dam) during June 1992 (LaGory and Van Lonkhuyzen 1994). Dam releases during this period were about 800 cfs; thus, river levels approximated those associated with low flow. Transects extended perpendicular to the river from the edge of the water to the upper edge of the riparian zone.

The woody riparian vegetation in the study area is adapted to the soil moisture levels provided by the current maximum releases (4,200 cfs). The plant species in this vegetation zone depend on the moisture provided by these flows, but they do not colonize the area below the maximum level where frequent inundation occurs. This vegetation corresponds to the new high-water and old high-water zones described for the Colorado River below Glen Canyon Dam (Section 3.4.1.2.1). Operational scenarios featuring maximum flows higher than 4,200 cfs would result in inundation and potential drowning of some existing woody riparian vegetation. Lower maximum flows under different operational scenarios could result in the

expansion of the woody riparian zone to lower elevations. Although the vegetation at the upper boundary of the zone would experience lower moisture levels under reduced flows, it was assumed that this vegetation would survive for 50 years or more, well beyond the 15-year period relevant to this Power Marketing EIS. Several factors were evaluated to assess the potential for expansion of woody riparian vegetation. It was assumed that woody riparian species could not colonize or survive on substrates that were continuously or daily inundated for a month or more each year. The spring peak flows required by the Biological Opinion for Flaming Gorge Dam (USFWS 1992) were not considered to be of sufficient duration to prevent vegetation survival. Flow velocity during the spring peak was not considered to be sufficient to remove rooted plants.

The marsh vegetation in the study area has adapted to intermittent inundation by fluctuating flow levels during the growing season (May 1-September 30). The intermittent saturation from flow fluctuations sustain soil-moisture levels without drowning vegetation. Marsh vegetation could respond rather quickly (within several years) to changes in the moisture regime. Continuous inundation (i.e., nonfluctuating high flows) for a month or more during the growing season was considered sufficient to kill existing marsh vegetation by drowning if the water was greater than 1 ft deep. Additionally, if a period of two months or more of exposure occurred during the growing season (i.e., without inundation due to fluctuating flows), it was assumed that existing marsh vegetation would die back because of drought stress. If the exposure followed at least two months of current maximum flow levels, drought-intolerant marsh vegetation would be replaced with more drought-tolerant marsh species. A decrease in maximum flows during the growing season was assumed to reduce the amount of existing marsh vegetation by killing plants at higher elevations. Therefore, the total amount of marsh vegetation would be directly related to the width of the fluctuating zone during the growing season. A shift in the location of the fluctuation zone would result in loss of some existing marsh vegetation and simultaneous replacement with new marsh vegetation. Such a situation could result in no net change in the area of this vegetation type once equilibrium to the new flow regime was achieved. However, a seasonal shift would cause alternate drowning and exposure, resulting in a net loss of marsh vegetation. Spring-peak flows were not considered to be of sufficient duration to drown marsh vegetation.

Results of the assessments are summarized in Section 4.2.4.2.2. More detailed results are presented in Section D.3 and LaGory and Van Lonkhuyzen (1994).

D.2.2 Aspinall Unit

D.2.2.1 Methodology for Assessment of Impacts to Aquatic Ecology

Potential impacts to the aquatic ecology of the Aspinall Unit were evaluated only for the area between the upstream end of Blue Mesa Reservoir and Crystal Dam. Only this area was evaluated because releases from Crystal Dam would be steady (i.e., would not be controlled to produce hydropower under either of the operational scenarios analyzed). Therefore, this analysis of impacts focuses on fish in the three Aspinall Unit reservoirs (Blue

Mesa, Morrow Point, and Crystal). The daily changes in reservoir elevation attributable to hydropower operations were examined to evaluate the potential impacts to kokanee salmon and trout from the two hydropower operational scenarios (seasonally adjusted steady flows and seasonally adjusted high fluctuating flows). The methods and assumptions used in that evaluation are summarized here.

The hourly change in reservoir elevation under each operational scenario was calculated on the basis of the volume of water to be released (see Section 4.2.3.3 and Appendix C for details). Because the volume of water to be released during a day would be the same under both operational scenarios, beginning- and end-of-day reservoir elevations would be similar. Thus, the seasonally adjusted steady flow operational scenario would result in a linear increase or decrease in reservoir during the day, while the seasonally adjusted high fluctuating flows operational scenario would result in a nonlinear change in reservoir elevation during the day.

The difference in the potential for entrainment of kokanee salmon through the penstocks of the Aspinall Unit facilities was evaluated by examining how far the preferred depths of kokanee salmon would be above the penstock intakes throughout the day under each operational scenario. In the summer, when adult kokanee salmon seek cold water, the preferred depths of these fish in Blue Mesa Reservoir are between 50 and 100 ft, and the preferred depths in Morrow Point Reservoir are between the surface and 40 ft.

Evaluation of impacts to growth, condition, and habitat availability of the operational scenarios was also based upon examination of differences in daily changes in reservoir elevation. This approach took into account the shoreline surface area that would be inundated and exposed on a daily basis and the amount of benthic food resources that could be affected. The major source of food for kokanee salmon is zooplankton, which is assumed to be unaffected by the fluctuations in reservoir elevation attributable to hydropower operations.

D.2.2.2 Methodology for Assessment of Impacts to Riparian Vegetation

Multispectral aerial videography for the Aspinall Unit reservoirs was used to determine the amount of riparian vegetation present. The videography was obtained from a low flying fixed-wing aircraft during May, June, and October 1992. Information was collected in red, green, and infrared bands similar to those collected by Landsat multispectral scanner satellites. The taping, which was conducted for four flow releases from the Aspinall Unit dams, covered an area that included each reservoir and dam. Images of the half-mile section of riverine habitat at the headwaters of Crystal Reservoir, 11 locations along Blue Mesa Reservoir, 6 locations along Morrow Point Reservoir, and 6 locations along Crystal Reservoir were captured, transferred to a computer format, and analyzed (Figure D.2). Riparian areas were identified, and the area of coverage was calculated. The amount of riparian vegetation was calculated in units of acres per mile.

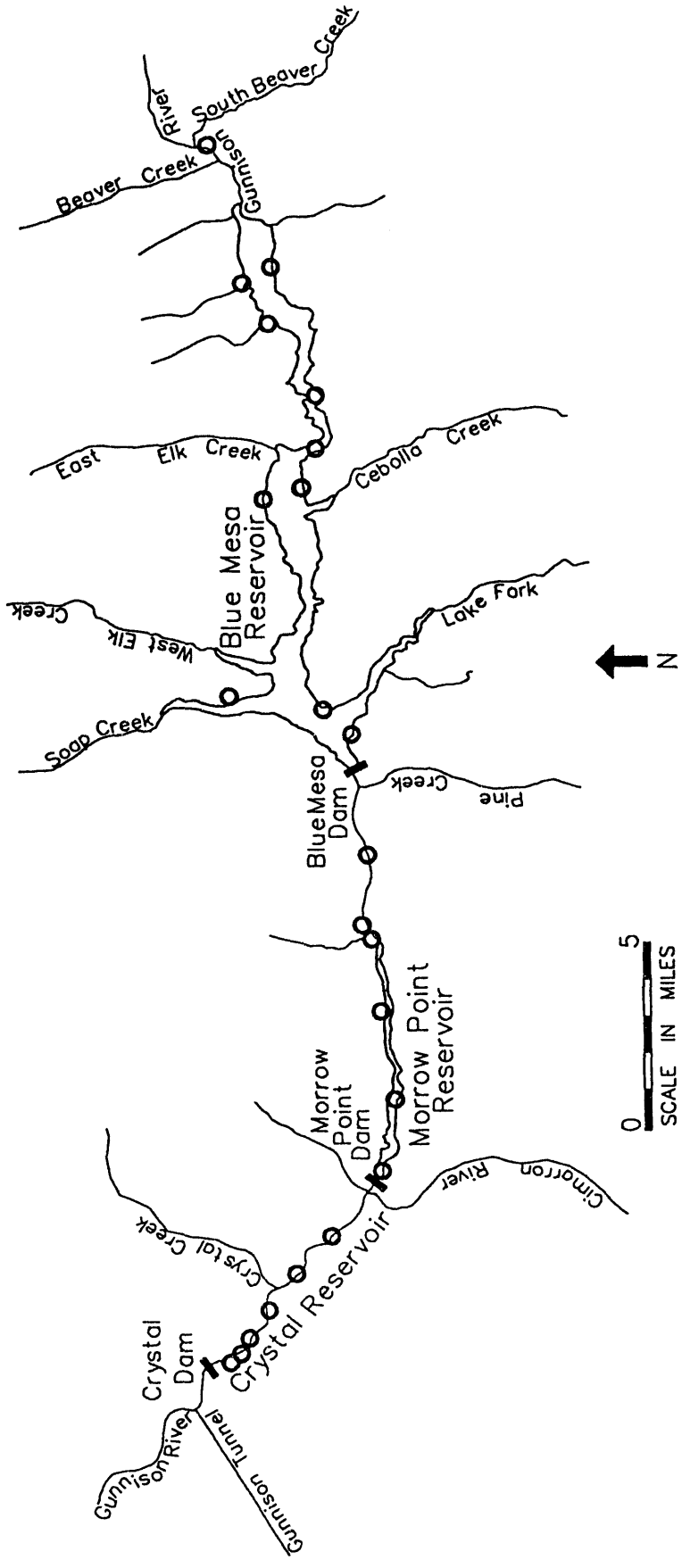


FIGURE D.2 Location of Aerial Videography Sites Used in Ecological Impact Assessment of the Aspinall Unit Reservoirs

Aspinall Unit reservoir levels were calculated from Bureau of Reclamation storage volumes and a reservoir routing model (Section 4.2.3.3.1). Stage changes were used to determine which types of plant communities would be affected by different water levels and to what extent they would be inundated (see Section D.2.1.3 for approach used to assess impacts to riparian vegetation). Results of the assessments are summarized in Section 4.2.4.3.2; more detailed results are presented in Section D.3 of this appendix.

D.3 WETLANDS ASSESSMENT

This wetlands assessment has been prepared to comply with Executive Order 11990, *Protection of Wetlands*. The assessment focuses on the potential impacts to wetlands that could result from implementation of the various hydropower operational scenarios considered in this EIS for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Each of the commitment-level alternatives considered could use any of the hydropower operational scenarios considered here; thus, the impacts of these alternatives would essentially be the same with regard to associated hydropower impacts.

The analysis presented in Section 4.1.1.1 indicates that certain commitment-level alternatives would be more likely than others to result in the construction of new power plants, and this new construction also could result in impacts to wetlands. The types of impacts to wetlands possible include (1) disturbance (e.g., dredge or fill) during construction or (2) discharge of materials (intentional or inadvertent) to any adjacent wetlands during operation of the power plant. Any such impacts would depend on the location of new power plants and would not necessarily be a function of the projected number of new power plants. Since the locations of any new power plants cannot be determined at this time, it is not possible to assess these potential indirect impacts to wetlands. Any such action would require an environmental review that would consider impacts to wetlands before construction.

Wetland delineations (delineation of jurisdictional wetlands following U.S. Army Corps of Engineers [COE] methods [COE 1987]) have not been performed for any of the areas considered in this EIS. As a conservative approach, all riparian vegetation considered here is assumed to meet the Corps of Engineers definition of wetlands, (i.e., "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" [COE 1987]). To be considered a wetland under this definition, an area must possess the following characteristics: (1) a predominance of plant species typically adapted to saturated soil conditions; (2) hydric soils; and (3) periodic or permanent inundation or soil that is saturated to the surface at some time during the growing season (COE 1987). It is assumed that all riparian vegetation in these areas possess these characteristics, although jurisdictional wetlands probably do not occupy the entire riparian zone, especially the woody riparian zone. Any wetlands above the riparian zone would, by definition, not be dependent hydrologically on river flow or reservoir water level and, thus, would not be affected by any of the operational scenarios under consideration.

D.3.1 Glen Canyon Dam

D.3.1.1 Description of Riparian Vegetation below Glen Canyon Dam

Riparian vegetation occurs within the 290 mi of river corridor between Glen Canyon Dam and the headwaters of Lake Mead. This riparian habitat, which would be considered wetland under the USFWS wetlands classification system (Cowardin et al. 1979; Table D.8) and is here assumed to meet the COE criteria for wetland, is the largest protected riparian corridor in the western United States (Anderson and Ruffner 1987). Before Glen Canyon Dam was completed in 1963, two zones of riparian vegetation occurred along the Colorado River in the Glen Canyon and Grand Canyon corridors (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 (approximately the 90,000-cfs level), the plant community consisted of long-lived shrubs and trees that depended on occasional elevated flows to provide suitable

TABLE D.8 Wetland Classification of Riparian Habitats of the Colorado River Corridor below Glen Canyon Dam[a]

Vegetation Type	Common Plant Species	Wetland Type[b]
Woody riparian vegetation		
Old-high water zone	Western honey mesquite, catclaw acacia, apache plume, redbud, netleaf hackberry	Palustrine, broad-leaved deciduous scrub-shrub, intermittently flooded
New-high water zone	Tamarisk, desert broom, willows, arrowweed	Palustrine, broad-leaved deciduous scrub-shrub, intermittently flooded
Marsh	Sedges, bulrush, rushes, cattail, scouring rush, common reed	Palustrine, persistent emergent, regularly or irregularly flooded

[a] All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).

[b] Wetland types are from Cowardin et al. (1979). *Palustrine* = wetlands dominated by trees, shrubs, or persistent emergents; *scrub-shrub* = dominated by woody vegetation less than 20 ft tall; *emergent* = dominated by erect, rooted, herbaceous plants present for most of the growing season; *persistent* = plants remain standing until the beginning of the next growing season; *nonpersistent* = plants fall to the surface before the next growing season; *intermittently flooded* = substrate usually exposed but with variable periods of inundation and unpredictable, possibly long periods between inundations; *regularly flooded* = substrate alternately inundated and exposed at least once daily; *irregularly flooded* = substrate alternately inundated and exposed less often than daily.

substrates, nutrients, and groundwater necessary for growth and reproduction (Anderson and Ruffner 1987; 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). The upper limit of the old high-water zone was apparently determined by soil-moisture levels and soil depth (Reclamation 1988).

Riparian vegetation in the old high-water zone has remained relatively stable since 1963 (Pucherelli 1986) and occupies about 1,870 acres between the dam and Lake Mead (Reclamation 1993). Typical old-high water zone species reproduce in both the old high-water zone and below, but the greater survival of seedlings closer to the river suggests an eventual shift of the community closer to the river's edge (Anderson and Ruffner 1987).

One of the most noticeable changes in the river corridor that resulted from construction of Glen Canyon Dam was the establishment of long-lived riparian vegetation closer to the river. This new community, termed the "new high-water zone," consists of woody and perennial herbaceous species that grow in the old ephemeral zone at and above the 31,500-cfs level (Carothers and Brown 1991) and occupy about 1,320 acres between the dam and Lake Mead (Reclamation 1993). Establishment of these species at lower elevations resulted from the elimination of the large annual floods that previously removed vegetation below the 90,000-cfs level. The new high-water zone is dominated by a mix of native and nonnative species, including tamarisk, desert broom, willows, and arrowweed (Pucherelli 1986).

In the wet year of 1983, flows in excess of 90,000 cfs occurred below the dam (Reclamation 1990; 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 (Pucherelli 1986; Stevens and Waring 1986; Brian 1987). The lack of floods since 1986 has allowed vegetation in the new high-water zone to begin recovery.

In contrast to the adverse effects of flooding on new high-water zone vegetation, the 1983 flood resulted in a slight increase in plant cover in the old high-water zone, presumably because of an increase in soil moisture and replenishment of nutrients (Brian 1987). Occasional floods of this magnitude appear to be necessary for the long-term maintenance of this community (Pucherelli 1986; Brian 1987; Carothers and Brown 1991).

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 scouring and inundation prevent colonization by many long-lived plant species. However, within the fluctuation zone, marsh vegetation (mostly cattail and bulrush) 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.

Approximately 1,100 marshes are present along the river corridor. The total marsh area is about 62 acres (Reclamation 1993). Marshes become progressively more common but smaller downstream of Lees Ferry. In the upper canyon, marshes occur only along wide

reaches. In the lower canyon, marshes occur in both wide and narrow reaches and are more common than they are nearer the dam because of the increased amount of sediment available for colonization of wetland plants.

The number of small marshes has increased since institution of interim flows in August 1991, especially in backwater areas at the 20,000-cfs level (Wegner 1992). Above that level, marshes appear to be drying out because of the reduction in water levels under interim flows.

D.3.1.2 Impacts to Riparian Vegetation below Glen Canyon Dam

Table D.9 summarizes impacts to riparian vegetation under the nine operational scenarios considered in the Glen Canyon Dam EIS (Reclamation 1993). Operational scenarios differ considerably in the expected amount of impact to wetlands. Most of these differences exist between the various fluctuating flow scenarios and steady flow scenarios. These differences are discussed below.

Continuation of historical operations (defined as no-action operations in the Glen Canyon Dam EIS) would not result in impacts to existing wetlands because the extent and nature of this vegetation in the river corridor are primarily a function of these historical operations. Riparian vegetation has increased in abundance due to the elimination or reduction in annual flooding that occurred with construction of the dam. With this reduction, riparian vegetation became established at lower elevations determined by the maximum flows (32,000 cfs) that occurred during historical operations.

Under operations at maximum power plant capacity, a slight increase in maximum flow would reduce the area available for woody riparian vegetation. Some additional shoreline area would be regularly inundated by the higher flows, and any woody plants in this area would be lost. These losses would represent up to 9% of the woody riparian area. In addition, the small (5%) increase in maximum flows would increase the fluctuation zone, thus slightly increasing the area available for colonization by marsh plants. However, this increase is not expected to result in a substantial change from current conditions.

The restricted high fluctuation operational scenario would have the same maximum flow as historical operations. No change in the extent of woody riparian vegetation or marsh vegetation is anticipated with restricted high fluctuations. Existing marshes would be wetted at approximately the same frequency and thus would be maintained.

The moderate fluctuation operational scenario would result in reduced daily fluctuations that would increase the area of woody riparian vegetation by 23-40%. The 29% decrease in maximum flow would decrease the fluctuation zone, thus decreasing the area available for marsh vegetation.

TABLE D.9 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 beneficial 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 as based on change in maximum stage; area coverage cannot be predicted (Reclamation 1993).

Source: Adopted from Reclamation (1993).

Under the modified and interim low fluctuation operational scenarios, a zone between the 20,000- and 31,500-cfs levels would no longer be inundated. The substantial (37%) reductions in maximum flows under this operational scenario would result in up to a 47% increase in the area of woody riparian vegetation. Marshes would continue to occupy sites below the 20,000-cfs stage. Existing marshes above this stage would not be wetted regularly by fluctuating flows and would be gradually replaced by woody riparian vegetation.

The greatly reduced maximum flows under the existing monthly volume steady flow operational scenario would increase the area available for woody riparian plants by about 45-65%. The zone between the 16,300- and 31,500-cfs stages would no longer be inundated by fluctuating flows. These reductions in fluctuations are expected to favor woody vegetation over marsh vegetation. Marsh species above the 16,300-cfs level would lose their water supply, and marshes below this level would be inundated for extended periods, including most of the growing season. The lack of a daily fluctuation zone and the occurrence of only

minor monthly fluctuations during the growing season would greatly reduce marsh vegetation. Monthly changes in flow could allow some marsh species to become established between the elevations of 13,000- and 15,000-cfs flows, but no vegetation would be expected below the elevation of 13,000-cfs flows because this area would be inundated for most of the growing season.

Under seasonally adjusted steady flows, the area between the elevations of 18,000- and 31,500-cfs flows would no longer be inundated, thus permitting a 38-58% increase in the area of woody riparian vegetation. The seasonal variation in steady flows is expected to be detrimental to marsh plants. Under this operational scenario, existing marsh plants would either (1) lose their water supply for five months when flows are at 9,000 cfs or less (October, November, December, August, September); (2) be partially inundated for five months when flows range from 11,000 to 12,500 cfs (January through April, July); or (3) be completely inundated for two months when flows are at 18,000 cfs (May and June). The timing of complete inundation followed by complete exposure during the growing season would be particularly detrimental, and it is assumed that a loss of marsh vegetation would occur. Some marsh vegetation could be reestablished around the 18,000-cfs level. Because of the seasonal changes in flow, however, some marsh plants could occur between the 12,000- and 18,000-cfs levels. No vegetation would be expected below the 12,000-cfs level because this area would be inundated for most of each year.

The year-round steady flow operational scenario would result in steady flows of about 11,400 cfs and would result in a 63-94% increase in the area of woody riparian vegetation. Existing marshes below the elevation of 11,400-cfs flows would be under water year-round, while those above this level would be dry, resulting in a reduction in existing marsh vegetation. Any marsh vegetation that persisted would be located around the elevation of 11,400-cfs flows.

D.3.2 Flaming Gorge Dam

D.3.2.1 Description of Riparian Vegetation below Flaming Gorge Dam

Riparian vegetation occurs along most of the 93 mi of the Green River corridor between Flaming Gorge Dam and Jensen, Utah. Riparian vegetation is absent only in the few areas where sheer rock walls abut the river. Table D.10 summarizes information on the characteristics of the riparian vegetation along the river. Since the construction of Flaming Gorge Dam, the characteristic seasonal flow pattern has been replaced by a shift in monthly releases to meet irrigation demands (higher flows in summer) and relatively large 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, take on a more natural flow regime that includes high spring flows.

TABLE D.10 Wetland Classification of Riparian Habitats of the Green River Corridor below Flaming Gorge Dam[a]

Vegetation Type	Common Plant Species	Wetland Type[b]
Woody riparian vegetation		
Scrub-shrub	Box elder, coyote willow, tamarisk, grasses, wild licorice, giant whitetop, scouring rush	Palustrine, broad-leaved deciduous, scrub-shrub, intermittently flooded
Woodlands	Cottonwood, box elder, sweet clover, grasses	Palustrine, broad-leaved deciduous, forested, intermittently flooded
Marsh	Cattail, bulrush, rushes, common reed, scouring rush, spikerush	Palustrine, persistent emergent, regularly or intermittently flooded

[a] All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).

[b] Wetland types are from Cowardin et al. (1979). Terms are defined in Table D.8 with the exception of *forested* = dominated by woody vegetation at least 20 ft tall.

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 high spring flows, and 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 permanently colonized much of the old flood zone and formed a more stable riparian corridor. Species that spread by underground stems, such as wild licorice, common reed, and scouring rush, have formed dense stands along the shoreline in some areas and appear to be gradually making the channel narrower and deeper with steep banks. Riparian vegetation above the high water line, including pre-dam woody riparian vegetation, is estimated to occupy about 13.3 acres per mile.

Between Flaming Gorge Dam and Jensen, the Green River alternately flows through narrow canyons and broad valleys that are relatively distinct in terms of riparian vegetation. The major areas are Red Canyon, Browns Park, Canyon of Lodore, Whirlpool Canyon, Island and Rainbow Parks, and Split Mountain Canyon. These areas are described below.

The riparian zone in Red Canyon occurs on a predominantly rocky substrate (mostly cobble and boulder) and is relatively narrow (less than 100 ft wide). Riparian vegetation extends up to 25 ft above the low-water level (800-cfs level). 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, and squawbush) are common. Individual ponderosa pine occur near the river in some areas. Tamarisk is uncommon except for stands at Little Hole and near Red Creek.

Through Browns Park, the river meanders within a broad, open floodplain of mostly sand, silt, and gravel. The riparian zone is relatively broad (up to 200 ft wide) except in a few areas (e.g., Swallow Canyon) and extends to 15 ft above the low-water level. Above the high-water line, grasses, sedges, coyote willow, wild licorice, and sow thistle are common; tamarisk forms occasional dense stands at higher elevations throughout Browns Park. Some relatively large cottonwood groves occur on high terraces above the river, particularly below Swinging Bridge (30 mi below the dam). Few young cottonwoods are present, apparently because the dam eliminated the periodic floods needed for seedling establishment (Bureau of Land Management [BLM] 1990). Steep cutbanks are common in lower Browns Park, and in some areas almost all banks are cut and severely eroded.

Within the Canyon of Lodore, many of the canyon walls are nearly vertical, with narrow talus slopes at the base or occasionally with cliffs descending directly into the water; substrates within the riparian zone vary from sand to gravel, cobble, or boulder. Although the riparian zone within the canyon is generally more narrow than in Browns Park because of the restricting canyon walls, it can be up to several hundred feet wide near the confluence of tributary streams. Riparian vegetation extends up to 35 ft above the low-water level. Grasses, scouring rush, box elder, and tamarisk are prevalent above the high-water line. Box elder groves occur throughout the canyon but are largest near the confluence with tributaries. Small tamarisk stands are common throughout the canyon.

The riparian zone within Whirlpool Canyon is similar to that of the Canyon of Lodore in terms of species, but sandy beaches are more common and riparian vegetation is further above the normal river level because of the greater seasonal variations in flow below the Yampa River. Tamarisk is very common below the old high-water line (Fischer et al. 1983).

In Island and Rainbow Parks, the Green River again flows through a wide floodplain with predominantly sand and silt substrate. Islands and backwaters are abundant throughout this section of river. The riparian zone is relatively wide (several hundred feet in areas) and extends up to 20 ft above the water level. Riparian vegetation is similar to that in Browns Park, and large stands of cottonwood, box elder, or tamarisk are common on high terraces.

Below Rainbow Park, the Green River enters Split Mountain Canyon, which has steep, rocky walls and a narrow riparian zone. The vegetation is similar to that found in the Canyon of Lodore except that cottonwoods are more frequent than box elder. Below Split Mountain Canyon, the topography is flatter and the river has steep cutbanks and a high terrace. Tamarisk is a dominant riparian species on the upper terrace throughout the area. Russian olive is also common.

Marshes occur along the Green River between the dam and Jensen. 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 exist. Common species in marshes are cattail, bulrush, rush, common reed, scouring rush, and spikerush. In the Canyon of Lodore, common reed is the most common marsh species, while cattails are less common. Although no estimate of acreage is available for marsh vegetation, the fluctuation zone (between the elevations of 800- and 4,200-cfs flows), where most marshes occur, totals about 5.8 acres per mile along the river.

D.3.2.2 Impacts to Riparian Vegetation below Flaming Gorge Dam

Changes in river stage under each operational scenario during a moderate water year (October 1 through September 30) are presented in Figures D.3 through D.6. These figures show the seasonal patterns in stage changes under each operational scenario and the expected shifts in riparian vegetation zones that would result. Operational scenarios would differ considerably in their expected impact to riparian vegetation, as summarized in Table D.11. These impacts are discussed below and in LaGory and Van Lonkhuyzen (1994).

As discussed in Section D.3.2.1, the abundance of riparian vegetation has increased along the Green River because of the elimination or reduction of annual flooding following construction of Flaming Gorge Dam. With this reduction, riparian vegetation became established at lower elevations determined by the maximum flows that occurred during previous operations. With the year-round high fluctuation operational scenario, the area of woody riparian vegetation above the high-water line would decrease by 7% because maximum releases of 4,700 cfs under this operation scenario would be slightly greater than the historical maximum flows of 4,200 cfs. The extent of the fluctuation zone would increase slightly (17%). The zone would continue to support existing marsh vegetation and additional areas could become available for marsh species.

With seasonally adjusted high fluctuations, maximum flows would be 4,700 cfs, slightly higher than historical levels, for most of the year (from November 1 until July 10 in moderate water years) (Figure D.4). From July 10 to October 1, maximum flows would be reduced from 4,700 cfs to around 3,000 cfs. However, any woody riparian vegetation that colonized this area during this period would be inundated and killed by the higher maximum flows that would occur for the greater part of the year. The extent of woody riparian vegetation under this operational scenario is, therefore, expected to decrease by 7%. However, the area available for marsh vegetation would be increased by 17% because, for several months of the growing season, the fluctuation zone would extend higher than historical levels.

Maximum daily release would be variable under seasonally adjusted moderate fluctuations. For two months of the growing season, maximum flows would reach 4,700 cfs,

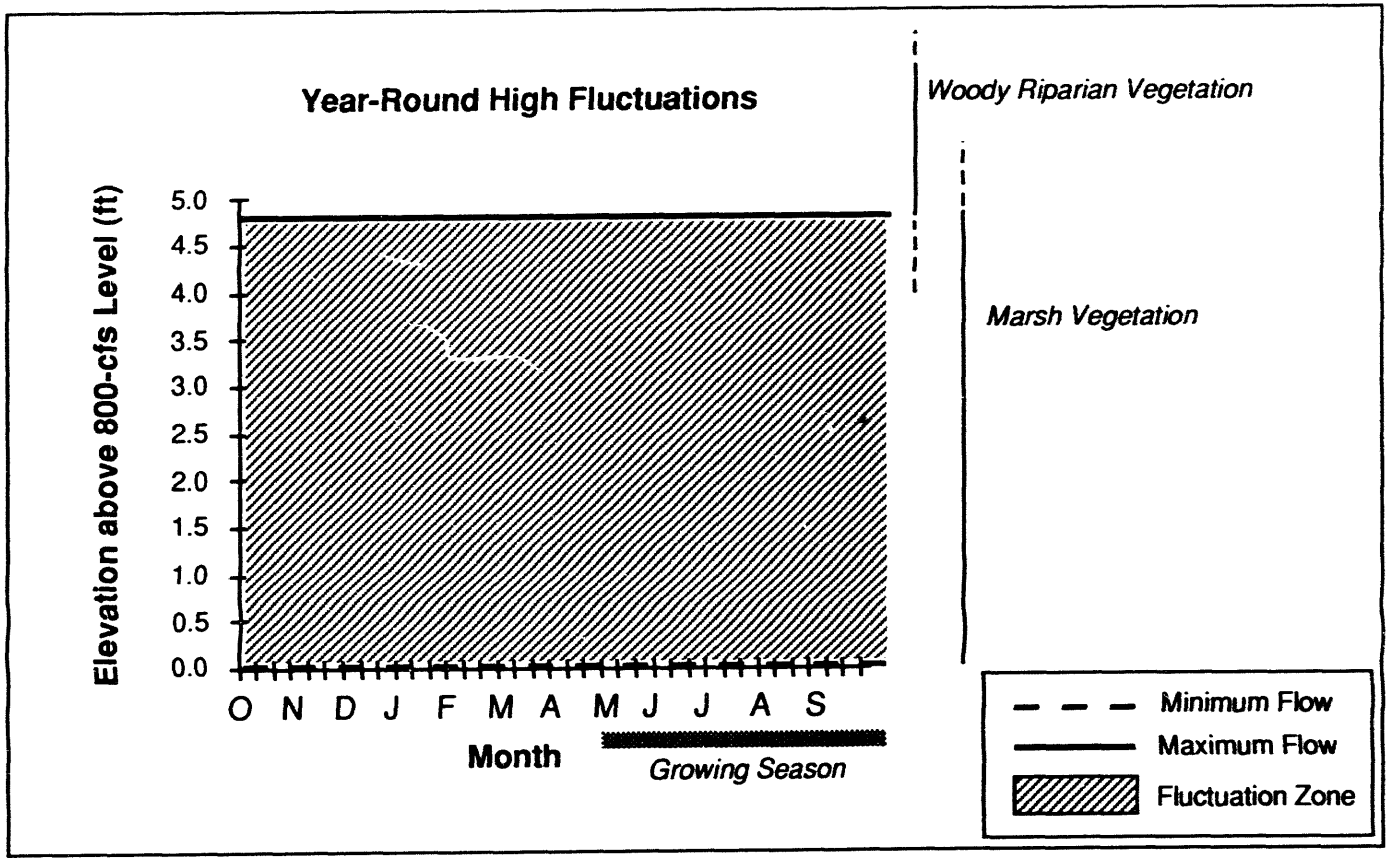


FIGURE D.3 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year (October 1 - September 30) under the Year-Round High Fluctuation Operational Scenario at Flaming Gorge Dam

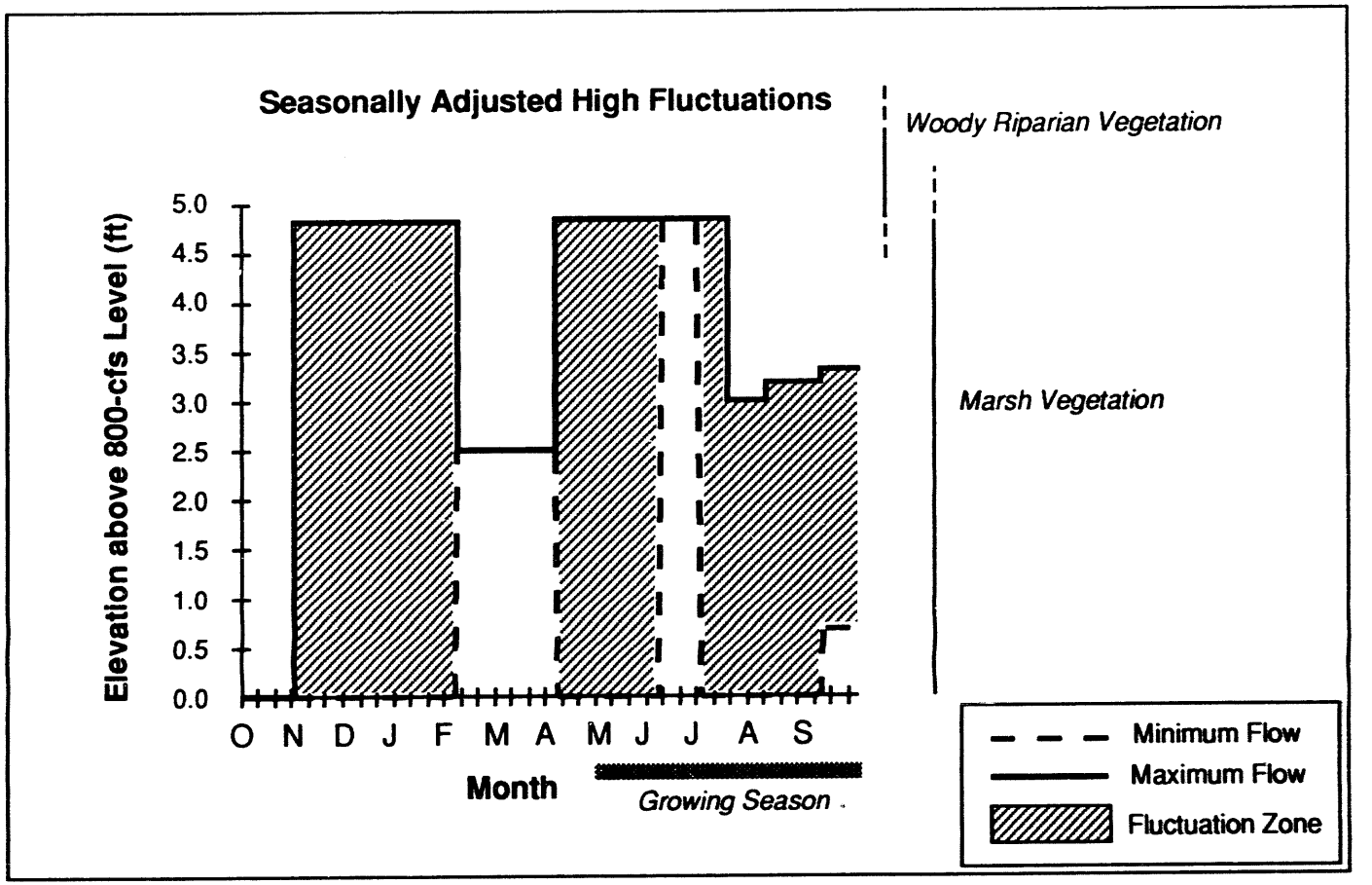


FIGURE D.4 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year (October 1 - September 30) under the Seasonally Adjusted High Fluctuation Operational Scenario at Flaming Gorge Dam

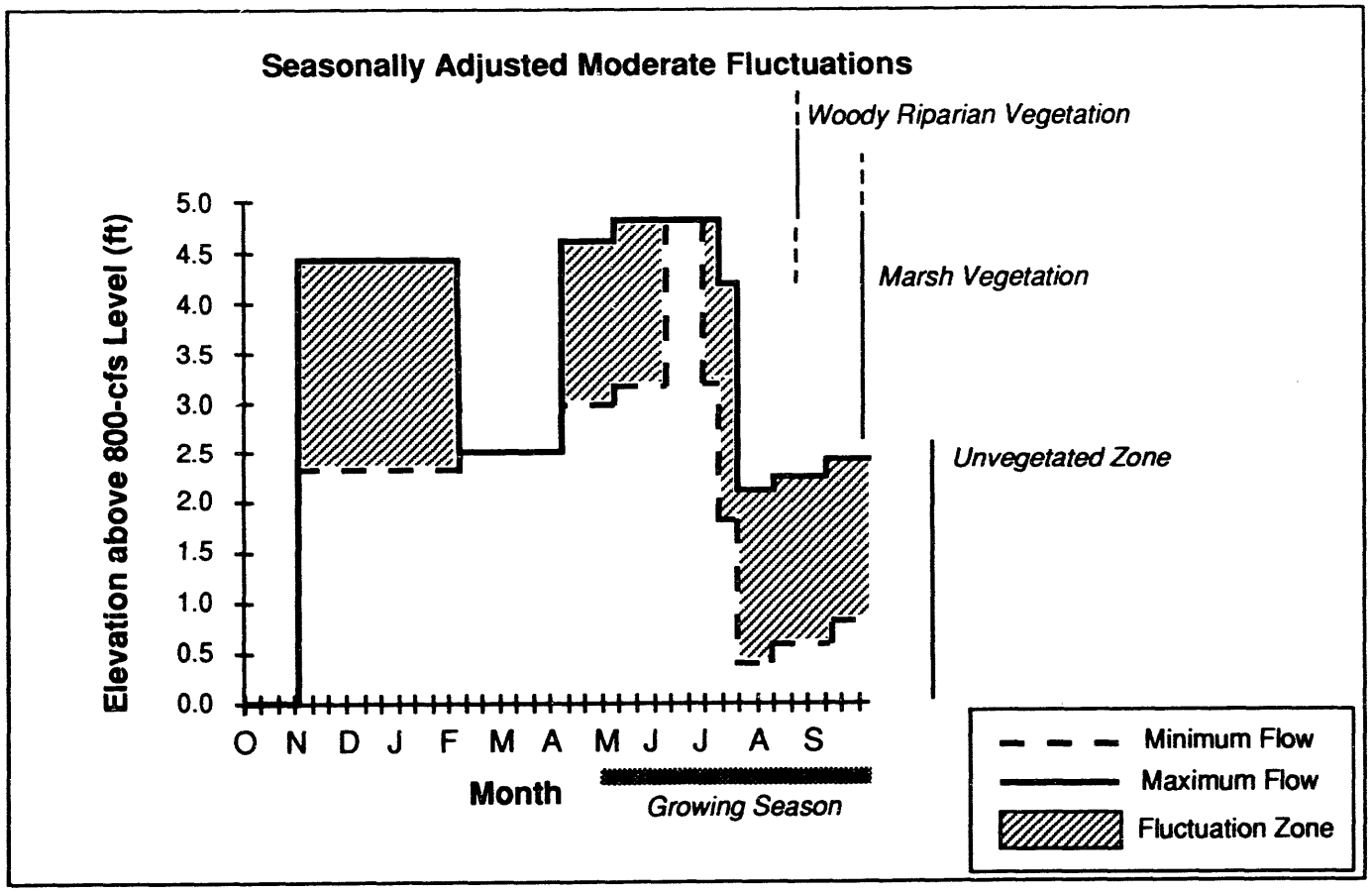


FIGURE D.5 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year (October 1 - September 30) under the Seasonally Adjusted Moderate Fluctuation Operational Scenario at Flaming Gorge Dam

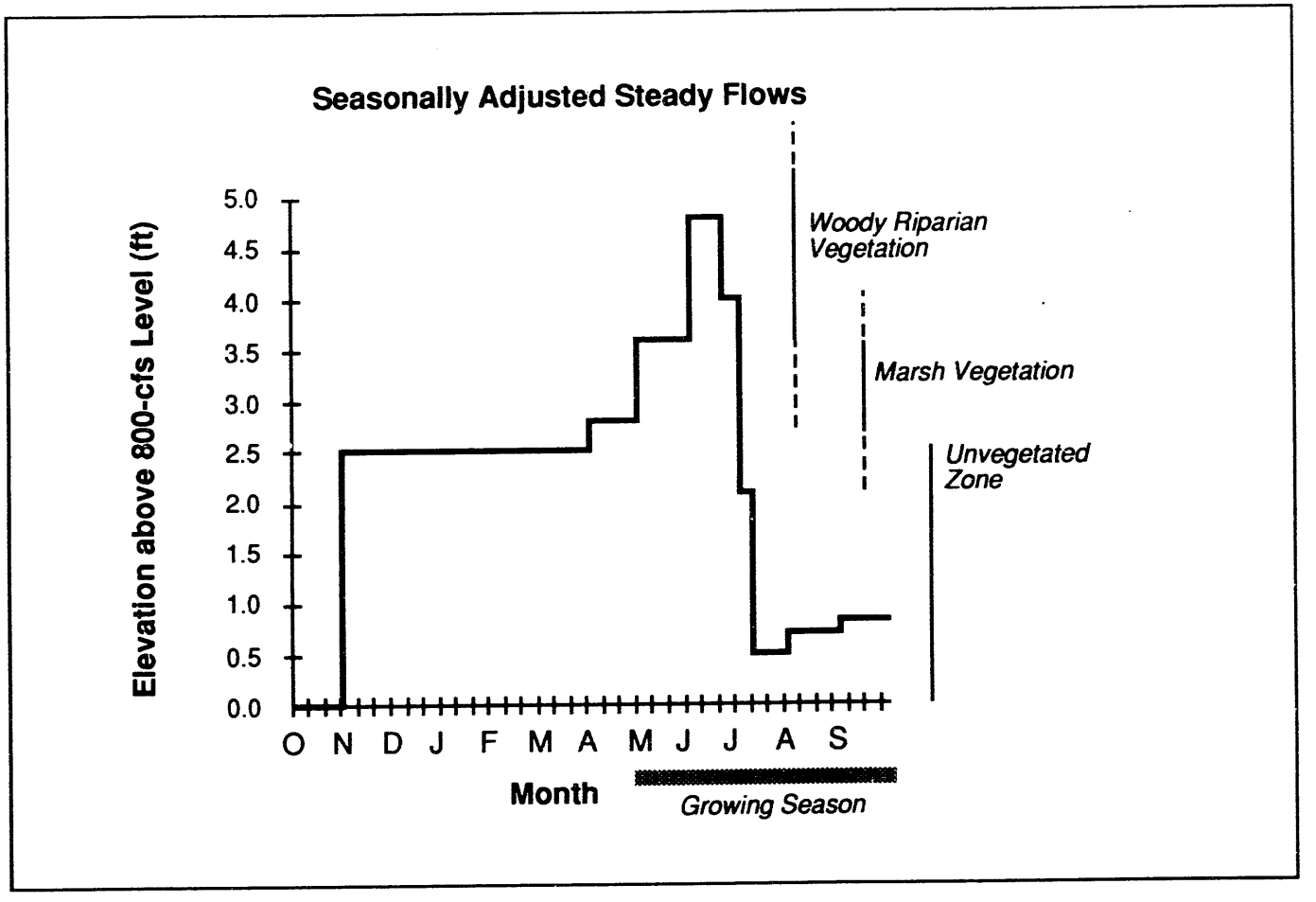


FIGURE D.6 Elevation of Daily Maximum and Minimum Flows and the Expected Location of Riparian Vegetation during the Hydrologic Year (October 1 - September 30) under the Seasonally Adjusted Steady Flow Operational Scenario at Flaming Gorge Dam (Maximum and minimum flows during a month are the same)

TABLE D.11 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Flaming Gorge Dam

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 as high-water line lowered to around the 3,400-cfs level.	Large adverse impact; area available for marsh vegetation decreases by about 69%.

thus reducing the area of woody riparian vegetation by 7%. Otherwise, maximum flows would generally be lower than under either year-round high fluctuations or seasonally adjusted high fluctuations (Figure D.5). However, woody riparian vegetation is not expected to expand to lower elevations because reductions in maximum flow either would occur outside of the growing season (lower flows between October 1 and January 31) or would only occur during part of the growing season (lower flows between July 1 and September 30). Thus, woody vegetation would either not be able to respond to reductions in flow or would be drowned when higher flows occurred from May 1 to June 30.

Under seasonally adjusted moderate fluctuations, marsh vegetation would be affected by the seasonal shifting in location of the fluctuation zone (between about 2,400- and 4,700-cfs levels from November through January and April through May; and 1,000- and 2,000-cfs levels from mid July to September 30) (Figure D.5). This shifting would inhibit the establishment or maintenance of stable marshes and result in a decrease of 24% in the area available for marsh vegetation. Marsh plants that germinated in the of lower fluctuation zone prevalent for most of the growing season would be under water for most of the year and would not persist. No vegetation is expected to occur below about the 2,400-cfs level because this area would be inundated for eight months each year (November through June).

With seasonally adjusted steady flows, daily fluctuations in flow would be eliminated, and only seasonal fluctuations would occur (Figure D.6). Although the maximum release during the year would be the same as the daily maximum achieved each day under year-round high fluctuations, this peak flow would not occur long enough to prevent establishment woody riparian plants at lower elevations. It is expected that woody riparian species could become established down to approximately the elevation of 3,400-cfs flows (which would occur

early in the growing season). Establishment of woody riparian plants down to this new high-water line would represent an increase in this vegetation type of about 1.6 acres per mile; this represents an increase of about 12%.

The lack of daily fluctuations in flow and the wide seasonal variation would greatly reduce the area available for marsh plants under seasonally adjusted steady flows (Figure D.6). Because there would be no fluctuation zone, marsh vegetation would probably be limited to areas wetted by tributary streams or seeps and the area between the elevations of 2,400- and 3,400-cfs flows. This latter area would be wetted during much of the growing season and would not be inundated for more than a few weeks at a time. No vegetation or only short-lived annual plants are expected to occur below the 2,400-cfs level because this area would be inundated for eight months each year (November through June).

D.3.3 Aspinall Unit

D.3.3.1 Description of Riparian Vegetation at the Aspinall Unit

The Aspinall Unit reservoirs occupy areas that for the most part had been canyon and gorge or, in sections of Blue Mesa Reservoir, somewhat wider steep-walled valleys. Little of the original riparian zone escaped inundation upon completion of the Aspinall Unit dams. At normal reservoir levels, most riparian vegetation occurs along the tributaries of the reservoirs rather than along the reservoir itself. Table D.12 summarizes the characteristics of the riparian vegetation that occurs in the area.

Areas surrounding Blue Mesa Reservoir are moderately to steeply sloped. Little riparian vegetation of any kind grows along the reservoir, either above or below the normal

TABLE D.12 Wetland Classification of Riparian Habitats of the Aspinall Unit Reservoirs[a]

Vegetation Type	Common Plant Species	Wetland Type[b]
Woody riparian vegetation	Box elder, narrowleaf cottonwood, coyote willow	Palustrine, broad-leaved deciduous, scrub-shrub, intermittently flooded
Marsh	Sedges, spikerush, horsetail, grasses	Palustrine, persistent or nonpersistent emergent, seasonally or regularly flooded

[a] All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).

[b] Wetland types are from Cowardin et al. (1979). Terms are defined in Table D.8 with the exception of *seasonally flooded* = substrate inundated for extended periods early in the growing season but exposed by the end of the growing season.

high-water line (only about 0.03 acre per mile of shoreline and 0-10 ft wide), and in most areas upland vegetation or bare rock occurs down to the water. Some areas do, however, support woody riparian vegetation, mainly near the confluences with tributaries. Vegetation found in such areas includes narrowleaf cottonwood, coyote willow, Bebb willow, Geyer willow, Pacific willow, thinleaf alder, and sweet clover. Approximately 10 acres of marsh (dominated by sedges) occurs where the Gunnison River enters the upstream end of Blue Mesa Reservoir, between South Beaver Creek and Beaver Creek. This marsh receives water when reservoir elevations are relatively high (around 7,510 ft MSL), and water enters the marsh through a road embankment consisting of boulders and fill material.

Morrow Point Reservoir is surrounded by steep rocky slopes. Little riparian vegetation of any kind occurs along the reservoir. Much of the northern shore consists of unvegetated rocky cliffs, and in other areas upland vegetation is found 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 containing narrowleaf cottonwood, willow, and thinleaf willow near the reservoir.

Crystal Reservoir also is surrounded by steep rocky slopes. The woody riparian zone 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 moderate water years (Section 3.3.3.1), some marsh vegetation (e.g., spikerush, horsetail, and grasses) occurs within the fluctuation zone. Farther downstream, no distinct riparian zone occurs. Woody riparian vegetation, including box elder, narrowleaf cottonwood, and willow, grows along the shore where Crystal Creek enters the reservoir.

D.3.3.2 Impacts to Riparian Vegetation at the Aspinall Unit

Because only a limited amount riparian vegetation occurs along any of the reservoirs of the Aspinall Unit, the potential for impact from the two operational scenarios considered here is greatly reduced. Table D.13 summarizes the limited impacts that could occur.

With seasonally adjusted high fluctuations, monthly variation in reservoir elevations at Morrow Point and Crystal reservoirs would be within the historical range of elevations (Section 4.2.3.3.1). Because woody riparian vegetation currently exists only above this range, both along the shorelines and at tributary mouths, changes in reservoir elevation resulting from hydropower operations should not affect this existing vegetation. New riparian vegetation would be unlikely to develop because of the wide range in inundation during the year. At Blue Mesa Reservoir, the monthly high-water elevation in a moderate water year would be somewhat higher than the historical monthly high-water elevation resulting from Reclamation operations. However, the influence of hydropower on Blue Mesa Reservoir elevations would not increase levels above historical levels. Consequently, no impacts to the marsh in the upper reach of the reservoir are expected to result from hydropower operations.

TABLE D.13 Summary of Impacts of Hydropower Operational Scenarios on Riparian 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.

With seasonally adjusted high fluctuations, some expansion of woody riparian vegetation could occur along the headwaters of Crystal Reservoir (tailwaters of Morrow Point Dam) as fluctuations in flow would be reduced in this riverine section during three months (May through July) of the growing season. During this period, flows would fluctuate daily below 3,800 cfs (Section 4.2.3.3.1), and woody riparian vegetation could expand downward to this new high-water line. Such an increase would represent a vertical expansion of about 1 ft (ranging from 0.2 to 1.7 ft throughout the half-mile reach) by this vegetation type. Reduction in the fluctuation zone in this reach would result in a decrease in the limited marsh vegetation that now occurs there. Under this operational scenario, marsh vegetation would be limited to the area between the 1,800- and 3,800-cfs levels, which represents a vertical range of about 1.6 ft (ranging from 0.2 to 3.1 ft throughout a half-mile section). Vegetation below the 1,800-cfs level (2.2 ft above the current low-water line, ranging from 0.1 to 4.9 ft) would be eliminated because of extended periods of inundation. About 0.4 acre of marsh vegetation could be lost under the seasonally adjusted high fluctuation operational scenario.

Seasonally adjusted steady flows could result in some expansion of woody riparian vegetation along the headwaters of Crystal Reservoir because fluctuations in flow would be reduced in this riverine section during the growing season. Whereas historical releases from Morrow Point ranged from 0 to 5,300 cfs, under seasonally adjusted steady flows, releases would range from 1,770 to 3,325 cfs (Section 4.2.3.3.1). This difference would represent a drop in stage of about 1.3 ft (ranging from 0.2 to 2.4 ft), and woody riparian vegetation would be expected to extend down to this new high-water line, representing an increase of 0.2 acre. The fluctuation zone (and potentially all of the marsh vegetation) in the headwaters of Crystal Reservoir would be eliminated under the seasonally adjusted steady flow operational scenario. Vegetation below the 3,325-cfs level (3.5 ft above the low-water line, ranging from 0.2 to 7.4 ft) would be eliminated because of monthly changes in inundation and exposure. About 0.6 acre of marsh vegetation could be lost under this operational scenario.

D.3.4 Conclusions

Impacts of the various hydropower operational scenarios follow a distinct trend at the three facilities studied. Impacts to woody riparian vegetation would range from slight adverse impacts to a large benefit, with steady flows tending to create the greatest benefit. Impacts to marsh vegetation would range from slight benefits to moderate adverse impacts. Generally, lower maximum flows during the growing season would tend to increase the areas of woody riparian vegetation. Reduced daily fluctuations would tend to decrease the areas of marsh vegetation.

D.4 THREATENED AND ENDANGERED SPECIES

This section provides definitions of species-listing categories for the Federal Government and the states of Arizona, Colorado, and Utah (Sections D.4.1 through D.4.4). Correspondence with the U.S. Fish and Wildlife Service and state agencies regarding the presence of listed species within the areas of the facilities considered in this EIS is reproduced in Section D.4.5.

D.4.1 Federal Listing Categories

Federal categories of protected species are defined as follows:

- *Endangered*: Any species that is in danger of extinction throughout all or a significant portion of its range.
- *Threatened*: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

- *Category 1 (C1)*: Taxa for which the U.S. Fish and Wildlife Service has on file enough substantial information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species. Proposed rules have not yet been issued because this action is precluded by other listing activity. Development and publication of proposed rules on Category 1 taxa are anticipated, however.

- *Category 2 (C2)*: Taxa for which information now in the possession of the U.S. Fish and Wildlife Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules.

- *Category 3:* Taxa that once were considered for listing as threatened or endangered but are no longer under such consideration. Taxa in Category 3 are not current candidates for listing. Reasons for losing candidacy include extinction (Category 3A), determination that the taxa are not a valid species (3B), and determination that the species is common or well protected (3C).

D.4.2 State of Arizona

Plant species in Arizona are protected under the Arizona Native Plant Law, administered by the Arizona Department of Agriculture. The law establishes the following protection categories:

- *Highly Safeguarded:* Species whose prospects for survival in the state are in jeopardy or which are in danger of extinction throughout all or a significant portion of their range, and those species which are likely in the foreseeable future to become jeopardized or in danger of extinction.

- *Salvage Restricted:* Species which are not in the highly safeguarded category but are nevertheless subject to a high potential for damage by theft or vandalism.

- *Export Restricted:* Species which are not in the highly safeguarded category but are nevertheless subject to over-depletion if their exportation from the state is permitted.

- *Salvage Assessed:* Species which are neither in the highly safeguarded category or salvage restricted categories but nevertheless have a sufficient value if salvaged to support the cost of salvage requirements.

- *Harvest Restricted:* Species which are not in the highly safeguarded category but are subject to excessive harvesting or over-cutting because of the intrinsic value of their byproducts, fiber, or woody parts.

The Arizona Game and Fish Department maintains a list of threatened native wildlife in the state. The following listing categories are used:

- *Endangered:* Species extirpated from Arizona since the mid-1800s or for which extinction or extirpation is highly probable without conservation efforts.
- *Threatened:* Animal species whose continued presence in Arizona could be in jeopardy in the near future. Serious threats have been identified and populations are (a) lower than they were historically or (b) extremely local and small.
- *Candidate:* Species with known or suspected threats, but for which substantial population declines from historical levels have not been documented.

D.4.3 State of Colorado

Plant species in Colorado are not protected by statute, but several lists of species of special concern are maintained, depending on rarity in the state (Colorado Natural Areas Program 1991). The lists are as follows:

- *List 1:* Federal threatened or endangered plant species and species that are rare throughout their range. This includes species that are extinct.
- *List 2:* Plant species that are rare or extirpated from Colorado but are relatively common elsewhere within their range.
- *List 3:* Plant species which appear to be rare but for which conclusive information is lacking.
- *List 4:* Plants of limited distribution or special interest that appear secure at this time.

The Colorado Department of Natural Resources maintains the following listing categories for animals:

- *Endangered:* Any species or subspecies of native wildlife whose prospects for survival or recruitment within Colorado are in jeopardy.
- *Threatened:* Any species or subspecies of wildlife which is not in immediate jeopardy of extinction but is vulnerable because it exists in such small numbers or is so extremely restricted throughout all or a significant portion of its range that it may become endangered.

- *Special Concern:* A native species or subspecies which has been threatened or endangered or could become threatened or endangered due to low population levels.

D.4.4 State of Utah

The state of Utah uses the following species listing categories:

- *Endangered:* Any species, subspecies or subpopulation that is threatened with extinction resulting from very low or declining numbers, alteration and/or reduction of habitat, detrimental environmental changes, or any combination of the above. Continued survival is unlikely without implementation of special measures.

- *Threatened:* Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

- *Sensitive:* Any species which, although still occurring in numbers adequate for survival, has been greatly depleted or occurring in limited areas and/or numbers due to a restricted or specialized habitat. A management program, including protection or habitat manipulation, is needed.

D.4.5 Correspondence Regarding Listed Species

The following pages contain copies of correspondence with Federal and state officials concerning the presence and status of listed species.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
3616 W. Thomas, Suite 6
Phoenix, Arizona 85019

May 9, 1991

Memorandum

To: Field Supervisor, Utah/Colorado Field Office, Fish and Wildlife Service, Salt Lake City, Utah

From: Field Supervisor

Subject: List of Threatened or Endangered Species for Western Area Power Administration's (Western) Power Marketing Program

Thank you for faxing a copy of Western's April 24, 1991 letter discussing the environmental impact statement being produced by their Salt Lake City Area Office. In that letter, Western requested information on threatened or endangered species that may be affected by changed dam operations. The following information pertains to the area in Arizona downstream of Glen Canyon Dam.

ENDANGERED SPECIES

Bald eagle	Haliaeetus leucocephalus
Humpback chub	Gila cypha
Peregrine falcon	Falco peregrinus

PROPOSED SPECIES

Razorback sucker	Xyrauchen texanus

CANDIDATE CATEGORY 1

Flaveria	Falveria macdougalli

CANDIDATE CATEGORY 2

Southwestern willow flycatcher	Empidonax traillii

Species with Historic Range within the Project Area and May Be Considered for Conservation Recommendations

Bonytail chub	Gila elegans
Colorado squawfish	Ptychocheilus lucius

We would appreciate being informed of the consultation number assigned to this project. Please advise us when we need to assist your office in regard to Section 7 work. If we can be of further assistance, please contact Frank Baucom or me (602/379-4720 or FTS 261-4720).

Sam F. Spiller

Sam F. Spiller

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM (FWE/SE)
Regional Director, Fish and Wildlife Service, Denver, CO (FWE/SE)
Director, Arizona Game and Fish Department, Phoenix, AZ
Superintendent, Grand Canyon National Park, Grand Canyon, AZ
Superintendent, Glen Canyon National Recreation Area, Page, AZ

United States Department of the Interior

FISH AND WILDLIFE SERVICE
FISH AND WILDLIFE ENHANCEMENT
UTAH-COLORADO FIELD OFFICE
2060 ADMINISTRATION BUILDING
1745 WEST 1700 SOUTH
SALT LAKE CITY, UTAH 84104-5110

TAKE PRIDE IN AMERICA

RECEIVED WAPA SL AREA
OFFICIAL FILE COPY
JUL 13 1991

In Reply Refer To

(FWE)

July 10, 1991

Lloyd Greiner
Western Area Power Administration
P.O. Box 11606
Salt Lake City, Utah 84147

Dear Mr. Greiner:

In response to your April 24, 1991 memorandum, we have prepared the following information which should help you in complying with the Endangered Species Act (Act).

Initially we should inform you that procedures for compliance with the Act differ somewhat based on your proposed action. You are technically not required to ask for a species list or prepare a biological assessment for your marketing program since these steps are required for major construction projects only. You are, however, required by Section 7(a)(2) of the Act to ensure that any action your agency authorizes, funds or conducts is not likely to jeopardize the continued existence of any listed endangered or threatened species. Since your proposed marketing strategy could affect the timing and release of flows from existing dams, and thereby impact downstream aquatic and terrestrial environments, we believe the receipt of a species list and preparation of a biological assessment would be in your best interest. This process should help your agency determine what affect your marketing plan will have on endangered species.

The following listed endangered and threatened species may occur in the area of influence of this action:

Endangered Species

Bald Eagle	Haliaeetus leucocephalus
Bonytail chub	Gila elegans
Colorado squawfish	Ptychocheilus lucius
Humpback chub	Gila cypha
Peregrine falcon	Falco peregrinus
Whooping crane	Grus americanus

Proposed Species

Razorback sucker	Xyrauchen texanus
Ute ladies-tresses orchid	Spiranthes diluvialis

We would also like to bring to your attention species which are candidates for official listing as threatened or endangered (see 55 Fed. Reg. 6184 and 54 Fed. Reg. 554). While these species have no legal protection under the Endangered Species Act, we ask that you try to avoid them if they are found in the area. Candidate species which may occur in the area of your project include:

Flaveria	Flaveria macdougalli
Southwestern willow flycatcher	Empidonax traillii

Western Area Power Administration should review its proposed action and determine if the action would affect any listed species or their critical habitat. You should also determine if the action is likely to jeopardize the continued existence of any proposed species or adversely modify proposed critical habitat for such species. If the determination is "may affect" for listed species, you must request in writing formal consultation from the Field Supervisor, at the address given above. In addition, if you determine that the proposed action is likely to jeopardize the continued existence of a proposed species or result in the destruction or adverse modification of proposed critical habitat, you must confer with our Fish and Wildlife Enhancement office. At that time you should provide us with a copy of the biological assessment and/or any other relevant information that assisted you in reaching your conclusion.

The Service can enter into formal Section 7 consultation only with another Federal agency. State, county, or any other governmental or private organizations can participate in the consultation process, help prepare information such as the biological assessment, participate in meetings, etc.

Your attention is also directed to Section 7(d) of the Endangered Species Act, as amended, which underscores the requirement that the Federal agency or the applicant shall not make any irreversible or irretrievable commitment of resources during the consultation period which, in effect, would deny the formulation or implementation of reasonable and prudent alternatives regarding their actions on any endangered or threatened species.

With regard to formal consultation already being conducted by the Service and the Bureau of Reclamation on Flaming Gorge and Glen Canyon dams, this office does not want to duplicate data gathering or interfere with established reporting schedules. Nonetheless, the Act does provide specific time frames for issuance of assessments and opinions to ensure timely consideration of potential program impacts while trying to avoid delays in program implementation. Therefore, we request that a complete, mutually agreeable and specific time schedule for completing the consultation be developed as soon as possible. If your review period needs to exceed 180 days, please contact out office to insure that the species lists remains accurate and timely.

Given the scope and nature of your power marketing program and its relationship to on-going consultations, perhaps we should meet to discuss appropriate reporting schedules and determine the extent of involvement required of our offices including those in Albuquerque, Phoenix, and Cheyenne.

Sincerely,

Reed E. Harris

Reed E. Harris
Field Supervisor

cc: FWE/Phoenix
FWE/Albuquerque
FWE/Cheyenne

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
FISH AND WILDLIFE ENHANCEMENT
Western Colorado Sub-Office
529 25½ Road, Suite B-113
Grand Junction, CO 81505-6199
FTS 332-0351 PHONE: (303) 243-2778
FAX: (303) 245-6933

IN REPLY REFER TO:
FWE/WAPA-Power Marketing
MS 65412 GJ

January 8, 1992

Dr. Ihor Hlohowskyi
Argonne National Laboratory
Environmental Assessment and Information Sciences Division
97 South Cass Ave
Argonne, Illinois 60439

Dear Dr. Hlohowskyi:

This responds to your December 3, 1991, letter regarding the Power Marketing Environmental Impact Statement for Western Area Power Administration (WAPA). You requested information on federally listed threatened and endangered species on the Gunnison River from Blue Mesa Reservoir to its mouth, the Colorado River from Plateau Creek to the Colorado state line, and Plateau Creek downstream of the Upper and Lower Molina hydropower facilities. You also requested information on species locations, distributions, and references.

Federally Listed Species

bald eagle	Haliaeetus leucocephalus
peregrine falcon	Falco peregrinus
whooping crane	Grus americana
Colorado squawfish	Ptychocheilus lucius
humpback chub	Gila cypha
bonytail chub	Gila elegans
razorback sucker	Xyrauchen texanus

Bald eagles winter along the Colorado and Gunnison rivers and Plateau Creek. Riparian areas with large cottonwood trees are used for roosting, and perching. There are no known bald eagle nests in the area of concern.

There are several peregrine falcon documented breeding territories on the Gunnison and Colorado rivers in the subject area. There are also several potential breeding locations

downstream of the Black Canyon of the Gunnison National Monument and downstream of Grand Junction on the Colorado River.

Whooping cranes migrate through western Colorado with sandhill cranes in the spring and fall on their annual migration from Gray's Lake National Wildlife Refuge, Idaho to Bosque del Apache National Wildlife Refuge, New Mexico. They stop over in agricultral fields, wetlands, and small reservoirs in western Colorado.

Colorado squawfish inhabit the Colorado River from the Price-Stubb dam, upstream of Palisade, to Lake Powell, Utah. They inhabit the Gunnison River from Escalante to it's mouth. Flow regime, water temperatures, and sediment dynamics are important factors on the Colorado and Gunnison rivers.

Humpback chub are found in canyon areas on the Colorado River. In Colorado, they are found in De Beque Canyon and the Black Rocks area of the Colorado River. They are not known to occur in the Gunnison River.

Bonytail chub are extremely rare. The last known capture was on the Colorado River in the Black Rocks area.

The razorback sucker was listed as endangered on October 23, 1991 (56 FR 54957). Razorback sucker inhabit the Colorado River from Rifle to Lake Powell, Utah. They historically occurred on the Gunnison River from Delta to it's mouth. Only two specimens have been collected in the Gunnison River since 1970.

As you requested, we have enclosed a list of references that may be of use to you. Critical habitat has not been designated for any of the species listed above in the area of concern.

If we can be of further assistance, please contact Patty Schrader at the letterhead address and phone.

Sincerely,

Keith L. Rose
Acting Colorado State Supervisor

cc: FWS/FWE, Golden
FWS/FWE, Salt Lake City
CDOW, Grand Junction and Montrose

REFERENCES

Behnke, R.J., and D.E. Benson. 1983. Endangered and threatened fishes of the Upper Colorado River Basin. Ext. Serv. Bull. 503A, Colorado State University, Fort Collins, CO. 38 pp.

Bestgen, K.R. 1990. Status Review of the Razorback Sucker, Xyrauchen texanus. Larval Fish Laboratory #44. Colorado State University.

Holden, P.B., and C.B. Stalnaker. 1975. distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Transactions of the American Fisheries Society 104(2):217-231.

Kaeding, K.R. and D.B. Osmundson. 1989. Biologically Defensible Flow Recommendations for the Maintenance and Enhancement of Colorado Squawfish Habitat in the "15-mile" reach of the Upper Colorado River During July, August and September. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 169pp.

Kidd, G. 1977. An investigation of endangered and threatened fish species in upper Colorado River as related to Bureau of Reclamation Projects. Final report, Bureau of Reclamation, Salt Lake City. 36 pp.

McAda, C.W., and R.S. Wydoski. 1980. The razorback sucker, Xyrauchen texanus, in the upper Colorado River basin, 1974-76. U.S. Fish and Wildlife Service Technical Paper 99. 50 pp.

Osmundson, D.B., and L.R. Kaeding. 1989. Studies of Colorado Squawfish and Razorback Sucker Use of the "15-mile Reach" of the Upper Colorado River as Part of Conservation Measures for the Green Mountain and Ruedi Reservoir Water Sales. Final Report. U.S. Fish and Wildlife Service. Colorado River Fishery Project. Grand Junction, Colorado. 85pp.

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. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 82pp.

Seethaler, K. 1978. Life History and Ecology of the Colorado Squawfish (Ptychocheilus lucius) in the upper Colorado River basin. Thesis, Utah State University, Logan, Utah.

Tyus, H.M., B.D. Burdick, R.A. Valdez, C.M. Haynes, T.A. Lytle, and C.R. Berry. 1982. Fishes of the Upper Colorado River Basin: Distribution, abundance and status. pp. 12-70. In: Miller, W.H., H.M. Tyus and C.A. Carlson, (eds) 1982. Fishes of the Upper Colorado River System: Present and Future. Western Division, American Fisheries Society, Bethesda, MD.

U.S. Fish and Wildlife Service. 1982. Colorado River Fishery Project Final Report. Part I (42 pp), Part II (356 pp), and Part III (342 pp). Prepared for the U.S. Bureau of Reclamation, Salt Lake City. April 1982.

U.S. Fish and Wildlife Service, 1987. Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. U.S. Fish and Wildlife Service, Denver, Colorado. 82 pp.

U.S. Fish and Wildlife Service. 1990. Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 56 pp.

U.S. Fish and Wildlife Service. 1990. Humpback Chub Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 43 pp.

U.S. Fish and Wildlife Service. 1990. Bonytail Chub Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 35 pp.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

FISH AND WILDLIFE ENHANCEMENT
UTAH STATE OFFICE
2060 ADMINISTRATION BUILDING
1745 WEST 1700 SOUTH
SALT LAKE CITY, UTAH 84104-5110

In Reply Refer To
(FWE)

November 16, 1992

Dave Sabo
Western Area Power Administration
P.O. Box 11606
Salt Lake City, Utah 84147

Dear Mr. Sabo:

The Fish and Wildlife Service (Service) has received a request from Aargon Laboratory requesting an updated species list for the reach of river between Flaming Gorge Dam and Jensen, Utah. Since Western Area Power Administration (Western) is the federal agency authorizing this project, we are directing this correspondence to you.

It appears that the following listed threatened and endangered species may occur within the area of influence of this action:

Bald eagle	Haliaeetus leucocephalus
American peregrine falcon	Falco peregrinus
Whooping crane	Grus americanus
Ute ladies'-tresses	Spiranthes diluvialis
Colorado squawfish	Ptychocheilus lucius
Razorback sucker	Xyrauchen texanus
Humpback chub	Gila cypha
Bonytail chub	Gila elegans
Mexican spotted owl	Strix occidentalis lucida (Proposed)

Western should review the proposed action and determine if the action would affect any listed or proposed species or their critical habitat. If the determination is "may affect" for listed species or "may jeopardize the continued existence" of proposed species, you must request in writing formal consultation for listed species or critical habitat, or a conference for proposed species or proposed critical habitat, from the State Supervisor, at the address given above. At that time you should provide this office a copy of a biological assessment or any other relevant information that assisted you in reaching your conclusion.

The Service can enter into formal Section 7 consultation only with another Federal agency. State, county, or any other governmental or private organizations can participate in the consultation process, help prepare information such as the biological assessment, participate in meetings, etc.

Your attention is also directed to Section 7(d) of the Endangered Species Act, as amended, which underscores the requirement that the Federal agency or the applicant shall not make any irreversible or irretrievable commitment of resources during the consultation period which, in effect, would deny the formulation or implementation of reasonable and prudent alternatives regarding their actions on any endangered or threatened species.

We would also like to bring to your attention species which are candidates for official listing as either threatened or endangered species (Federal Register Vol. 55, No. 35, February 21, 1990 and Federal Register Vol. 56, No. 225, November 21, 1991). While these species have no legal protection, at present, under the Endangered Species Act, we would ask that you take care to avoid them if they are found in the area of your project. These species are:

Flannelmouth sucker	Catostomus latipinnis
Roundtail chub	Gila robusta

If you have any questions please contact us (801) 975-3620.

Sincerely,

for Robert D. Williams
State Supervisor

cc: Ihor Hlohowskyj, Aargon National Laboratory, Building 900 EID, 9700 S. Cass Ave., Aargon, Ill. 60439

D.5 REFERENCES FOR APPENDIX D

AFS (American Fisheries Society), 1991, *Common and Scientific Names of Fishes from the United States and Canada*, 5th ed., Special Publication 20, Bethesda, Md.

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.

BLM (Bureau of Land Management), 1990, *Diamond Mountain Resource Management Plan, Management Situation Analysis*, unpublished working document, Diamond Mountain Resource Area, Vernal District, Vernal, Utah.

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.

Carothers, S.W., and B.T. Brown, 1991, *The Colorado River through Grand Canyon — Natural History and Human Change*, University of Arizona Press, Tucson, Ariz.

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 Natural Areas Program, 1991, *Colorado Plant Species of Special Concern*, Colorado Division of Parks and Outdoor Recreation, Denver, Colo.

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.

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, April 30.

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.

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.

Hebein, S., 1992, letter from Hebein (Colorado Division of Wildlife, Montrose, Colo.) to J.W. Hayse (Argonne National Laboratory, Argonne, Ill.), Dec. 7.

Hlohowskyj, I., and J.W. Hayse, 1994, *Effects of Flaming Gorge Hydropower Operations on the Fishes of the Green River, Utah and Colorado*, ANL/EAD/TM-11, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Holmgren, A.H., 1962, *The Vascular Plants of the Dinosaur National Monument,* Utah State University, Logan, Utah.

Kaeding, L.R., and D.B. Osmundson, 1988, "Interaction of Slow Growth and Increased Early-Life Mortality: An Hypotheses of the Decline of the Colorado Squawfish in the Upstream Regions of Its Historic Range," *Environmental Biology of Fishes* 22(4):287-298.

Karp, C.A., and H.M. Tyus, 1990, "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.

LaGory, K.E., and R.A. Van Lonkhuyzen, 1994, *Effects of Flaming Gorge Dam Hydropower Operations on Riparian Vegetation of the Green River, Utah and Colorado*, ANL/EAD/TM-10, Argonne National Laboratory, Environmental Assessment Division, Argonne, Ill.

Maddux, H.R., et al., 1987, *Evaluation of Varied Flow Regimes on Aquatic Resources of Glen and Grand Canyons, Final Report*, prepared for Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Salt Lake City, Utah.

Minckley, W.L., 1991. "Native Fishes of the Grand Canyon Region: An Obituary?" in *Colorado River Ecology and Dam Management*, Symposium Proceedings, National Academy Press, Washington, D.C., pp. 124-177.

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., 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, Utah Division of Wildlife Resources, Salt Lake City, Utah.

National Park Service, 1983, "Vegetation Type Map of Dinosaur National Monument," Sept.

Pflieger, W.L., 1975, *The Fishes of Missouri*, Missouri Department of Conservation, Jefferson City, Mo.

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 U.S. Bureau of Reclamation, 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.

Reclamation (U.S. Bureau of Reclamation), 1988, *Glen Canyon Environmental Studies Final Report* (Revised May 1989), Salt Lake City, Utah, Jan.

Reclamation, 1990, *Historic Streamflows, Water Releases, and Reservoir Storage for Glen Canyon and Lake Powell, Baseline Reference Data for Glen Canyon Dam EIS*, Denver, Colo.

Reclamation, 1993, *Operation of Glen Canyon Dam Colorado River Storage Project, Arizona, Draft Environmental Impact Statement*, Salt Lake City, Utah.

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.

Smith, P.W., 1979, *The Fishes of Illinois*, Illinois State Natural History Survey, University of Illinois Press, Urbana, Ill.

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.

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 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, April 15.

Tyus, H.M., and J.M. Beard, 1990, "*Escox lucius* (Esocidae) *and Stizostedion vitreum* (Percidae) in the Green River Basin, Colorado and Utah," *Great Basin Naturalist* 50(1):33-79.

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.

USFWS (U.S. Fish and Wildlife Service), 1992, *Final Biological Opinion on the Operation of Flaming Gorge Dam*, U.S. Fish and Wildlife Service, Mountain-Prairie Region, Denver, Colo., Nov. 25.

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.

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.

Wegner, D.L., 1992, *Interim Test Flows, Glen Canyon Environmental Studies Update*, Flagstaff, Ariz. (summer issue, p. 1).

Woodling, J., 1985, *Colorado's Little Fish, A Guide to the Minnows and Other Lesser Known Fishes in the State of Colorado*, Colorado Division of Wildlife, Denver, Colo., June.

DATE
FILMED
6/6/94

END