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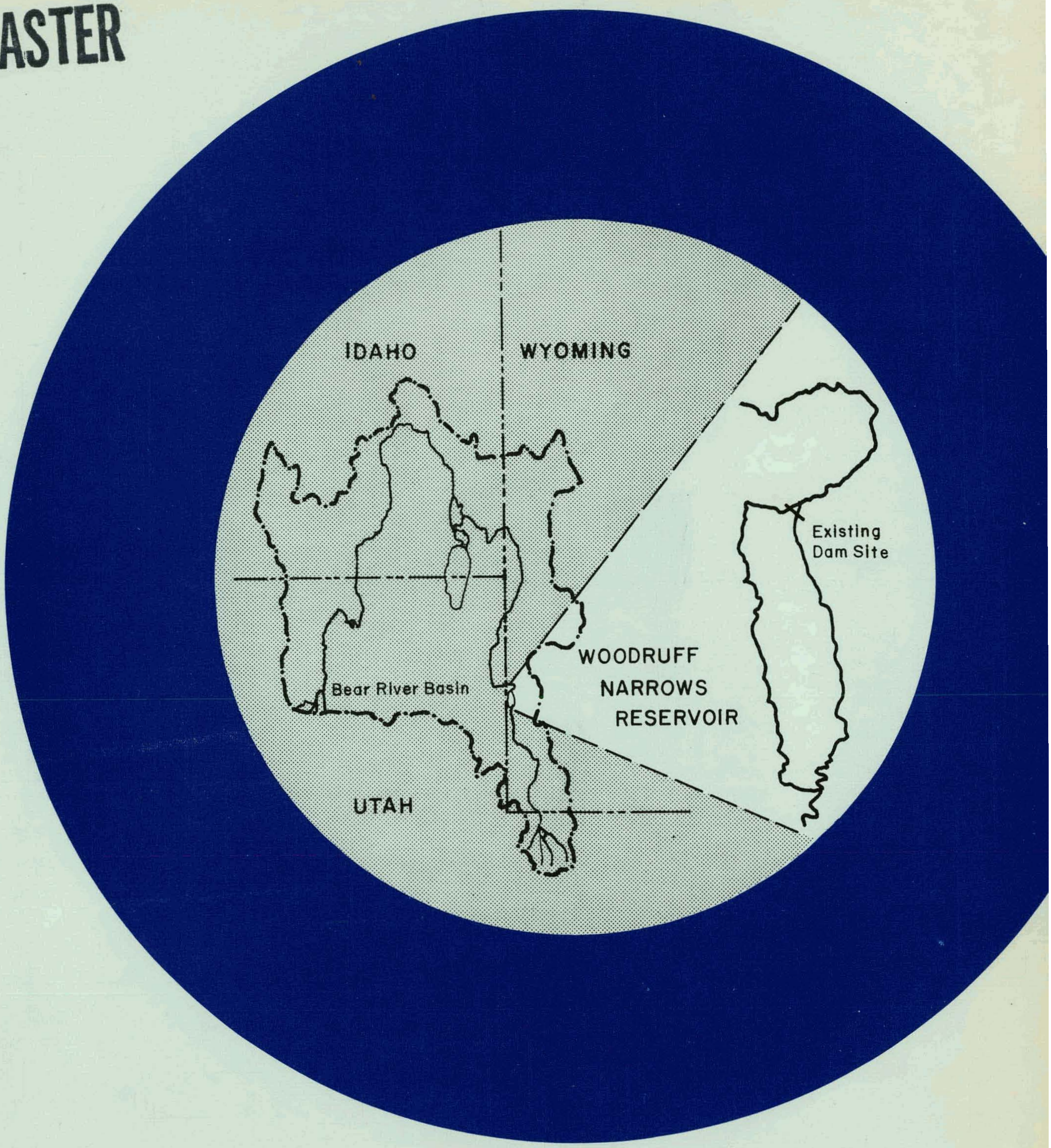

WOODRUFF NARROWS
Low Head Hydroelectric Power Plant Feasibility Determination

STATE OF UTAH - Division of Water Resources

International Engineering Company, Inc.

Utah Water Research Laboratory - Utah State University

March 1979

DISCLAIMER

WOODRUFF NARROWS

Low Head Hydroelectric Power Plant
Feasibility Determination

by

STATE OF UTAH - Division of Water Resources
International Engineering Company, Inc.
Utah Water Research Laboratory - Utah State University

Final Report to

United States Department of Energy
Idaho Operations Office

Under Cooperative Agreement
DE-FC07-78ID01767

Salt Lake City, Utah

March 1979

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ACKNOWLEDGMENTS

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CHAPTER 1

SUMMARY

1.1 INTRODUCTION

Woodruff Narrows Reservoir is owned by the State of Utah. The reservoir was built in 1961 as an irrigation reservoir and is located on the Bear River in Wyoming, near the Utah-Wyoming state line. The primary use of the reservoir is for irrigation of land in Rich County, Utah.

The reservoir outlet works and spillway are in need of repair. Plans have been made by the State of Utah to enlarge the reservoir from its present capacity of 28,000 acre-feet to 53,200 acre-feet when these repairs are made. The enlargement and repair project has been held up due to water right problems associated with the tri-state Bear River Compact. The purpose of this study is to determine if it is feasible to add hydropower facilities when the reservoir is repaired and enlarged. An alternative dam site a short distance downstream from the present dam (lower site) utilizing the same reservoir basin would yield a higher power head. Run-of-river hydropower alternatives were considered at both the present dam (upper site) and the lower site as well as peaking power production and pumped storage.

1.2 ENERGY POTENTIAL

The streamflow released from the reservoir during the fall and winter months of September through March generally ranges between 10 to 60 cfs. During this period, the reservoir level is generally low resulting in very little potential for power development. During the spring and summer months of April through August, the flow generally ranges between 300 and 1,000 cfs.

A computer simulation model based on mean monthly values, utilizing 26 years of recorded streamflow into the reservoir, was used to determine the mean annual energy potential for the following configurations: 1) present dam, 2) the proposed enlarged dam, 3) a new dam at the lower site with a maximum head of 65 feet, and 4) a new dam at the lower site which would store water to the same elevation as the proposed enlarged dam. Results of the simulation study show that the average annual energy potential of the above four configurations are respectively 3.4, 5.0, 7.1, and 8.3 gigawatt hours. The corresponding maximum power capacities are respectively 2.1, 3.0, 3.9, and 4.5 megawatts.

1.3 POWER MARKETING POTENITAL

A number of potential users in the area were contacted concerning the marketing of the potential energy that could be developed at the Woodruff Narrows site. The estimated current value of the energy that could be produced is approximately 30 mills per KWH. The power company in the area did not show much interest in purchasing the power but is willing to wheel the power at approximately 9 mills per KWH for a maximum plant capacity output of 3.0 megawatts based on a charge of $15 per KW-yr and an annual generation of 5 GWH. Therefore, the estimated net value of the energy produced at the Woodruff Narrows site is approximately 21 mills per KWH.

1.4 COST ESTIMATES AND ECONOMICS

The cost of repairing and enlarging the present dam is estimated to be $1.835 million. The cost of repairing the dam without the enlargement would be approximately $1.6 million. The irrigation benefits from agriculture from the reservoir enlargement are estimated to be $214,000 per year which when capitalized over a 50 year period at a discount rate of 4 7/8 percent would amount to $4.0 million. This is a benefit to cost ratio of 2.2 for repair and enlargement of the present reservoir. The discount rate of 4 7/8 percent is used by the Utah Division of Water Resources in economic analyses of projects built by the Utah Water Conservation and Development Fund. The agriculture interests would pay all of the costs of the reservoir enlargement and repairs.

The estimated cost of providing a power facility on the enlarged reservoir which would be capable of producing 5.0 GWH per year is $2.625 million. This cost estimate includes all the power features required for the project including a transmission line to the nearest area power company transmission lines. Annual operating costs are estimated at $40,000.

Amortizing the $2.625 million power facilities at an interest rate of 8 percent and including the $40,000 annual operating cost would result in an annual cost of $254,500. The cost of producing the 5.0 gigawatt hours of energy for this alternative is 51 mills per KWH which is more than double the current net market value of the energy.

Based on a discount rate of 4 7/8 percent used by the Utah Division of Water Resources for projects built by the Water Conservation and Development Fund the cost of producing power for this alternative would be 34 mills per KWH. This is more than 60 percent higher than the estimated net market value of the energy.

In order to produce energy at a cost of 21 mills per KWH with this alternative, an interest rate of less than 1 percent would have to be used for amortizing the capital cost of the power project. The other run-of-river alternatives are economically less favorable than the above alternative.

The cost of a reregulating reservoir at the lower site for allowing for peaking power production along with the additional cost of increased power plant capacity and increased wheeling charges makes power peaking an even less favorable alternative. A pumped storage alternative was also found to be uneconomical.

This study shows that hydroelectric power development at the Woodruff Narrows site is economically infeasible at the present time.

1.5 OTHER FINDINGS

Results of this study show that the addition of hydroelectric power development at the Woodruff Narrows site would have minimal social and environmental effects on the area. Power development would result in little or no changes in the present patterns of water and land use, income, population, and employment and would not result in any significant changes of the social structure or characteristics of the area. Power development would have negligible impact on the Bear River ecosystem over and above the existing structures and stream operations. The principal area of concern was the institutional problem associated with water rights. However, it now appears that this problem will be resolved. If the hydropower development were economically feasible, funding could probably be arranged by the State of Utah through the Utah Board of Water Resources from the Revolving Construction Fund and/or the Water Conservation and Development Fund.

CHAPTER 2

INTRODUCTION

2.1 PURPOSE AND AUTHORITY

The Utah Water and Power Board was created in 1947 and charged with the responsibility of preparing and implementing plans which would bring about the full development and utilization and promotion of the very vital, but limited, water resources of the State. The Board was charged with the review and coordination of federally funded water programs, and in addition was given a Revolving Construction Fund for the development of water on a small project basis.

In 1967, the Legislature changed the Board's name to the Board of Water Resources, retaining all of the assigned responsibilities, and named the Board's full-time staff the Division of Water Resources and placed it within a newly created Utah State Department of Natural Resources. Since then, as the need has grown and as the efficient use of water has become more critical, the legislatures have added new responsibilities. The latest was by the 1978 Legislature which created the "Water Conservation and Development Fund" at an initial funding of $25 million and charged the Board and Division to develop larger water storage projects, including the construction of hydroelectric generating plants. It is under this responsibility and authority that the Utah Division of Water Resources initiated this study to assess the feasibility of hydroelectric power development at the existing Woodruff Narrows Dam and Reservoir. The results of this study will also provide some insight for potential hydroelectric power development at other existing and planned dam sites in the State of Utah.

To assist in the feasibility study of hydroelectric power generation at the Woodruff Narrows site, the Utah Division of Water Resources, with the cooperation of International Engineering Company of San Francisco and Utah Water Research Laboratory at Utah State University, responded to a U.S. Department of Energy Program Research and Development Announcement number ET-78-D-07-1706 which resulted in Cooperative Agreement Number DE-FC07-78ID01767 Woodruff Narrows Power Plant. Under this agreement the feasibility study is being conducted with a cost-sharing of 66 percent by the U.S. Department of Energy and 34 percent by the State of Utah.

2.2 SCOPE OF STUDY

The Woodruff Narrows Dam is currently in need of repair. The repair work will be completed whether or not a power plant is installed at the site. Plans have been made to enlarge the reservoir when the repairs are made. The study included looking at various dam heights at the existing dam site (upper site) and various dam heights for a new dam a short distance downstream from the present dam (lower site) utilizing the same reservoir basin which would produce a higher head for hydroelectric power production. The lower site was also studied as a holding pond and regulating reservoir for pumped storage and peaking power considerations.

The various social, institutional, legal, environmental, economic, marketing, and engineering considerations were studied to assess whether or not hydroelectric development would be a viable project at the Woodruff Narrows Reservoir.

The Cooperative Agreement Number DE-FC07-78ID01767 requires that a final feasibility assessment report be written which includes, as a minimum, the following information:

1. Expected configuration and capacity of the hydropower facility.
2. Estimated performance characteristics of the hydroelectric power facility including the potential for peak power production and an estimate of average annual energy production.
3. Expected impact of the hydropower installation on other perceived water resource needs of the area and the current use of the reservoir.
4. Marketing potential of the power produced.
5. The necessary requirements of the Federal Energy Regulatory Commission, the U.S. Army Corps of Engineers, and other appropriate federal, state, regional, and local agencies.
6. Capital investment per installed kilowatt, total cost per KWH, and return on investment.
7. Anticipated annual operation and maintenance costs.
8. Anticipated project life.
9. An initial assessment of the environmental impact and socio-institutional factors.

10. An initial assessment of the safety hazard, if any, introduced by the addition or rehabilitation of a power plant and other hydropower appurtenances.

11. Appropriate analyses resulting in sound judgment as to the engineering acceptability of the proposed site for hydroelectric power development.

12. Investigation of the availability of a suitable turbine(s), generator(s), and accessories required for the proposed hydroelectric power development.

13. Development plan (schedule) for putting power on-line.

2.3 BASIC DATA AVAILABLE

2.3.1 TOPOGRAPHIC MAPS

The following topographic maps are available:

1. U.S. Geological Survey Quadrangle Maps in scale 1:24,000 (1"=2000′) and with 20 feet contour intervals.

2. Map of project area in scale 1"=400′ and 5 feet contour intervals.

3. Maps of Upper and Lower Sites in scale 1"=50′ and with 2 feet contour intervals.

2.3.2 GEOLOGIC DATA

The following geologic data are available:

1. Geologic maps of Upper Site in scale 1"=50′ and 2 feet contours, prepared by U.S. Bureau of Reclamation (USBR) in 1959.

2. Geologic map of Lower Site in scale 1"=50′ and 2 feet contours, prepared by State of Utah, Division of Water Resources in 1978.

3. Borelogs of four holes drilled at the Upper Site in 1958.

4. Borelogs of five holes drilled at the Lower Site in 1958.

5. Borelogs of two holes drilled in saddle about one mile west of Upper Site.

6. Report "Geologic Data on Lower Woodruff Narrows Dam," including data on construction material, by USBR in 1958.

7. Reconnaissance Geological Report on Lower Site, by USBR in 1959.

8. Reconnaissance Geological Report on the Upper Site, by USBR in 1959.

9. Review Report on Geology of Upper Site, prepared by State of Utah, Division of Water Resources, in 1978.

2.3.3 MISCELLANEOUS DATA

The following information is also available:

1. Set of 10 as-constructed drawings of the existing dam, prepared by Utah Water and Power Board in 1961.

2. Set of 17 drawings and preliminary specifications for enlargement and improvement of the existing dam, prepared by the Utah Division of Water Resources in 1978.

3. Reservoir area and volume curves for both the Upper and the Lower Sites.

4. Tailwater elevations at both Upper and Lower Sites.

5. Report by the Bureau of Mines on mineral deposits in the project area.

6. Various letters from turbine manufacturers, utilities, and FERC.

CHAPTER 3

BACKGROUND

3.1 GENERAL DESCRIPTION OF BEAR RIVER BASIN

3.1.1 GEOGRAPHIC SETTING

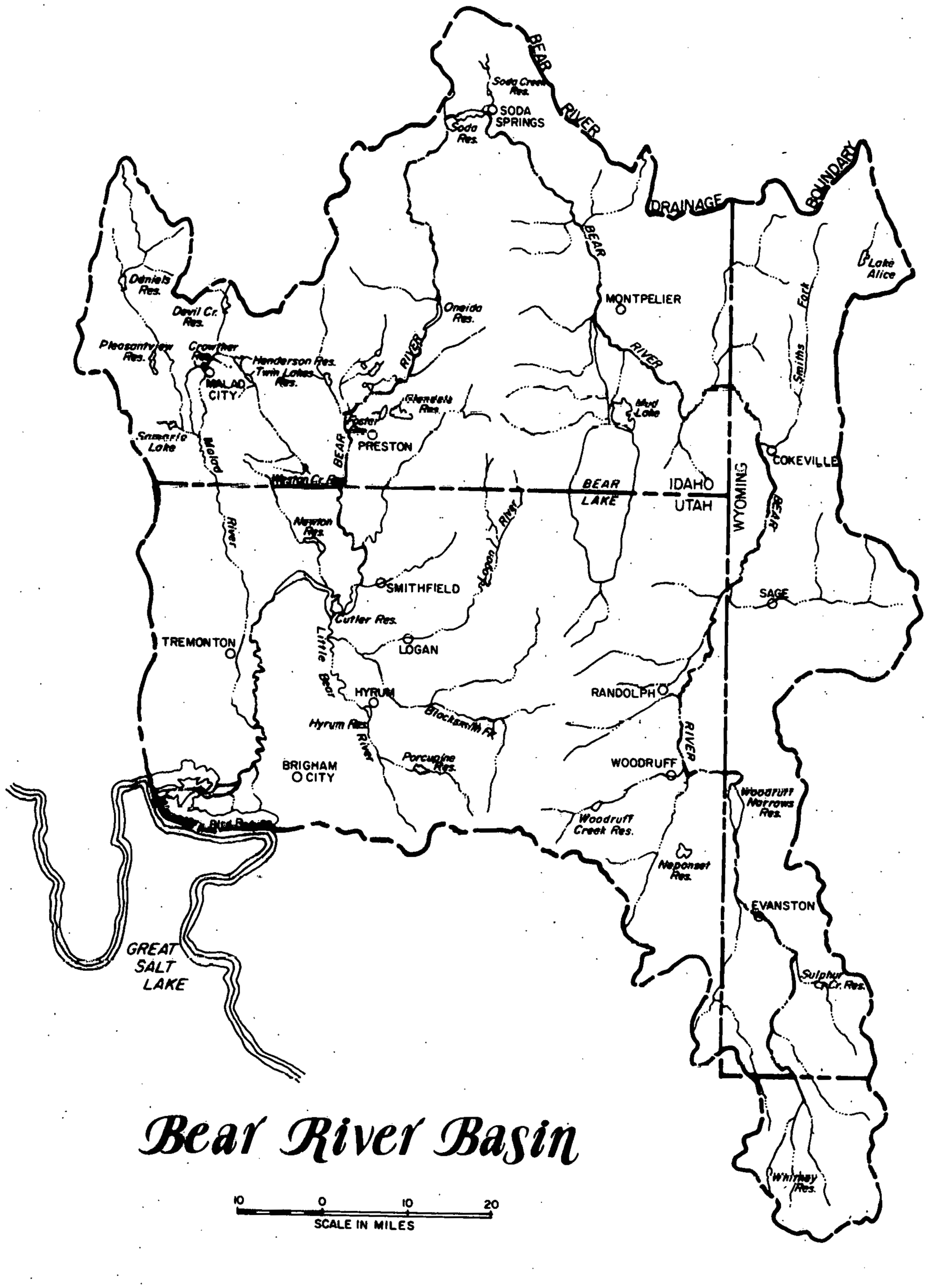
Bear River is the Western Hemisphere's largest stream that does not reach the ocean. The river rises in Utah but flows through parts of Wyoming and Idaho before returning to Utah to empty into Great Salt Lake as shown on Figure 3.1. In its circuitous course, the river flows about 500 miles, but the airline distance from its source to its mouth is only 90 miles. The Bear River Basin comprises 7,465 square miles of mountain and valley lands, including 2,695 in Idaho, 3,270 in Utah, and 1,500 in Wyoming.

For the first 20 miles of its course, the river flows down the north slopes of the Uinta Mountains in Utah. Then, at the Wyoming boundary, it enters the first of a series of five major valleys that extend along the remainder of its course. The valleys are separated by narrow canyons or gorges, some of which contain hydroelectric power developments.

The highest and longest valley in the Bear River Basin is the Upper Bear River Valley. It extends about 100 miles roughly along Wyoming's western boundary but includes a substantial area in Utah and a lesser area in Idaho. The valley is narrow with its bottom lands 5 miles or less in width. Communities in the valley include Evanston and Cokeville, Wyoming, and Randolph and Woodruff, Utah. The Woodruff Narrows project is located in this valley.

A few miles below its point of entry into Idaho, the Bear River flows westward into Bear Lake Valley, which is about 50 miles long and has a maximum width of 12 miles. Bear Lake, which is about 20 miles long and averages 7 miles in width, lies at the south end of the valley. Mud Lake, about 3 miles in diameter, is at the north end of Bear Lake. The river does not flow naturally into these lakes, but in 1902 connecting inlet and outlet canals were constructed north of the lake. In 1914, the Lifton Pumping Plant was constructed to pump from Bear Lake into the outlet canal. Bear and Mud Lakes, with a combined active storage capacity of 1,420,000 acre-feet, afford

Figure 3.1



Bear River Basin

virtually complete control of Bear River flows at that location. Valley bottom lands north of Bear Lake are generally irrigated by diversions from Bear River, while some of the arable bench lands on each side of the valley are irrigated from the many inflowing tributary streams. Among Idaho communities in Bear Lake Valley are Montpelier, Dingle, St. Charles, Fish Haven, Bloomington, Paris, Liberty, Bennington, and Georgetown. Utah communities include Pickleville, Garden City, and Laketown.

Leaving Bear Lake Valley at the north, the river flows through several miles of hilly and broken grazing lands and lava plains and thence through a deep, narrow channel cut through a lava sheet near Soda Springs, Idaho. In this channel are located the Soda Reservoir and hydroelectric power plant. Below the power plant, Bear River enters a broad agricultural area know as Gem Valley. Anciently, Bear River flowed northward through Gem Valley to the Snake River in the Columbia River Basin. A lava flow, however, turned the river south toward Great Salt Lake. The northern and central portions of Gem Valley consist of a plain formed by a lava flow and are occupied by large dry farms with some irrigation from Bear River and other inflowing streams. The southern part of Gem Valley, south of Grace, Idaho, and beyond the lava flow, is about 500 feet lower in elevation than the central portion. This lower portion is also known as Gentile Valley and the extreme southern portion as Mound Valley. The abrupt drop of Bear River into Gentile Valley is utilized for power generation at the Grace Power Plant. A further fall in the river immediately below the Grace Power Plant is utilized for power generation at the Cove Power Plant. Irrigation water sources in Gentile Valley are Bear River and tributary streams. Gem, Gentile, and Mound Valley communities include Grace, Thatcher, and Cleveland, Idaho.

At the south end of Mound Valley, the river enters the Oneida Narrows, a canyon about 11 miles in length. Here the existing Oneida Reservoir and Power Plant are located. Oneida Narrows is approximately the midpoint of the river in the sense that inflows above and below the narrows are nearly equal.

Below Oneida Narrows, the river enters Cache Valley, one of the more highly developed valleys in the Bear River Basin. Cache Valley is about 45 miles long and 10 miles wide. Among its principal communities are Preston, Dayton, and Franklin, Idaho, and Lewiston, Richmond, Smithfield, Logan, Providence, Hyrum, Paradise, and Wellsville, Utah. The river enters Cache

Valley from the northeast, meanders sluggishly southward down the valley, and exits westward through a 2-mile-long gorge into Lower Bear River Valley, which is a part of Great Salt Lake Valley. Several Bear River tributaries enter Cache Valley from the east and lesser streams from the west. Water of these streams is used for irrigation, particularly on the higher lands near the base of the mountains. In the gorge through which Bear River leaves Cache Valley are located the Cutler Dam and Power Plant, the lowest hydroelectric development on the river.

Below Cutler Dam, the Bear River continues southwest through Lower Bear River Valley to the Bear River Bay of Great Salt Lake. The Bear River Migratory Bird Refuge is located at the river terminus. Utah communities in Lower Bear River Valley include Garland, Tremonton, Bear River City, and Corinne. The Malad River, flowing southward, enters Bear River about 10 miles north of Bear River Bay. The Malad River Valley extends northward 50 miles from Lower Bear River Valley. Its principal communities are Malad, Samaria, and St. John, Idaho, and Portage and Plymouth, Utah.

Valley elevations range from 4,200 feet at Bear River Bay to 6,700 feet near Evanston, Wyoming, in the Upper Bear River Valley.

The climate of the Bear River Basin is of typical mountain continental character, with the usual wide range in temperature between summer and winter, and between day and night. The high mountain valleys experience long and rigorous winters and short, cool summers. The lower valleys are more moderate with less variance between the maximum and minimum temperatures. Precipitation is heaviest in the mountainous sections, with much of it occurring during the winter months in the form of snow. Precipitation during the May through September growing season is only about one-third of the annual amount. The precipitation ranges from 10 inches in the valley areas to over 40 inches in the high mountain areas. The average frost-free season varies from about 45 days in some high mountain valleys to more than 150 days in the Great Salt Lake Valley.

3.1.2 WATER RESOURCES

Streamflow records on the Bear River are numerous and of relatively long duration, some extending back to 1889. There are over 60 river gaging stations on the Bear River and its tributaries. Most of these stations are operated by or in cooperation with the United States Geological Survey. The streamflow data are published in the Water-Supply Papers of the Great Basin.

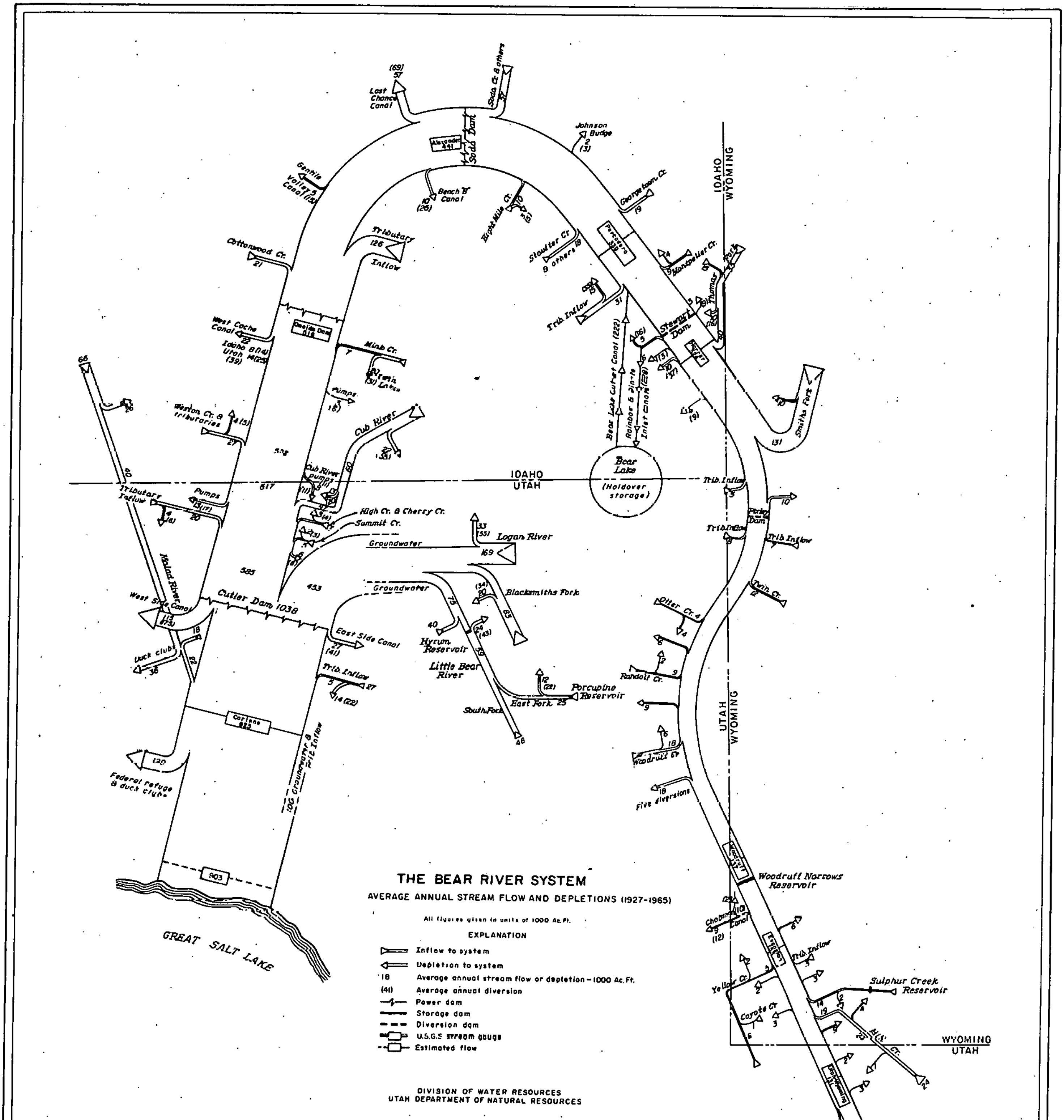
The flow chart of the entire Bear River system is shown on Figure 3.2 which indicates the over-all contributions and depletions to the system. This flow chart is based on historical streamflow records for the 1927-1965 period. The chart indicates that an average of 900,000 acre-feet of water per year from the Bear River Basin flowed into Great Salt Lake during the period of record. At the Woodruff Narrows site, the flow chart indicates a mean annual streamflow of 137,000 acre-feet for the 1927-1965 period.

The entire flow from the Upper Bear River is diverted into Bear Lake at Stewart Dam through the Rainbow Inlet Canal. Utah Power and Light Company controls the inflow and outflow of Bear Lake to meet power demands and satisfy contractual agreements with downstream water users for irrigated agriculture. The active storage capacity of Bear Lake is 1,420,000 acre-feet contained in the top 21 feet of the 200 foot deep lake.

In addition to Bear Lake, there are four small mainstem reservoirs on the river used by Utah Power and Light Company as forebays to supply hydroelectric power plants. The Soda, Grace, Oneida, and Cutler Reservoirs have a combined active storage of 37,200 acre-feet. The only other mainstem reservoir on Bear River is Woodruff Narrows Dam located in the Upper Bear River with a 26,500 acre-foot active storage capacity. There are 23 small reservoirs on the tributaries to the Bear River which have capacities of more than 1,000 acre-feet. The combined active storage capacity of these 23 reservoirs is 116,700 acre-feet. The Bear River Basin has a combined active storage capacity of 1.6 million acre-feet.

Essentially all of the flow of the Bear River is used for hydroelectric power generation and operations of the National Bear River Migratory Bird Refuge. The five hydroelectric power plants owned and operated by Utah Power and Light Company on the Bear River system have a total generating capacity of 125.5 MW. The plants and generating capacity are as follows: Soda - 14 MW, Grace - 44 MW, Cove - 7.5 MW, Oneida - 30 MW, and Cutler - 30 MW. Much of the water reaching the Great Salt Lake has been used for other purposes as well. Approximately one-half million acres of farm land are irrigated in the basin. Municipal and industrial withdrawals for a population of 100,000 (1970 census) are also made in the basin.

Figure 3.2



Bear River Flow Chart

3.2 EXISTING WOODRUFF NARROWS PROJECT

3.2.1 LOCATION

Woodruff Narrows Dam and Reservoir is located approximately 7 miles southeast of Woodruff, Utah, on the main stem of the Bear River in Townships 17N and 18N, R120W 6th Principal Meridian, Uintah County, Wyoming. A location map of the reservoir is shown on Figure 3.3 and on Exhibit 1.

3.2.2 PRESENT CONDITION OF EXISTING FACILITIES

Woodruff Narrows Dam is a homogeneous compacted earthfill dam. The dam is 58 feet in height above the stream bed. The hydraulic head from the spillway crest to normal tailwater level is 32 feet. The dam has a crest length of 600 feet and a crest width of 20 feet with a front side slope of 2-1/2:1 and backside slope of 2:1. The dam embankment is in good condition. Exhibits 2, 3, and 4 show the plan, profile, and spillway of the existing dam. The spillway was constructed by excavating through a rock abutment. The spillway was lined only at the upper end near the overflow crest. The unlined portion of the spillway has had some erosion from use over the years. The spillway is in fair condition, but will need to be lined or replaced sometime in the future, possibly in the next 5 to 10 years.

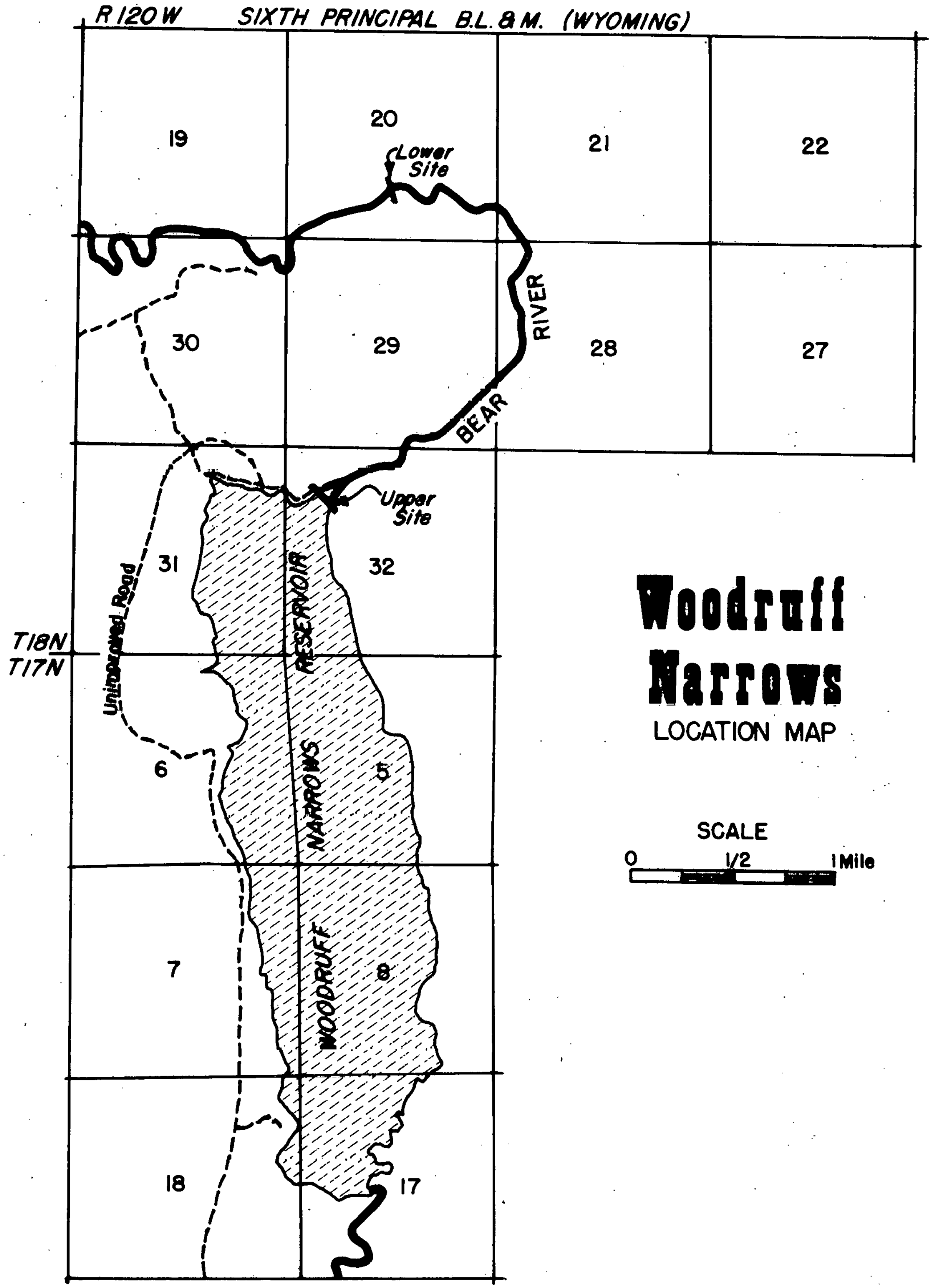
The outlet works consists of an intake structure and two rectangular reinforced concrete conduits. The intake structure was repaired in November 1977, which included replacing the existing trash racks and providing additional air vents to the intake gates from the gate house at the top of the dam. This was done to alleviate a cavitation problem under the intake gate thimble.

The outlet conduits are showing some signs of deterioration and will need to be repaired or replaced in the future. Bids were asked for on repair of the outlet conduits in October 1977. All bids were rejected, because they were considerably higher than the engineering cost estimate. It was decided to replace or repair the outlet conduits, and build a new concrete lined spillway as part of a reservoir enlargement project.

3.2.3 AGE, HISTORY, OWNERSHIP, AND PRESENT USE

The Woodruff Narrows Dam was constructed in 1961 by the Utah Board of Water Resources to provide supplemental irrigation water for approximately 36,000 acres of land of which 83 percent is in Utah and 17 percent in Wyoming.

Figure 3.3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SIXTH PRINCIPAL B.L. & M. (WYOMING)
19
20
21
22
Lower Site
30
29
28
27
RIVER
BEAR
31
32
Upper Site
T18N
T17N
Unimproved Road
RESERVOIR
NARROWS
WOODRUFF
6
5
7
8
18
17
Woodruff Narrows
LOCATION MAP
SCALE
0
1/2
1 Mile

The Utah Board of Water Resources has title to the dam and real property by Warranty Deed and title to the water storage rights in the reservoir and title to the irrigation distribution systems below the reservoir. A small portion of the reservoir is located on Bureau of Land Management land. The Utah Board of Water Resources has a right-of-way granted for that portion of the reservoir.

The reservoir has a total storage capacity of 28,000 acre-feet as shown in the following table.

	Compact Allocation	Holdover Stage	Total
Irrigation			
Utah	15,240	3,560	18,800
Wyoming	3,000	700	3,700
Subtotals	18,240	4,260	22,500
Fish Conservation			4,000
Inactive			1,500
Total			28,000

The Division of Water Resources has designed an enlargement of the present dam and reservoir to increase the storage capacity from 28,000 acre-feet to 53,200 acre-feet. Application has been made to the Wyoming State Engineer for a construction permit to enlarge the reservoir. Acquisition of reservoir right-of-way for the proposed enlargement is approximately 90 percent completed. The additional storage would store more spring runoff and release it during July and August for irrigation.

3.3 FUTURE BEAR RIVER DEVELOPMENT

3.3.1 AVAILABILITY OF WATER

In spite of the fact that approximately 900,000 acre-feet of water reaches the Great Salt Lake each year, most opportunities for further water use will depend upon adjustments in some present uses. Unless the hydroelectric power use, particularly, is subordinated to some extent to other uses, opportunities to develop the water supply further to meet present shortages and supply future demands are largely limited to such possibilities as exist below Cutler Reservoir. If it is assumed that in the future hydroelectric power uses will be subordinate to other uses to the extent required to permit development, the average quantity of available water that could be developed in various reaches of the Bear River area: 50,000 to 100,000 acre-feet at or above Bear Lake depending upon the operation of Bear Lake, 200,000 acre-feet from Bear Lake to Oneida Narrows, and 300,000 acre-feet from Oneida Narrows to Cutler Dam. This amounts to 550,000 to 600,000 acre-feet of additional water which could be developed in the entire basin. The availability of this water for future development will depend to a great extent on the states of Idaho, Utah, and Wyoming ratifying the Amended Bear River Compact and on negotiations with Utah Power and Light Company.

3.3.2 WOODRUFF NARROWS ENLARGEMENT

Plans have been completed by the Division of Water Resources for enlarging the Woodruff Narrows Reservoir from its present capacity of 28,000 acre-feet to 53,200 acre-feet. The 25,000 acre-feet of new storage will be used for supplemental irrigation of land in the Woodruff-Randolph area in Utah and the Cokeville area in Wyoming. Construction of this project is scheduled to begin in 1979 if water rights problems associated with the Bear River Compact can be resolved among the states of Idaho, Utah, and Wyoming.

3.3.3 OTHER POTENTIAL PROJECTS

The Oneida Narrows Project on the Bear River in Idaho could develop 200,000 acre-feet of water for use in both Utah and Idaho. Also, development of 25,000 acre-feet on the Cub River in Idaho could be used by both Utah and Idaho. These two projects have been studied in detail by the U.S. Bureau of Reclamation.

The U.S. Bureau of Reclamation has studied water development alternatives on the Blacksmith Fork River in southern Cache County. More recently, the Utah Division of Water Resources has studied several alternatives for water development on both the Blacksmith Fork and the Little Bear Rivers in southern Cache County. Construction of the South Cache projects could develop up to 50,000 acre-feet of water for irrigation of dryland areas on the benches and provide needed water for municipal needs by the rapidly growing population in Cache County.

Studies have been made by the U.S. Bureau of Reclamation and the Utah Division of Water Resources on possible development of Bear River water on the main stem near Honeyville and off-stream storage on the Malad River. The Honeyville project would develop 120,000 acre-feet of water for use by the Bear River Migratory Bird Refuge and irrigation of additional lands in eastern Box Elder County. Off-stream storage sites on the Malad River vary from 10,000 acre-feet to 450,000 acre-feet. Water developed from the off-stream sites would be for the same uses as the Honeyville project.

A potential reservoir site in the Upper Bear River above Evanston on Yellow Creek near the Bear River - Weber River drainage divide could store one-half million acre-feet of water for drought emergencies. Water to fill this potential reservoir would be diverted from the Bear River during excessively wet years. Evaporation losses at the high elevation reservoir would be minimal. Water could be released down the Bear River or the Weber River, or even the Jordan River by exchange with Weber River water via the Weber-Provo Canal. A number of reservoir sites above Evanston have been studied for potential development of water for uses in Wyoming.

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CHAPTER 4

BASIC ALTERNATIVES

4.1 GENERAL

Based on a review of all data available and on the present plans for improvement of the existing dam, the following basic alternatives for development of the hydroelectric potential at Woodruff Narrows were selected for detailed study and evaluation of economic feasibility:

Existing Dam (Baseline Condition) - Repair and renovation of existing dam as shown in Exhibits 2, 3, and 4 with and without addition of run-of-river power installation.

Alt. 1. Upper Site - Raised Dam - Run-of-river power installation at the existing dam at the upper site, as shown in Exhibits 5, 6, and 10, raised to provide a reservoir with normal maximum water surface at elevation 6,452.5.

Alt. 2. Lower Site - Low Dam* - Run-of-river power installation at a new dam at the lower site, as shown in Exhibits 7, 9, and 10, constructed to provide a reservoir with normal maximum water surface at elevation 6,442.5.

Alt. 3. Lower Site - High Dam* - Run-of-river power installation at a new dam at the lower site, as shown in Exhibits 8, 9, and 10, constructed to provide a reservoir with normal maximum water surface at elevation 6,452.5.

The possibilities of providing additional capacity for peaking or pumped storage and pipeline developments will be discussed separately following the presentation of the run-of-river alternatives. Power development at the existing dam without any raising of reservoir elevation, also will be discussed.

The reservoir area and volume curves and tailwater rating curves for the upper and lower sites are shown on Exhibits 5 and 7 respectively. The following table shows pertinent data for the basic alternatives selected for study and the corresponding data for the existing dam.

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*The terms "low dam" and "high dam" have been used herein for identification purposes only. The actual difference is height between the two dams is only 10 feet.

	Upper Site		Lower Site	
	Existing	Alt. 1	Alt. 2	Alt. 3
Normal Max. Res. Elev.	6,439.4	6,452.5	6,442.5	6,452.5
Reservoir Volume (acre-feet)	28,000	53,200	52,000	76,900
Normal Min. Res. Elev.	6,418.0	6,425.0	6,417.0	6,422.5
Ave. T.W. Elevation (ft)	6,403.4	6,403.4	6,376.0	7,376.0
Max. Gross Head (ft)	36.0	49.1	66.5	76.5
Min. Gross Head (ft)	14.6	22.6	41.0	46.5

The maximum normal reservoir elevation for an enlarged project at the upper site has been selected by the Utah Division of Water Resources to provide about 25,200 acre-feet of additional storage primarily for irrigation. Since definite plans already have been made for implementation, this enlargement was selected as one of the basic alternatives to be studied. Alternative 2 was selected to provide a direct comparison with alternative 1. Alternative 3 was included to investigate a maximum project at Woodruff Narrows.

The minimum reservoir elevations were selected on the basis of judgment with a view to optimizing power benefits and providing as much active storage as possible for irrigation and other purposes.

4.2 WATER AVAILABILITY

The historical discharges of the Bear River at Woodruff Narrows and the operation of the existing reservoir are discussed in Chapters 3 and 5. In general, the inflows into the reservoir during the winter months are stored for subsequent release during the period April through August. In some wet years release and/or spilling have taken place also in March and September. The average annual inflow into the reservoir since 1942 is about 156,900 acre-feet, equivalent to an average discharge of about 215 cfs.

It is assumed for the purposes of this study that the present mode of operation will continue also in the future, and that most of the water available will be released during the summer months. In general, the provision of power at the dam will not change this mode of operation. Thus, energy will be produced only about 4 to 6 months of the year depending on the runoff during the preceding winter.

The historical releases from the existing reservoir do not provide a good basis for determining the most economical mode of operation under future conditions. The reason for this is that the existing outlet gates are operated manually at periodic intervals only. As a result, more water than actually needed is often released. Much better control can be obtained if the water is passed through the hydraulic turbines of a power plant. Such controlled discharges for the purposes of irrigation is estimated to range from a low of about 300 cfs to a high of about 800 cfs. Most of the time the discharges are maintained at about 600 cfs when releases are made for irrigation.

4.3 RAISED DAM AT UPPER SITE

4.3.1 GENERAL

The present plans for raising the existing dam to provide more storage for irrigation are discussed in Chapters 3 and 5. It is proposed that the work be done in conjunction with necessary modifications and repairs of the existing spillway and outlet works. The cost of raising the dam would be paid for entirely by the irrigation benefits, as discussed elsewhere in the report. From the viewpoint of power developments, raising the dam is definitely advantageous since it would increase the output by about 30 percent with a relatively small increase in cost.

A description of the dam, spillway, and outlet works is presented in Chapter 3. The following description is limited to the power facilities only. The general layout of the raised dam and associated power facilities is shown in plan and sections on Exhibits 5 and 6.

4.3.2 POWERHOUSE LOCATION

A location of the powerhouse in the lower part of the existing spillway channel was selected from a careful review of possible alternatives. This location would result in minimum excavation and least interference with other construction. An alternative based on utilization of the existing irrigation outlet also for power was considered, but was rejected for the following reasons:

1. Velocities would be relatively high in the pipes to be installed in the existing conduits, up to 20 feet per second. This would result in high losses and much reduced output, especially significant at low reservoir elevations.

2. The transition from two elliptical pipes to one circular pipe leading to the turbine would be an additional and expensive item.

3. A separate bypass would be required to release water for irrigation when the power plant would be out of operation.

The selected powerhouse location in the existing spillway channel would be subject to the risk of rock falls from the steep slope on the left abutment. Therefore, careful clearing and removal of all loose rock must precede construction in that area. However, the overall safety of the dam would not be affected by the construction of the power facilities.

4.3.3 TURBINE SELECTION

Standardized generating units are now being produced by an American turbine manufacturer for heads up to 50 feet and for capacities up to 5,000 KW. These units, known under the designation "tube turbines," are available as pre-designed, packaged units which include the necessary control equipment. This type was selected for the upper site power plant on the basis of cost, availability, simple installation, and easy maintenance. The most economical and suitable size was determined to be a 2,000 mm* unit; it would perform well under all normal operating conditions. Curves showing maximum discharge and output against net head are presented in Figure 4.1. The turbine discharge capacity ranges from about 600 cfs at low reservoir elevation to about 875 cfs at maximum reservoir elevation. The corresponding generator output ranges from about 1,000 KW to about 3,000 KW. Average output is estimated to be about 2,400 KW.

4.3.4 ARRANGEMENT OF POWER FEATURES

The power features at the proposed raised dam at the upper site would consist of an intake, a penstock, a powerhouse, a tube turbine as discussed above, accessory electrical equipment, miscellaneous mechanical equipment, an access road, substation equipment and a transmission line.

The intake would be a concrete structure located approximately where the upstream slope of the embankment would intersect the approach channel to the existing spillway. The intake would be located at sufficient depth to permit operation with the reservoir at the minimum elevation of 6,425.0. The intake would be provided with trashracks and with provisions for stoplog closure.

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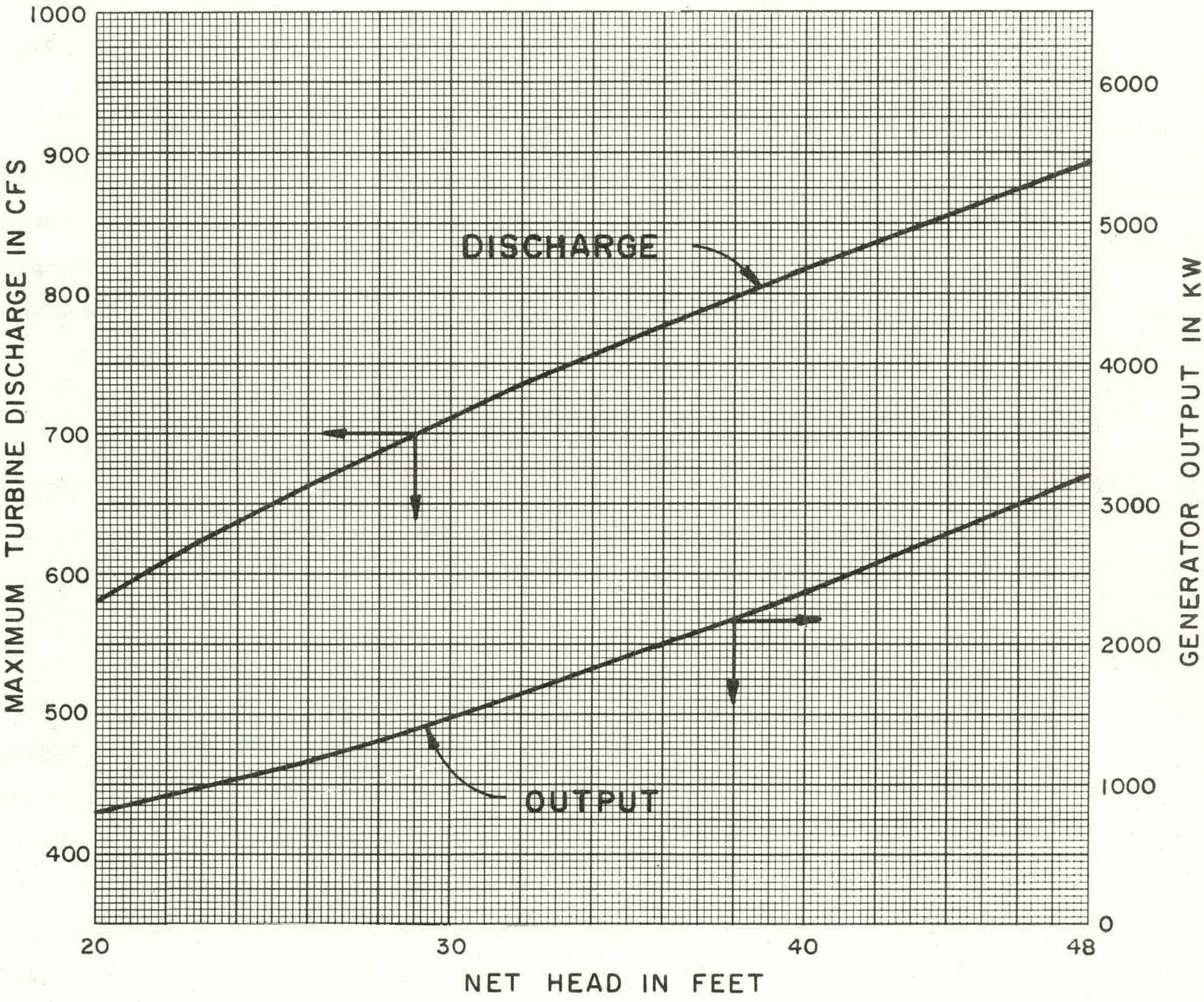
*Runner diameter in millimeters.

Figure 4.1

WOODRUFF NARROWS

TURBINE PERFORMANCE - 2000 MM TUBE TURBINE

(UPPER SITE - RAISED DAM)



MINIMUM DISCHARGE: 40% OF MAXIMUM

MINIMUM OUTPUT: 30% OF MAXIMUM

The penstock would consist of a 9′ x 9′ reinforced concrete conduit from the intake to a point directly below the crest where it would connect with a 9′-diameter steel pipe which would extend to the powerhouse. The pipe would be embedded in concrete and the entire penstock would be covered by embankment fill.

The powerhouse would be a concrete structure of the semi-outdoor type as shown on Exhibit 10. It is assumed that the installation of equipment would be done by the use of a mobil crane through openings provided in the main deck. Following installation the openings would be covered by weatherproof hatches. The tube turbines would be of the propeller type with adjustable blades and horizontal shaft. A butterfly valve in front of the turbine and the hydraulic control equipment is included in the packaged unit.

The accessory electrical equipment required for the operation of the plant would include station service equipment, grounding system, lighting system, power and control cables, battery system, control switchboard and supervisory control equipment. It is assumed that the plant would be operated by remote control except for starting up of the unit which would be done manually.

Accessory mechanical equipment would include heating and ventilation systems, water supply and drainage systems and draft tube gates and hoists.

The principal substation equipment would be a 4.16/46 KV step-up transformer and a 46 KV circuit breaker. Power from the plant would be transmitted to an existing 46 KV transmission line located about 5 miles west of Woodruff Narrows.

Access to the existing dam is by a road which terminates at the crest of the embankment on the left (west) side. This road follows the reservoir for a distance of about 3,000 feet and must be relocated to a higher elevation when the dam is raised. However, the terrain immediately upstream of the dam is very steep so that this relocation would be relatively expensive. Therefore, and to provide more convenient access to the powerhouse, an alternative route is suggested. It would follow an existing jeep trail which crosses the hills northwest of the site as shown on Exhibit 1. The trail would require minor improvement only to serve as an access road. A short spur would be extended up the left bank of the Bear River to the powerhouse. If necessary, access to the right bank could be provided by a small bridge near the existing gaging station. The total length of improved and new road would be about 1 mile.

4.3.5 CONSTRUCTION ASPECTS

The plan for improvement of the existing dam includes the following major work:

1. Removing the spillway from the present location near the left bank and constructing a new spillway at a slightly higher elevation on the right embankment.

2. Installing steel pipes in the existing outlet conduit and improving the existing outlet structure.

3. Raising the existing embankment 7 feet. Embankment would be made wider by adding fill to the downstream side.

This work and the construction of the power facilities could be accomplished in less than one year. Work would start in the spring on the access road and the new spillway. At the end of the irrigation season in August the new spillway would be completed. The reservoir would be at low level, and the work on the outlet and on the power facilities would start. Work on the embankment would proceed upon completion of the work on the intake and the penstock. By the end of the year all work except installation of some of the powerhouse equipment would be completed. The power plant could be ready for operation early next spring.

4.4 LOWER SITE ALTERNATIVES

4.4.1 SITE DESCRIPTION

Downstream from the Upper Narrows the Bear River changes direction gradually from northeast to southwest as it completes a half circle around Hanks Hill over a reach of about 3 miles. The Lower Narrows occupies the last mile of this reach. The valley side slopes are relatively steep except in a half-mile section between the two narrows where the country opens up in a northwesterly direction into the Salt Creek Valley.

The Lower Woodruff Narrows dam site is located about 2 miles downstream from the upper site as shown on Exhibit 1. The site was investigated by the Bureau of Reclamation in the late 1950s. The present study is based on basic data obtained at that time, including a map in scale 1" = 50′ with 2 foot contours and the geological logs from five drill holes.

The general topography of the site is shown in Exhibit 7. The river is normally confined to a 50-foot wide channel which at this point occupies a position on the right side of the 300-foot wide flood plain. The right abutment rises steeply more than 200 feet from the bank of the river. The left abutment is formed by the more gentle slopes of Hanks Hill.

The entire right abutment is exposed from the bank of the river at elevation 6,375 to above elevation 6,500. Therefore, no holes were drilled in this abutment. Two holes were drilled in the flood plain, one on each side of the river channel. Two holes were drilled in the left abutment since most of it is covered by slopework and residual gravels. One hole was drilled at a proposed location for a spillway stilling basin on the left bank downstream of the dam axis.

Based on information obtained from the above drill holes and from geological reconnaissance the site geology can be summarized to be as follows: The rock at the site consists of beds of shale and sandstone dipping about 12° east and striking N 5° W. The dip is upstream which is favorable for preventing seepage around the abutments. The shale decomposes to clay when exposed to alternate wetting and drying but will provide adequate foundation for structures in new excavations. The sandstone beds are resistant to erosion and will provide good foundation for structures. Four of these sandstone beds are exposed on the right abutment. On the left abutment rock is exposed at scattered points. The overburden probably reaches a depth of up to 15 feet in some areas. In the flood plain the rock is overlain by silt, sand, gravel and boulders to a maximum thickness of 25 feet.

Construction materials of all types are available in sufficient volume within reasonable haul distance from the site.

4.4.2 LOW DAM ALTERNATIVE

This alternative (Alt. 2) was selected for comparison with the raised dam alternative (Alt. 1) at the upper site. It would provide approximately the same amount of storage and would eliminate the need for any modifications and repairs of the existing dam. The alternative would provide about 50 percent more head than alternative 1, which would result in a similar increase in power benefits. A rating curve, showing the relationship between river elevations and discharge at this site is shown on Exhibit 7.

The maximum and minimum reservoir elevations were selected to be 6,442.5 and 6,417.0 based on the reservoir volume curves shown on Exhibit 7. Assuming a similar spillway arrangement and freeboard as for the raised dam at the upper site, the crest of the dam was selected to be at elevation 6,452.5, which would require an embankment of about 80 feet maximum height from the riverbed.

The general layout of this alternative is shown in plan on Exhibit 7 and in sections on Exhibit 9. The main dam would be an earthfill embankment across the valley. A side channel type spillway would be located in the left abutment. The power facilities also would be located on the left side of the valley with the penstock in a trench underneath the embankment.

The earthfill dam would consist of a central core of impervious material, supported by random fill on both sides. The core would be extended to bedrock across the entire valley by excavating and backfilling a cut-off trench. Rip-rap would be placed on the upstream side of the dam for protection against ice and wave action. Zones of transition and draining materials would be provided as appropriate. Grouting of the rock underlying the cut-off would be done as necessary to prevent seepage and to ensure the safety of the dam.

The spillway would consist of a free overflow concrete weir, a concrete lined side channel and chute with a concrete stilling basin at the downstream end. It is designed to pass a discharge of 6,000 cfs with a surcharge of 5 feet above the crest of the weir at elevation 6,442.5. This would leave 5 feet of freeboard to the top of the dam which is considered to be adequate in view of the short fetch of the reservoir upstream of the dam.

The power facilities would be similar to the facilities selected for alternative 1. They would include an intake structure, a penstock, a powerhouse, a turbine-generator unit, accessory electrical equipment, miscellaneous mechanical equipment, substation equipment, a transmission line and an access road. However, there would be some differences in the design and type of equipment:

a) The intake would be provided with a closure gate which would be operated from a hoist on the crest of the dam. This gate would be required because a separate low level outlet is not included in this plan for the lower site.

b) The cross-sectional area of the penstock would be slightly reduced. (More economical because of higher head.)

c) The turbine would be of the horizontal bulb type because the operating head of more than 60 feet is beyond the range of a standard tube turbine and because a vertical Kaplan type turbine would be more costly.

d) A separate outlet would be provided by branching off from the penstock near the powerhouse. This outlet would permit releases for irrigation if the bulb turbine unit is out of operation. The discharge would be controlled by a manually operated enclosed slide gate. Discharge capacity with the reservoir at minimum level would be about 700 cfs. A bypass pipe, which would permit small discharges of up to 20 cfs would be provided at the slide gate (See Exhibit 10).

The selected turbine would have a runner diameter of 1,800 mm and would perform approximately as shown on Figure 4.2. The discharge capacity would range from about 600 cfs at minimum reservoir elevation to about 880 cfs at maximum elevation. The maximum output would range from 1,750 KW to about 4,000 KW. The long term average output is estimated to be about 3,500 KW.

Access to the dam and powerhouse would be provided by an extension of a road which now terminates near a gaging station on the left bank of the river about 1 mile downstream from the site. This road extension would cross to the right bank of the river on a bridge about 1,000 feet downstream from the site.

The power produced by the plant would be transmitted to an existing 46 KV line about 5 miles west of the site.

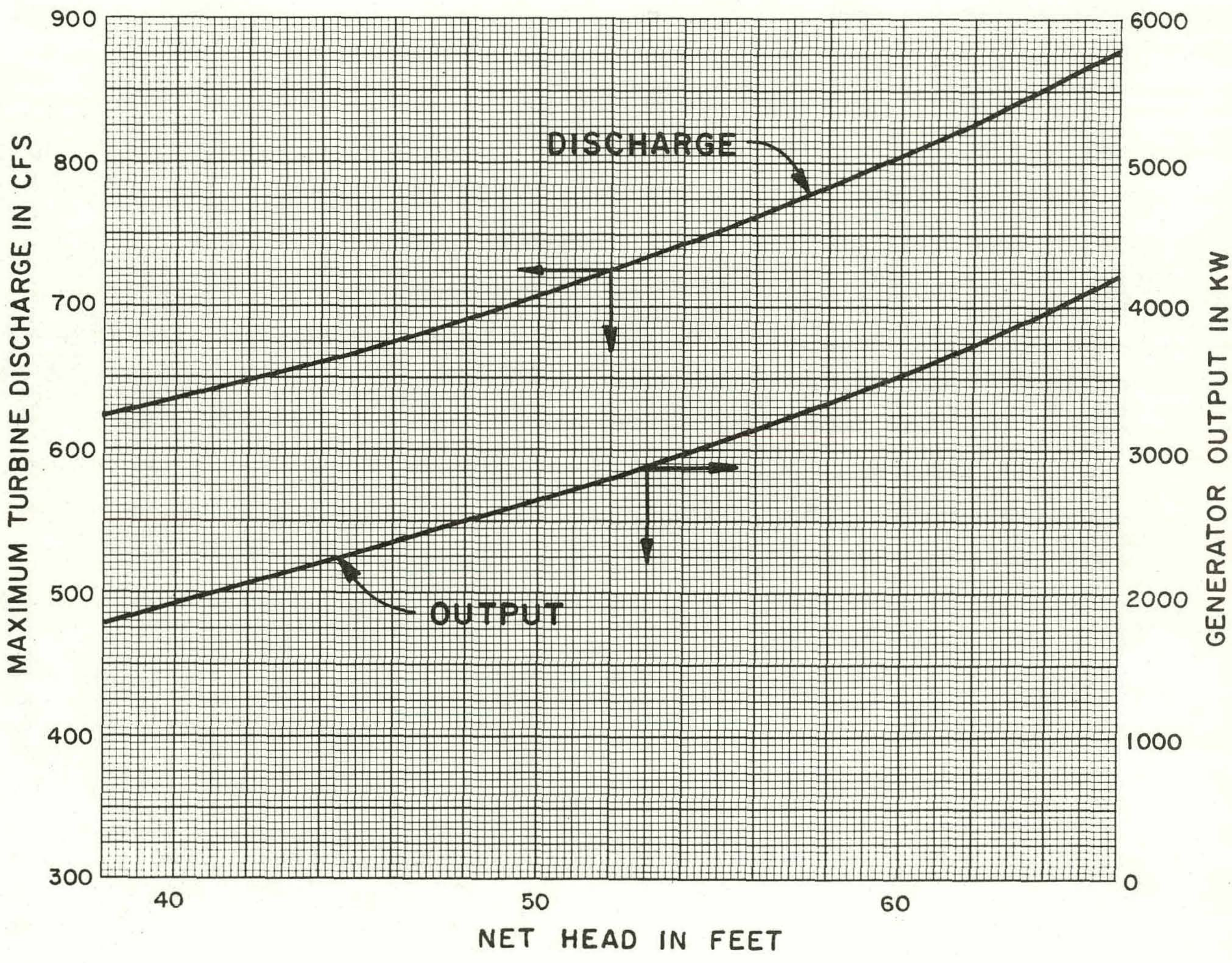
Construction of the project is estimated to require about 1 year. Most of the spillway, the intake and the penstock would be completed during the spring and the summer and would be carried out in the dry. Work in the riverbed would start in August, at the end of the irrigation season. During the next 4 to 5 months, releases from the existing reservoir would be held to the minimum required, about 10 cfs to facilitate the diversion past the work area in the riverbed. All work, including breaching and some leveling of the upstream dam, would be completed by April in the following year.

Figure 4.2

WOODRUFF NARROWS

TURBINE PERFORMANCE - 1800 MM BULB TURBINE

(LOWER SITE - "LOW" DAM)



MINIMUM DISCHARGE AND OUTPUT: 30% OF MAXIMUM

4.4.3 HIGH DAM ALTERNATIVE

This alternative (Alt. 3) was included to determine if a higher dam and a larger reservoir would result in a more economical development than the Low Dam Alternative (Alt. 2) discussed above. From a technical viewpoint, a dam of up to 100 feet in height could be constructed quite safely at this site. However, from a practical viewpoint, the highest dam that could be considered would be one which would provide for a reservoir to the same elevation as proposed for the raised dam at the upper site, elevation 6,452.5. The corresponding minimum reservoir elevation would be 6,422.5 (See the reservoir-volume curve on Exhibit 7).

The layout and design of this alternative would be similar to the layout and design for alternative 2, except as follows:

a) The dam would be 10 feet higher.

b) The spillway and the intake would be located at slightly higher elevations.

c) The turbine and the powerhouse would be of a different design.

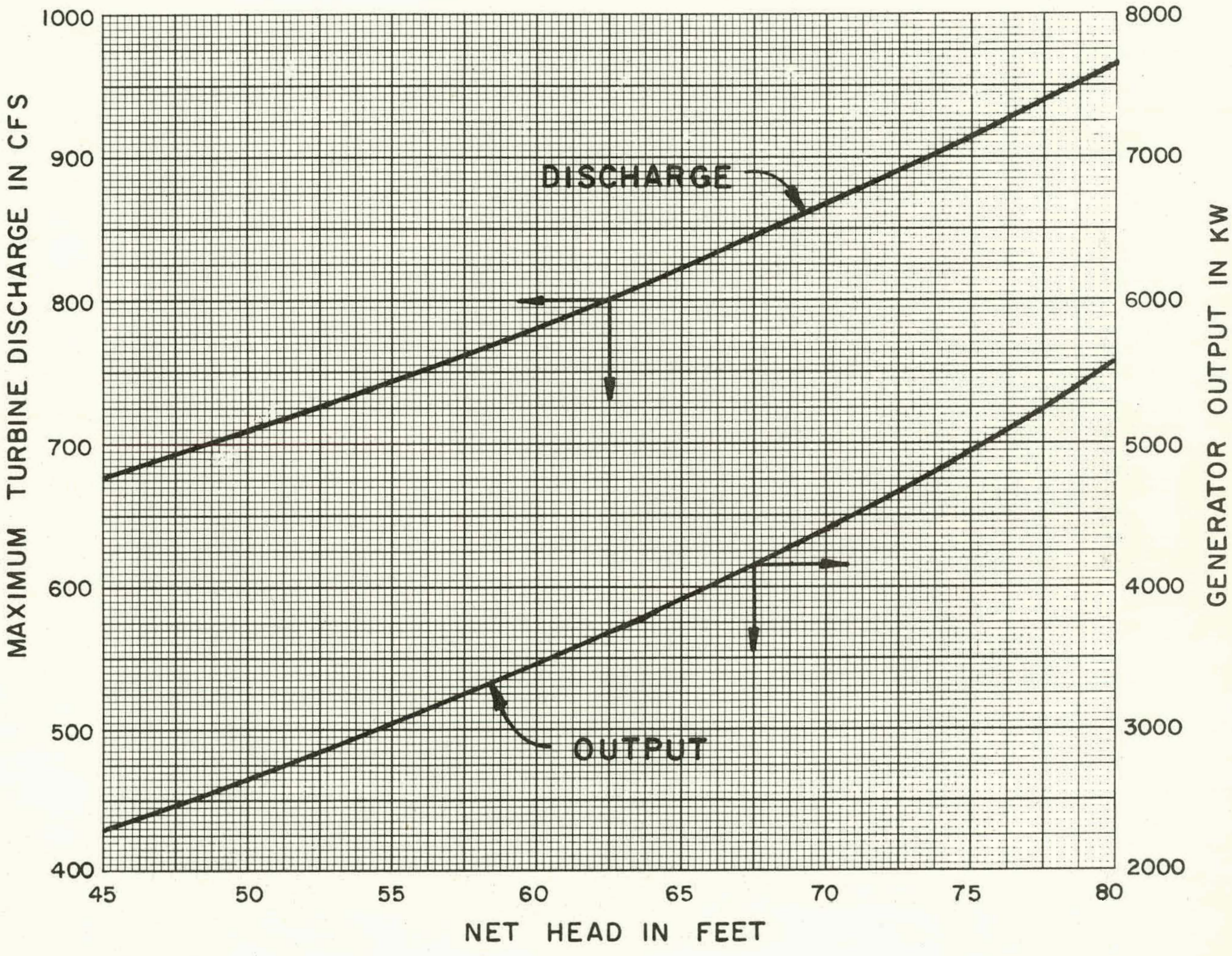
The general plan of this alternative is shown on Exhibit 8. The general design of the powerhouse is shown on Exhibit 10.

The average operating head of about 65 feet which will be obtained with this dam is higher than the normal range for a bulb turbine. Therefore, a vertical Kaplan turbine was selected for this alternative. The performance of this turbine is shown on Figure 4.3. The turbine discharge capacity would range from about 675 cfs at minimum reservoir elevation to about 900 cfs at maximum reservoir elevation. The output would range from about 2,300 KW to about 4,500 KW. Average output during long term operation is estimated to be about 4,000 KW.

WOODRUFF NARROWS

KAPLAN UNIT - 4000 KW AT 66 FEET NET HEAD

(LOWER SITE - "HIGH" DAM)



MINIMUM DISCHARGE: 25 % OF MAXIMUM

MINIMUM OUTPUT: 20 % OF MAXIMUM

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CHAPTER 5

RESERVOIR OPERATION AND ENERGY POTENTIAL

5.1 RESERVOIR OPERATION AND USES

5.1.1 PRESENT OPERATION AND USES

The present Woodruff Narrows Reservoirs was built primarily for supplemental irrigation of approximately 36,000 acres of meadow hay in the Upper Bear River Valley in Utah and Wyoming. The total storage capacity of the reservoir is 28,000 acre-feet, of which 22,500 acre-feet is used for irrigation, 4,000 acre-feet is used for fish conservation for maintaining a minimum flow release from the reservoir of 10 cfs to the main stem of the Bear River during the nonirrigation season, and 1,500 acre-feet is used for dead storage for fish conservation in the reservoir.

Recreation facilities at the reservoir include a parking lot, rest rooms, and a boat ramp. The principal recreation uses are fishing and duck and goose hunting.

Of the 22,500 acre-feet of storage for irrigation, 18,240 acre-feet is generally used as active storage each year, and 4,260 acre-feet is reserved for hold-over storage for use in drought years. The irrigation season generally begins about the first of May. Flows below the reservoir from spills and/or releases ranging from 500 cfs to 700 cfs are required to maintain the irrigation canals to their capacity depending upon tributary inflow and irrigation return flows. Irrigation of the meadow hay generally continues until approximately the 10th of July, when the flow from the reservoir is reduced to approximately 30 cfs for stockwatering and fishery purposes. The reservoir releases remain low until approximately the 20th of August when releases of 600 to 700 cfs are made from 5 to 10 days to provide for an additional irrigation on the meadow hay and pasture to increase production for fall grazing. If sufficient water is not remaining in the reservoir above the hold-over storage for at least 5 days of irrigation, no late season releases are made. The late season water is available only about 50 percent of the time. The hold-over storage is generally not used for late season irrigation but is saved for low water years for use in June or early July.

5.1.2 POTENTIAL OPERATION AND USE

The proposed enlargement of Woodruff Narrows Reservoir would increase the present capacity by 25,200 acre-feet to a total capacity of 53,200 acre-feet. The total increase in storage would be used for irrigation purposes. It is estimated that of the 25,200 acre-feet of new storage, 9,240 would be used as hold-over storage and 15,960 as active storage. This would provide a total active storage of 34,200 acre-feet and a hold-over storage of 13,500 acre-feet. The hold-over storage when combined with the fish conservation storage and dead storage would amount to 19,000 acre-feet. With this additional storage capacity, water would be made available for late season irrigation almost every year (4 out of 5), and would guarantee water for production of at least a partial crop of hay during an extreme drought year.

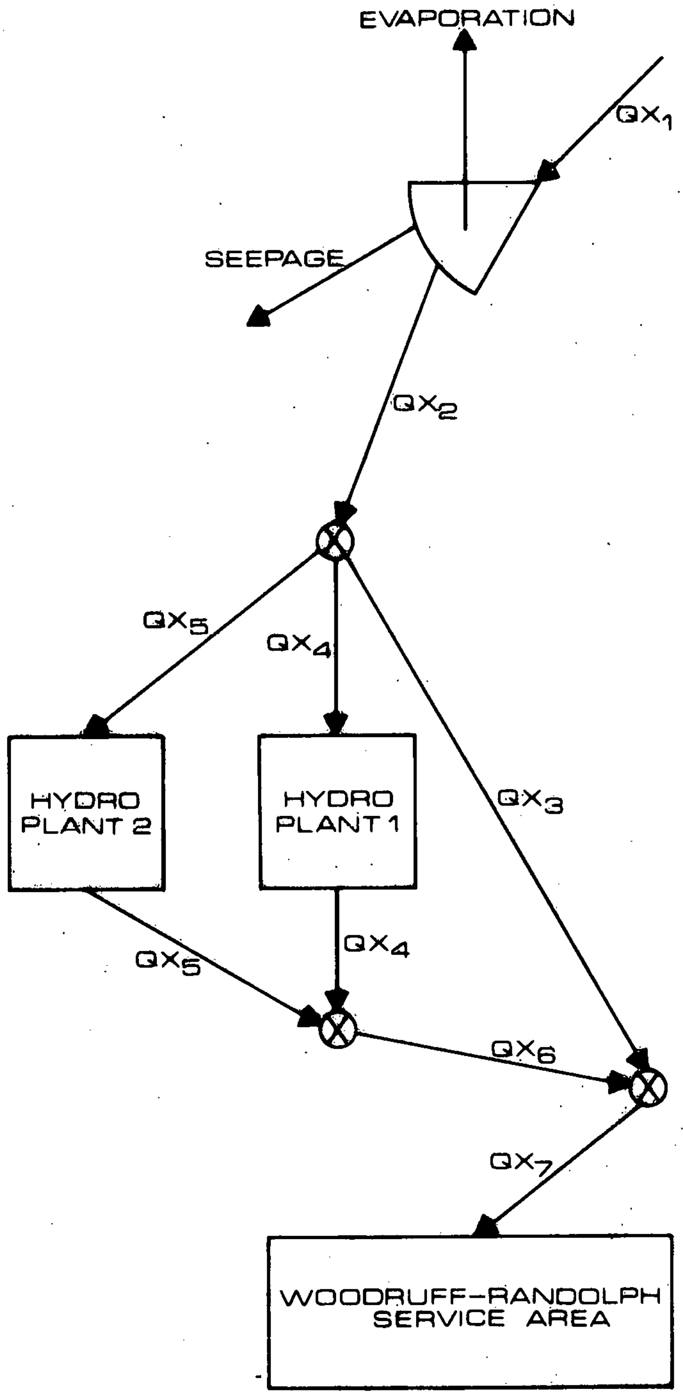
5.2 HYDROELECTRIC ENERGY POTENTIAL

5.2.1 RESERVOIR OPERATION SIMULATION MODEL

A computer simulation model was developed in order to facilitate the sizing and determination of the potential hydroelectric power and energy available at the Woodruff Narrows site for several different reservoir sizes. The simulation model is based on mean monthly flow values using 26 years of streamflow records. A skematic diagram of the basic elements of the computer simulation and the printout notation are shown on Figure 5.1. The program regulates the streamflow into the reservoir, computes evaporation, seepage and minimum flows, releases water upon demand to the service area, releases water to the hydroelectric plants on demand if the reservoir level is above a given target level for the month, releases water on demand to hydroplant 1 if the anticipated spring runoff is expected to fill the reservoir in succeeding months, and computes the hydroelectric energy generated at each hydroplant.

A sample of some of the simulation output is shown in Tables 5.1 through 5.6 for the proposed reservoir enlargement at the upper site for a single hydroplant rated at 2.77 MW maximum output with a flow range from 267 to 800 cfs and a head range from 20 to 48 feet using an average efficiency of 85 percent. Table 5.1 shows the recorded inflow in acre-feet to the reservoir for the 1942 through 1977 simulation period. Table 5.2 shows the simulated

Figure 5.1



QX_1 – Bear River inflow into Woodruff Narrows Reservoir (acre-feet)

QX_2 – Total water releases and spills from the reservoir (acre-feet)

QX_3 – Water not used for hydro-power (acre-feet)

QX_4 – Water used by hydro-power plant I

QX_5 – Water used by hydro-power plant 2

QX_6 – $QX_4 + QX_5$ – Total water used for hydro-power (acre-feet)

QX_7 – Total water supply from Reservoir (acre-feet)

QX_9 – Reservoir end-of-month elevation (acre-feet)

QX_{10} – Average monthly head above tailwater for hydro-power generation (feet)

QX_{11} – Hydro-power energy generation from plant 2 (Megawatt hours)

QX_{12} – Hydro-power energy generation from plant I (Megawatt hours)

QX_{13} – Total hydro-power energy generation from both plants (Megawatt hours)

Woodruff Narrows Hydropower Simulation and Notation

GX(1) SIMULATION OUTPUT DATA

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	5160.	5060.	4610.	3690.	3890.	7380.	36450.	41590.	42390.	1920.	80.	0.	152220.
1943	50.	890.	1860.	2090.	3450.	10790.	30370.	40100.	37440.	5410.	1000.	60.	133510.
1944	800.	1840.	2350.	2550.	2690.	2690.	31130.	64260.	59390.	12150.	70.	0.	179920.
1945	340.	1120.	1620.	2720.	2890.	7910.	21700.	37470.	36480.	10140.	7950.	2220.	132560.
1946	3490.	5790.	5320.	4920.	3690.	10770.	37460.	41500.	22380.	450.	30.	0.	135800.
1947	1030.	4340.	5360.	4060.	3940.	24260.	14460.	58950.	54110.	11040.	2880.	1200.	185630.
1948	2680.	4460.	5040.	5160.	4600.	6350.	35100.	58890.	26510.	370.	10.	0.	149170.
1949	120.	1510.	3750.	3640.	3330.	6020.	31760.	44900.	44310.	8650.	130.	90.	148410.
1950	1800.	2860.	3460.	3300.	3920.	8140.	45020.	67380.	86210.	15600.	2470.	1590.	241750.
1951	3180.	4810.	5050.	4390.	4600.	8530.	37780.	48840.	50260.	10740.	7000.	2040.	187220.
1952	7450.	4850.	5710.	6010.	5950.	6210.	58710.	106200.	71760.	12190.	6090.	2220.	293350.
1953	2270.	2240.	4100.	5610.	4080.	6350.	13040.	20540.	62090.	3590.	900.	40.	124850.
1954	190.	1360.	3670.	4000.	3870.	4960.	12520.	24520.	5380.	650.	40.	0.	61160.
1955	60.	420.	1800.	2640.	2400.	1580.	9510.	28740.	20530.	420.	140.	0.	68240.
1956	210.	2010.	7800.	5980.	4830.	14500.	14880.	57090.	37330.	1310.	60.	0.	146000.
1957	10.	1360.	2750.	2520.	2910.	5080.	16780.	42800.	97960.	23260.	1530.	670.	197630.
1958	1930.	3930.	4200.	3740.	4220.	5800.	12110.	47760.	20150.	700.	10.	0.	104550.
1959	70.	230.	530.	1660.	2280.	4680.	10390.	20480.	39010.	6100.	400.	830.	86660.
1960	3620.	4740.	2010.	2380.	2830.	18010.	12920.	24280.	23150.	230.	90.	10.	94270.
1961	310.	840.	2130.	2120.	2060.	1480.	3150.	13680.	8830.	70.	280.	1410.	36360.
1962	800.	1320.	3410.	2990.	11860.	7290.	38510.	41420.	45780.	8210.	600.	240.	162430.
1963	710.	1770.	2900.	1300.	6140.	2250.	8020.	30110.	31080.	750.	180.	280.	85490.
1964	440.	1860.	2680.	2460.	2010.	2480.	17050.	58700.	60870.	10710.	260.	200.	159720.
1965	190.	880.	5270.	6120.	4990.	5130.	30780.	58810.	102600.	41390.	14690.	12380.	283230.
1966	12130.	7270.	6330.	5620.	4140.	16570.	24710.	42370.	7510.	570.	340.	530.	128090.
1967	1330.	3260.	5570.	4700.	4010.	10660.	12280.	45340.	79420.	29520.	1990.	850.	198930.
1968	5540.	4430.	4260.	4000.	5500.	8280.	15910.	42090.	86510.	9460.	7720.	4450.	198150.
1969	6940.	6520.	6190.	6240.	4770.	7110.	39910.	54950.	26050.	3790.	850.	680.	164000.
1970	3020.	3210.	3560.	4290.	4280.	4240.	13860.	51860.	50970.	3760.	1100.	1780.	145930.
1971	4930.	5190.	7530.	8710.	9200.	17310.	26350.	56730.	72840.	11720.	620.	2130.	223260.
1972	5390.	7190.	6810.	5760.	6250.	29050.	26980.	63350.	71270.	2950.	380.	670.	226550.
1973	4880.	5450.	4610.	5040.	5000.	8090.	24390.	76610.	36930.	9570.	2340.	7520.	190430.
1974	9200.	11790.	7980.	6590.	5920.	16080.	32280.	90870.	58590.	6020.	740.	870.	246930.
1975	1280.	2440.	3710.	3810.	3250.	5150.	10540.	40940.	80660.	53500.	4150.	2460.	211890.
1976	4010.	6620.	6190.	4850.	4750.	14060.	24730.	45910.	17620.	1750.	590.	350.	131430.
1977	360.	1050.	970.	1010.	1350.	1650.	4620.	6410.	11340.	2360.	600.	430.	32650.
MEAN	2692.	3470.	4197.	4080.	4329.	8802.	23227.	47123.	46825.	8917.	1897.	1339.	156899.

Table 5.1

QX(2) SIMULATION OUTPUT DATA

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	600.	600.	600.	600.	600.	600.	36000.	36000.	39853.	24909.	9362.	600.	150324.
1943	600.	600.	600.	600.	600.	600.	26322.	25156.	36000.	27658.	10000.	600.	129336.
1944	600.	600.	600.	600.	600.	600.	36000.	36000.	55800.	35139.	9352.	600.	176491.
1945	600.	600.	600.	600.	600.	600.	12496.	24187.	36000.	32382.	16232.	600.	125497.
1946	600.	600.	600.	600.	600.	600.	36000.	40543.	36000.	13000.	4592.	600.	134335.
1947	600.	600.	600.	600.	600.	5446.	36000.	36994.	53351.	34029.	11162.	600.	180582.
1948	600.	600.	600.	600.	600.	600.	36000.	48893.	36000.	13231.	9292.	600.	147616.
1949	600.	600.	600.	600.	600.	600.	31957.	32041.	36000.	30947.	9412.	600.	144557.
1950	600.	600.	600.	600.	600.	600.	36000.	60384.	85451.	36000.	13311.	600.	235346.
1951	600.	600.	600.	600.	600.	600.	36000.	44165.	49501.	33729.	15282.	600.	182877.
1952	600.	600.	600.	600.	600.	687.	58560.	105869.	71001.	35179.	14372.	600.	289268.
1953	600.	600.	600.	600.	600.	600.	1623.	36000.	45657.	26579.	10000.	600.	124059.
1954	600.	600.	600.	600.	600.	600.	600.	24000.	36000.	10553.	0.	0.	74753.
1955	0.	365.	600.	600.	600.	600.	600.	24000.	36000.	3187.	0.	0.	66552.
1956	113.	600.	600.	600.	600.	600.	29013.	25107.	36000.	23558.	9342.	600.	126732.
1957	600.	600.	600.	600.	600.	600.	10939.	36000.	85014.	36000.	19949.	600.	192102.
1958	600.	600.	600.	600.	600.	600.	22078.	24000.	36000.	13000.	2396.	600.	101674.
1959	600.	500.	600.	600.	600.	600.	600.	24000.	36000.	13000.	5669.	600.	83469.
1960	600.	600.	600.	600.	600.	600.	8339.	24000.	36000.	13000.	5865.	600.	91405.
1961	600.	600.	600.	600.	600.	600.	600.	24000.	20780.	0.	36.	600.	49616.
1962	600.	600.	600.	600.	600.	600.	29464.	33500.	36000.	30518.	9882.	600.	143563.
1963	600.	600.	600.	600.	600.	600.	600.	24000.	36000.	13000.	3152.	600.	80952.
1964	600.	500.	600.	600.	600.	600.	25683.	36000.	47983.	33699.	9542.	600.	157107.
1965	600.	500.	600.	600.	600.	600.	36000.	36829.	101841.	40179.	36000.	600.	255049.
1966	966.	7233.	6293.	5605.	4125.	16510.	36000.	30631.	36000.	13000.	600.	600.	157563.
1967	600.	600.	600.	600.	600.	600.	15499.	36000.	66482.	36000.	26607.	600.	184788.
1968	600.	600.	600.	600.	600.	600.	28577.	36000.	73562.	32449.	16002.	600.	190790.
1969	600.	600.	600.	600.	600.	4687.	39760.	54619.	36000.	16197.	10000.	600.	164863.
1970	600.	600.	600.	600.	600.	600.	25860.	36000.	38055.	26749.	10000.	600.	140865.
1971	600.	600.	600.	600.	600.	16505.	36000.	46626.	72081.	34709.	9902.	600.	219423.
1972	600.	600.	600.	600.	600.	24558.	36000.	53874.	70511.	25939.	9662.	600.	224144.
1973	600.	500.	600.	600.	600.	600.	36000.	59187.	36171.	32559.	10622.	600.	178739.
1974	600.	600.	851.	6575.	5905.	16020.	36000.	86679.	57831.	29009.	10000.	600.	250671.
1975	600.	600.	600.	600.	600.	600.	8740.	36000.	67708.	52289.	36000.	600.	204937.
1976	600.	600.	600.	600.	600.	5788.	36000.	34191.	36000.	13000.	1800.	600.	130379.
1977	600.	500.	600.	600.	600.	600.	600.	24000.	16861.	2065.	356.	264.	47747.
MEAN	580.	778.	765.	905.	845.	2972.	24514.	38763.	48097.	24624.	10438.	557.	153838.

Table 5.2

WOODRUFF NARROWS RESERVOIR END OF MONTH STORAGE ACRE-FT

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	24391.	28807.	32773.	35838.	39105.	45825.	46131.	51410.	53200.	29000.	19000.	18036.	35293.
1943	17323.	17566.	18779.	20265.	23052.	33182.	37100.	51760.	52451.	29000.	19282.	18376.	28175.
1944	18412.	19605.	21308.	23226.	25286.	27316.	22322.	50349.	53200.	29000.	19000.	18036.	27255.
1945	17613.	18086.	19059.	21145.	23403.	30653.	39730.	52720.	52444.	29000.	20000.	21248.	28759.
1946	23966.	29111.	33787.	38083.	41151.	51261.	52572.	53200.	38821.	25234.	20000.	19028.	35518.
1947	19292.	22986.	27700.	31132.	34446.	53200.	31510.	53200.	53200.	29000.	20000.	20228.	32991.
1948	22139.	25953.	30349.	34882.	38859.	44549.	43506.	53200.	42951.	29000.	19000.	18036.	33535.
1949	17393.	18256.	21359.	24567.	27267.	32627.	32300.	44890.	52500.	29000.	19000.	18126.	28107.
1950	19163.	21376.	24190.	26860.	30152.	37632.	46517.	53200.	53200.	31589.	20000.	20618.	32042.
1951	23028.	27192.	31598.	35363.	39339.	47209.	48844.	53200.	53200.	29000.	20000.	21068.	35753.
1952	27747.	31953.	37020.	42407.	47737.	53200.	53200.	53200.	53200.	29000.	20000.	21248.	39159.
1953	22746.	24341.	27796.	32778.	36233.	41923.	53200.	37409.	53200.	29000.	19182.	18257.	33005.
1954	17083.	18396.	21419.	24787.	28027.	32327.	44118.	44332.	13016.	2500.	2500.	2500.	20967.
1955	2500.	2500.	3645.	5636.	7390.	8310.	17125.	21655.	5687.	2500.	2500.	2500.	6829.
1956	2500.	3855.	11000.	16340.	20535.	34375.	20110.	51870.	52450.	29000.	19000.	18036.	23256.
1957	17283.	17996.	20099.	21986.	24265.	28685.	34400.	40924.	53200.	39249.	20000.	19698.	28149.
1958	20860.	24144.	27699.	30811.	34405.	39545.	29440.	52941.	36333.	23030.	20000.	19028.	29853.
1959	18332.	17915.	17798.	18824.	20470.	24490.	34160.	30365.	32792.	24937.	19000.	18866.	23162.
1960	21721.	25815.	27181.	28932.	31135.	48485.	52920.	52870.	39263.	25450.	19000.	18046.	32568.
1961	17593.	17786.	19269.	20755.	22183.	23003.	25435.	14870.	2500.	2500.	2500.	3144.	14295.
1962	3243.	3908.	6664.	9009.	20227.	26857.	35780.	43420.	52511.	29000.	19000.	18276.	22325.
1963	18223.	19346.	21599.	22267.	27776.	29366.	36660.	42487.	36884.	23623.	20000.	19308.	26461.
1964	18981.	20195.	22228.	24057.	25437.	27257.	18500.	40984.	53200.	29000.	19000.	18236.	26423.
1965	17063.	17896.	22518.	28007.	32369.	36839.	31485.	53200.	53200.	53200.	30928.	42256.	34963.
1966	53200.	53200.	53200.	53200.	53200.	53200.	41760.	53200.	23951.	10701.	9989.	9641.	39037.
1967	10237.	12847.	17768.	21833.	25211.	35211.	31860.	40933.	53200.	45509.	20000.	19878.	27874.
1968	24650.	28435.	32051.	35426.	40302.	47922.	35110.	40922.	53200.	29000.	20000.	23478.	34208.
1969	29540.	35517.	41065.	46684.	50837.	53200.	53200.	53200.	42491.	29000.	19132.	18847.	39401.
1970	21102.	23666.	26580.	30242.	33896.	37476.	25340.	40956.	53200.	29000.	19382.	20195.	30086.
1971	24356.	28901.	35787.	43874.	52455.	53200.	43400.	53200.	53200.	29000.	19000.	20166.	38045.
1972	25287.	31833.	38000.	43138.	48768.	53200.	44030.	53200.	53200.	29000.	19000.	18706.	38113.
1973	22621.	27626.	31592.	36006.	40383.	47813.	36058.	53200.	53200.	29000.	20000.	26548.	35354.
1974	34962.	46110.	53200.	53200.	53200.	53200.	49330.	53200.	53200.	29000.	19022.	18928.	43046.
1975	19442.	21236.	24300.	27480.	30102.	34592.	36260.	40918.	53200.	53200.	20388.	21872.	31916.
1976	25109.	31084.	36631.	40858.	44988.	53200.	41780.	53200.	34061.	21838.	20000.	19378.	35177.
1977	19471.	19875.	20198.	20575.	21293.	22283.	26166.	8348.	2500.	2500.	2500.	2500.	14019.
MEAN	20558.	23203.	26589.	29735.	33191.	38961.	37538.	45615.	43645.	26877.	17675.	18121.	30142.

Table 5.3

Table 5.4

QX(4) SIMULATION OUTPUT DATA

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	0.	0.	0.	0.	0.	0.	36000.	36000.	39853.	24909.	9362.	0.	146124.
1943	0.	0.	0.	0.	0.	0.	26322.	25156.	36000.	27658.	10000.	0.	125136.
1944	0.	0.	0.	0.	0.	0.	36000.	36000.	48000.	35139.	9352.	0.	164491.
1945	0.	0.	0.	0.	0.	0.	12496.	24187.	36000.	32382.	16232.	0.	121297.
1946	0.	0.	0.	0.	0.	0.	36000.	40543.	36000.	13000.	4592.	0.	130135.
1947	0.	0.	0.	0.	0.	0.	36000.	36994.	48000.	34029.	11162.	0.	166185.
1948	0.	0.	0.	0.	0.	0.	36000.	48000.	36000.	13231.	9292.	0.	142523.
1949	0.	0.	0.	0.	0.	0.	31957.	32041.	36000.	30947.	9412.	0.	140357.
1950	0.	0.	0.	0.	0.	0.	36000.	48000.	48000.	36000.	13311.	0.	181311.
1951	0.	0.	0.	0.	0.	0.	36000.	44165.	48000.	33729.	15282.	0.	177177.
1952	0.	0.	0.	0.	0.	0.	48000.	48000.	48000.	35179.	14372.	0.	193551.
1953	0.	0.	0.	0.	0.	0.	0.	36000.	45657.	26579.	10000.	0.	118236.
1954	0.	0.	0.	0.	0.	0.	0.	24000.	36000.	10553.	0.	0.	70553.
1955	0.	0.	0.	0.	0.	0.	0.	24000.	36000.	3187.	0.	0.	63187.
1956	0.	0.	0.	0.	0.	0.	29013.	25107.	36000.	23558.	9342.	0.	123019.
1957	0.	0.	0.	0.	0.	0.	10939.	36000.	48000.	36000.	19949.	0.	150888.
1958	0.	0.	0.	0.	0.	0.	22078.	24000.	36000.	13000.	2396.	0.	97474.
1959	0.	0.	0.	0.	0.	0.	0.	24000.	36000.	13000.	5669.	0.	78669.
1960	0.	0.	0.	0.	0.	0.	8339.	24000.	36000.	13000.	5865.	0.	87205.
1961	0.	0.	0.	0.	0.	0.	0.	24000.	20780.	0.	0.	0.	44780.
1962	0.	0.	0.	0.	0.	0.	29464.	33500.	36000.	30518.	9882.	0.	139363.
1963	0.	0.	0.	0.	0.	0.	0.	24000.	36000.	13000.	3152.	0.	76152.
1964	0.	0.	0.	0.	0.	0.	25683.	36000.	47983.	33699.	9542.	0.	152907.
1965	0.	0.	0.	0.	0.	0.	36000.	36829.	48000.	40179.	36000.	0.	197008.
1966	0.	0.	0.	0.	0.	0.	36000.	30631.	36000.	13000.	0.	0.	115631.
1967	0.	0.	0.	0.	0.	0.	15499.	36000.	48000.	36000.	26607.	0.	162106.
1968	0.	0.	0.	0.	0.	0.	28577.	36000.	48000.	32449.	16002.	0.	161028.
1969	0.	0.	0.	0.	0.	0.	39760.	48000.	36000.	16197.	10000.	0.	149957.
1970	0.	0.	0.	0.	0.	0.	25860.	36000.	38055.	26749.	10000.	0.	136665.
1971	0.	0.	0.	0.	0.	0.	36000.	46626.	48000.	34709.	9902.	0.	175237.
1972	0.	0.	0.	0.	0.	0.	36000.	48000.	48000.	25939.	9662.	0.	167601.
1973	0.	0.	0.	0.	0.	0.	36000.	48000.	36171.	32559.	10622.	0.	163352.
1974	0.	0.	0.	0.	0.	0.	36000.	48000.	48000.	29009.	10000.	0.	171009.
1975	0.	0.	0.	0.	0.	0.	8740.	36000.	48000.	48000.	36000.	0.	176740.
1976	0.	0.	0.	0.	0.	0.	36000.	34191.	36000.	13000.	0.	0.	119191.
1977	0.	0.	0.	0.	0.	0.	0.	24000.	16861.	2065.	0.	0.	42927.
MEAN	0.	0.	0.	0.	0.	0.	24076.	35055.	40149.	24504.	10360.	0.	134144.

Table 5.5

QX(3) SIMULATION OUTPUT DATA

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1943	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1944	600.	600.	600.	600.	600.	600.	0.	0.	7800.	0.	0.	600.	12000.
1945	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1946	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1947	600.	600.	600.	600.	600.	5446.	0.	0.	5351.	0.	0.	600.	14397.
1948	600.	600.	600.	600.	600.	600.	0.	893.	0.	0.	0.	600.	5093.
1949	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1950	600.	600.	600.	600.	600.	600.	0.	12384.	37451.	0.	0.	600.	54035.
1951	600.	600.	600.	600.	600.	600.	0.	0.	1501.	0.	0.	600.	5701.
1952	600.	600.	600.	600.	600.	687.	10560.	57869.	23001.	0.	0.	600.	95717.
1953	600.	600.	600.	600.	600.	600.	1623.	0.	0.	0.	0.	600.	5823.
1954	600.	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	4200.
1955	0.	365.	600.	600.	500.	600.	600.	0.	0.	0.	0.	0.	3365.
1956	113.	600.	600.	600.	500.	600.	0.	0.	0.	0.	0.	600.	3713.
1957	600.	600.	600.	600.	600.	600.	0.	0.	37014.	0.	0.	600.	41214.
1958	600.	600.	600.	600.	500.	600.	0.	0.	0.	0.	0.	600.	4200.
1959	600.	600.	600.	600.	500.	600.	600.	0.	0.	0.	0.	600.	4800.
1960	600.	600.	600.	600.	500.	600.	0.	0.	0.	0.	0.	600.	4200.
1961	600.	600.	600.	600.	500.	600.	600.	0.	0.	0.	36.	600.	4836.
1962	600.	600.	600.	600.	500.	600.	0.	0.	0.	0.	0.	600.	4200.
1963	600.	600.	600.	600.	500.	600.	600.	0.	0.	0.	0.	600.	4800.
1964	600.	600.	600.	600.	500.	600.	0.	0.	0.	0.	0.	600.	4200.
1965	500.	600.	600.	600.	500.	600.	0.	0.	53841.	0.	0.	600.	58041.
1966	966.	7233.	6293.	5605.	4125.	16510.	0.	0.	0.	0.	600.	600.	41931.
1967	600.	600.	600.	600.	500.	600.	0.	0.	18482.	0.	0.	600.	22682.
1968	600.	600.	600.	600.	500.	600.	0.	0.	25562.	0.	0.	600.	29762.
1969	600.	600.	600.	600.	600.	4687.	0.	6619.	0.	0.	0.	600.	14906.
1970	600.	600.	600.	600.	600.	600.	0.	0.	0.	0.	0.	600.	4200.
1971	600.	600.	600.	600.	600.	16505.	0.	0.	24081.	0.	0.	600.	44185.
1972	600.	600.	600.	600.	600.	24558.	0.	5874.	22511.	0.	0.	600.	56543.
1973	600.	600.	600.	600.	600.	600.	0.	11187.	0.	0.	0.	600.	15387.
1974	600.	600.	851.	6575.	5905.	16020.	0.	38679.	9831.	0.	0.	600.	79662.
1975	600.	600.	600.	600.	600.	600.	0.	0.	19708.	4289.	0.	600.	28198.
1976	600.	600.	600.	600.	600.	5788.	0.	0.	0.	0.	1800.	600.	11188.
1977	600.	600.	600.	600.	600.	600.	600.	0.	0.	0.	356.	264.	4820.
MEAN	580.	778.	765.	905.	845.	2972.	438.	3708.	7945.	119.	78.	557.	19694.

Table 5.6

QX(12) SIMULATION OUTPUT DATA

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1942	0.	0.	0.	0.	0.	0.	1411.	1452.	1664.	913.	264.	0.	5703.
1943	0.	0.	0.	0.	0.	0.	903.	966.	1500.	1009.	283.	0.	4661.
1944	0.	0.	0.	0.	0.	0.	1036.	1229.	1994.	1287.	263.	0.	5810.
1945	0.	0.	0.	0.	0.	0.	428.	948.	1507.	1182.	463.	0.	4527.
1946	0.	0.	0.	0.	0.	0.	1498.	1702.	1407.	423.	126.	0.	5156.
1947	0.	0.	0.	0.	0.	0.	1343.	1380.	2021.	1247.	318.	0.	6308.
1948	0.	0.	0.	0.	0.	0.	1381.	1926.	1440.	457.	262.	0.	5466.
1949	0.	0.	0.	0.	0.	0.	1054.	1148.	1450.	1130.	265.	0.	5047.
1950	0.	0.	0.	0.	0.	0.	1349.	1957.	2021.	1344.	388.	0.	7058.
1951	0.	0.	0.	0.	0.	0.	1442.	1821.	2021.	1236.	436.	0.	6955.
1952	0.	0.	0.	0.	0.	0.	2021.	2021.	2021.	1289.	410.	0.	7761.
1953	0.	0.	0.	0.	0.	0.	0.	1395.	1769.	974.	282.	0.	4420.
1954	0.	0.	0.	0.	0.	0.	0.	923.	1064.	57.	0.	0.	2045.
1955	0.	0.	0.	0.	0.	0.	0.	609.	579.	0.	0.	0.	1187.
1956	0.	0.	0.	0.	0.	0.	868.	847.	1501.	860.	263.	0.	4339.
1957	0.	0.	0.	0.	0.	0.	355.	1278.	1899.	1410.	619.	0.	5561.
1958	0.	0.	0.	0.	0.	0.	749.	881.	1384.	407.	64.	0.	3485.
1959	0.	0.	0.	0.	0.	0.	0.	789.	1171.	403.	153.	0.	2517.
1960	0.	0.	0.	0.	0.	0.	343.	1008.	1408.	425.	159.	0.	3343.
1961	0.	0.	0.	0.	0.	0.	0.	616.	139.	0.	0.	0.	755.
1962	0.	0.	0.	0.	0.	0.	952.	1218.	1439.	1114.	278.	0.	5002.
1963	0.	0.	0.	0.	0.	0.	0.	873.	1311.	411.	85.	0.	2681.
1964	0.	0.	0.	0.	0.	0.	707.	1113.	1899.	1235.	269.	0.	5222.
1965	0.	0.	0.	0.	0.	0.	1217.	1374.	2021.	1692.	1337.	0.	7641.
1966	0.	0.	0.	0.	0.	0.	1431.	1217.	1267.	305.	0.	0.	4220.
1967	0.	0.	0.	0.	0.	0.	520.	1255.	1899.	1460.	862.	0.	5995.
1968	0.	0.	0.	0.	0.	0.	1062.	1284.	1899.	1189.	456.	0.	5889.
1969	0.	0.	0.	0.	0.	0.	1674.	2021.	1436.	558.	282.	0.	5971.
1970	0.	0.	0.	0.	0.	0.	835.	1191.	1506.	980.	283.	0.	4794.
1971	0.	0.	0.	0.	0.	0.	1444.	1870.	2021.	1272.	279.	0.	6885.
1972	0.	0.	0.	0.	0.	0.	1448.	1931.	2021.	950.	272.	0.	6623.
1973	0.	0.	0.	0.	0.	0.	1345.	1845.	1523.	1193.	303.	0.	6208.
1974	0.	0.	0.	0.	0.	0.	1488.	1984.	2021.	1063.	282.	0.	6838.
1975	0.	0.	0.	0.	0.	0.	301.	1294.	1899.	2021.	1227.	0.	6741.
1976	0.	0.	0.	0.	0.	0.	1431.	1359.	1366.	395.	0.	0.	4551.
1977	0.	0.	0.	0.	0.	0.	0.	550.	11.	0.	0.	0.	561.
MEAN	0.	0.	0.	0.	0.	0.	890.	1313.	1542.	886.	312.	0.	4942.

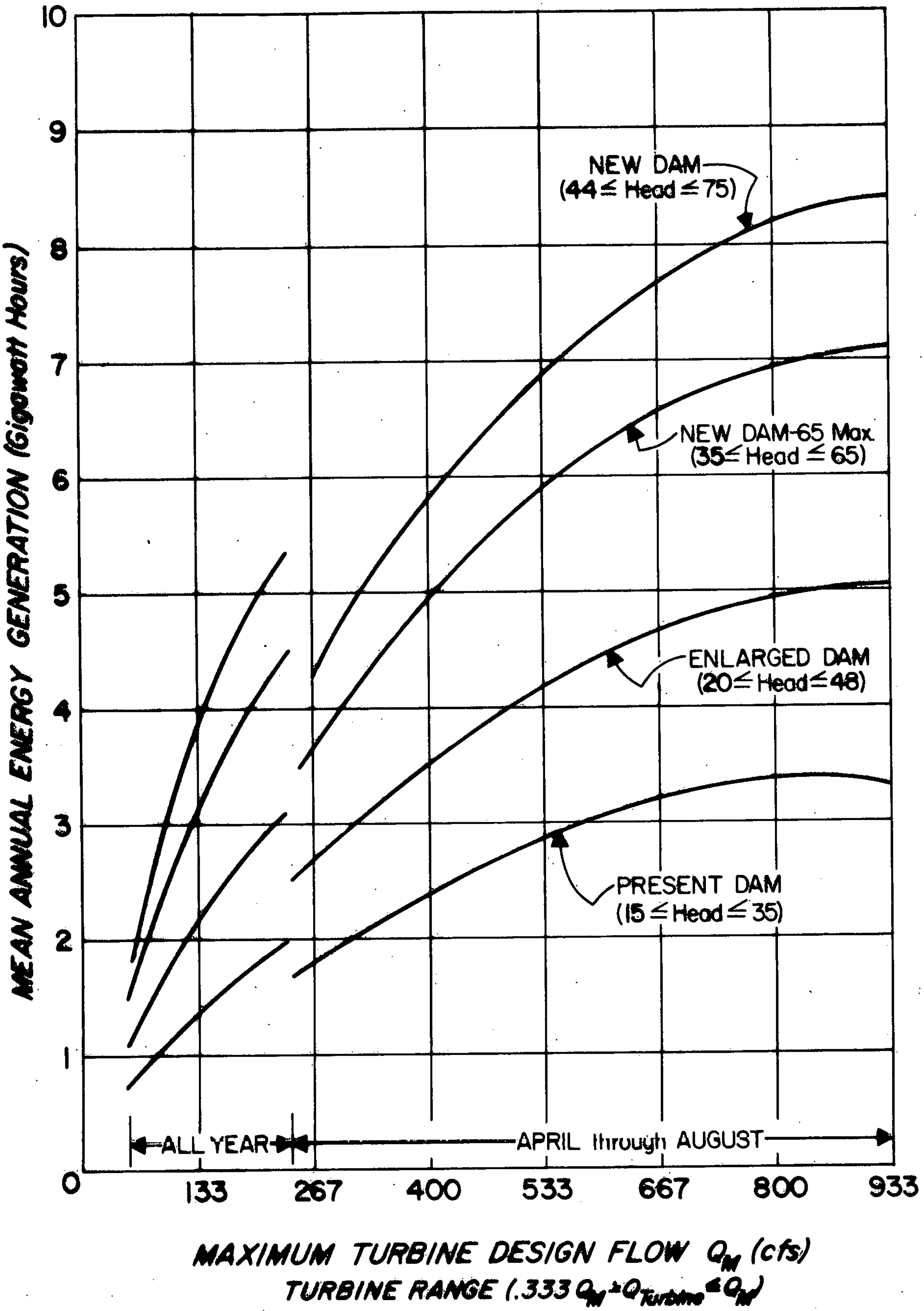
regulated releases and/or spills from the reservoir and also reflects the losses due to evaporation and seepage. Table 5.3 shows the enlarged reservoir simulated end of month storage content. Table 5.4 shows the simulated flows to the hydroplant. Table 5.5 shows the simulated "spills" or water from the system that is not used for hydroelectric generation. It should be noted that although power is generated only during the 5 month period from April 1 through the month of August, an average of 87 percent of the volume of water is used for power generation and only 13 percent bypasses the hydroplant. Table 5.6 shows the energy produced for the plant in megawatt hours for the 1942 through 1977 simulated period.

5.2.2 SIMULATION RESULTS

The simulation was developed with two hydroplants so that a small hydroplant could be simulated all year and a larger hydroplant could be simulated during the high flow season. It was soon realized after a few simulation runs that the smaller hydroplant with a larger hydroplant used in the high flow season produced a negligible amount of energy over and above a single hydroplant of the same capacity as the seasonal hydroplant. This is because the flow and head are both low during the majority of the time the small hydroplant operates and the smaller plant takes water from the larger seasonal plant in all but the peak month. Therefore, a dual hydroplant combination was not further studied.

The simulation model was used to determine the mean annual energy potential for the present dam, the proposed enlarged dam, a new dam at the lower site limited to 65 feet of head which has a storage capacity approximately the same as the proposed enlargement, and a new dam at the lower site which would store water to the same elevation as the proposed enlarged dam which would result in a maximum net head of 75 feet. The additional storage of the high dam at the lower site would all be allocated to dead storage. Maximum turbine flows from 50 cfs to 1,000 cfs were evaluated for each of the above dam configurations for a single hydroplant. The turbine flow was assumed to have a flow range with the maximum to minimum flow ratio of 3:1. An average efficiency of 85 percent was used in the analysis. A summary of the energy potential is shown on Figure 5.2. The streamflow during the fall and winter months of September through March generally ranges between 10 to 60 cfs. Therefore, turbines designed for larger flows would operate only during the spring and summer months of April through August when the flow ranges

Figure 5.2



WOODRUFF NARROWS HYDRO-POWER ENERGY SUMMARY from approximately 300 to 1,000 cfs. The maximum annual energy potential of the present dam is approximately 3.4 gigawatt hours. For the proposed enlargement of the present dam an average annual production of 5.0 gigawatt hours could be developed. For the new dam at the lower site with the head limited to 65 feet, approximately 7.0 gigawatt hours of energy could be produced annually. If the lower site dam were built which would store water to the same elevation as the proposed enlargement of the present dam site, approximately 8.3 gigawatt hours of energy could be produced annually. The power capacities of the above four dam configurations based on a maximum turbine flow of 850 cfs and maximum head are respectively 2.1, 3.0, 3.9, and 4.5 megawatts.

CHAPTER 6

ECONOMIC AND FINANCIAL ANALYSIS

6.1 CAPITAL COST

Estimates of capital costs were made of the three basic alternatives described in Chapter 4. The detailed estimates are presented in Table 6.1 at the end of this chapter. The costs were developed in accordance with normal procedures for appraisal type estimates. Much use was made of recent data on construction costs of similar projects or project features. All costs are based on January 1979 price level.

The construction costs were estimated on the basis of computed quantities of work, to which unit prices were applied, as appropriate. The quantities were calculated on the basis of the drawings presented as exhibits herein, supplemented by sketches as necessary. The unit prices of the different items reflect the total cost of the work involved, including the cost of all labor, materials, and equipment as well as such indirect items as the contractor's overhead and profit. Lump sums were used for items for which cost could not readily be established by the unit-price method. Cost of generators and turbines were obtained on the basis of recent quotations from manufacturers. A contingency allowance of 15 percent was included in all estimates to cover possible increases in quantities and prices. The cost of engineering and design was assumed to range from 5 to 12 percent of the construction cost depending on the complexity and the amount of work already accomplished.

Interests on construction expenditures were added to the total construction costs to obtain total capital cost. However, no interest during construction was charged to the dam construction because it would be financed from a state fund assigned to this purpose at no interest. For the power features, interest during construction was estimated to be 5 percent of the total construction cost. This corresponds to about one year construction period and 9 percent annual interest rate.

A summary of the estimated capital cost of the three alternatives is shown in the following table:

	Capital Cost ($1000)		
	Alt 1	Alt 2	Alt 3
Dam	1,835	2,805	3,275
Power Features	2,625	3,820	4,550
Total	4,460	6,625	7,825

The capital cost for the necessary repairs of the existing dam without any enlargement is estimated to be $1,600,000. Thus, the net cost of raising the dam and providing 25,200 acre-feet of additional storage is estimated to be $235,000, equivalent to about $10.00 per acre-foot of storage. The irrigation benefits from this additional storage will be more than sufficient to pay for the enlargement of the existing project, as discussed subsequently in this chapter. Therefore, the capital cost of repairing and raising the existing dam has been subtracted from the total costs of each alternative to obtain the net cost of the power features. The capital cost of the three power developments will then be as follows:

Alternative 1 - (Raised Dam - Upper Site) - $2,625,000
Alternative 2 - (Low Dam - Lower Site) - $4,790,000
Alternative 3 - (High Dam - Lower Site) - $5,990,000

6.2 ECONOMIC EVALUATION

6.2.1 GENERAL

A simplified economic evaluation of the three alternatives selected for study was made based on a comparison of annual costs and annual benefits. The comparison was made for two sets of assumptions as follows:

1) January 1979 price level with no escalation of annual costs and benefits, combined with an interest or discount rate of 4 percent which is considered to be a reasonable return on investment in an inflation free economy.

2) Ten percent annual interest or discount rate combined with a 6 percent annual escalation of future costs and benefits.

A project life of 50 years was assumed in all cases.

6.2.2 ANNUAL COSTS

Annual operating costs, such as operation and maintenance costs, transmission costs and administration and general expenses were estimated to be equivalent to about 1.5 percent of the total capital cost of the project, except that transmission costs (wheeling charges) were assumed to be $15.00 per kilowatt of plant capacity.

The total annual costs with assumption as under (1) above would then be:

ANNUAL COST IN DOLLARS(1)

Item	Alt 1	Alt 2	Alt 3
O & M Costs	39,375	71,850	89,850
Wheeling Charges	36,000	52,500	66,000
Subtotal	75,375	124,350	155,850
Capital Recovery (4%-50 yrs)	122,194	222,975	278,835
TOTAL ANNUAL	197,569	347,325	434,685

With assumptions as under (2) above the annual operation and maintenance costs and the wheeling charges must be escalated by a factor of 2.5. Thus the total annual costs in that case is estimated to be as follows:

ANNUAL COST IN DOLLARS (2)

Item	Alt 1	Alt 2	Alt 3
O & M Costs	98,438	179,625	224,625
Wheeling Charges	90,000	131,125	165,000
Subtotal	188,438	310,750	389,625
Capital Recovery (10%-50 yrs)	264,865	484,310	604,390
TOTAL ANNUAL	453,303	795,060	994,015

6.2.3 ANNUAL BENEFITS

The only benefits from a power development at Woodruff Narrows as described above will be the energy produced as estimated in Chapter 5. No value can be assigned to the capacity because operation is suspended throughout most of the year. Even during the months April through August the energy produced is not firm since releases are dictated by irrigation requirements. Therefore, the energy can only be considered as fuel (coal) replacement, estimated to have a value of 10 mills/KWH in January 1979. The escalated value estimated on the basis of the assumptions under (2) above, is about 25 mills/KWH. Thus the annual benefits will be as follows:

Alternative	Energy (GWH)	Annual Benefits ($) Assumption (1)	Annual Benefits ($) Assumption (2)
1	4.9	49,000	122,500
2	6.9	69,000	172,500
3	8.2	82,000	205,000

6.2.4 ECONOMIC COMPARISON

Representative economic values related to the three alternative studies are shown in the following table:

Item	Alt 1	Alt 2	Alt 3
Average Plant Capacity (KW)	2,400	3,500	4,000
Average Annual Energy (GWH)	4.9	6.9	8.2
Capital Cost ($1,000)	2,625	4,790	5,920
Cost per KW ($)	1,094	1,369	1,480
Plant Utilization (%)	24	23	22
Without Inflation			
Annual Cost ($1,000)	197.6	347.3	434.7
Annual Benefits ($1,000)	49.0	69.0	82.0
Benefit-Cost Ratio	0.25	0.20	0.19
Cost of Energy (mills)	40	50	53
With 6% Inflation			
Annual Cost ($1,000)	453.3	745.1	994.0
Annual Benefits ($1,000)	122.5	172.5	205.0
Benefit-Cost Ratio	0.27	0.22	0.21
Cost of Energy (mills)	93	115	121

The results indicate that the upper site alternative is clearly preferable to any of the two lower site alternatives, but they also indicate that none of the three alternatives can be justified economically. Costs exceed benefits by a ratio of approximately 4 to 1 for the upper site alternative and approximately 5 to 1 for both lower site alternatives.[1] There are several reasons for this unfavorable situation, including the following:

1. Low plant utilization due to large variations in plant discharge.
2. No capacity value or firm energy value can be assigned to the plant. The value of energy is only as fuel replacement.
3. The relatively remote location and small size of the project result in high transmission costs (wheeling charges).
4. Equipment cost is high in terms of cost per kilowatt because of the small unit size combined with relatively low head.

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[1]The fact that the benefit/cost ratios are similar for both the case with inflation and without inflation is probably a result of the assumptions made in which the rate of inflation is equal to the difference in interest rates.

Most of the above unfavorable factors are site determined and cannot be improved on. However, it may be possible to enhance the economics by adding pumped-storage features which would help to increase plant utilization. This possibility, and other alternatives will be discussed in Chapter 7.

6.2.5 AGRICULTURAL BENEFITS

The agricultural benefits are based on an enlargement of Woodruff Narrows Reservoir from its present capacity of 28,000 acre-feet to a proposed capacity of 53,200 acre-feet. The main benefits from enlarging the reservoir would be water available for an additional irrigation in the late summer to increase the fall grazing and having sufficient water to irrigate in drought years.

The mean monthly water supplies for the land before and after the enlargement were obtained from operation studies of Woodruff Narrows Reservoir. The average shortages for 26 years of record were subtracted from the irrigation demand to determine the water supply available. The following cropping pattern was used:

Crop	Acreage
Alfalfa	4,000 acres
Barley	4,000 acres
Meadow Hay & Pasture	28,000 acres
TOTAL	36,000 acres

The water supply available with and without the enlarged reservoir was compared with the ideal irrigation requirement to determine crop yields. A production cost curve for the meadow hay and pasture was developed using Soil Conservation Service farm budgets. A yield curve was developed using Soil Conservation Service methods and procedures. The meadow hay is cut in July and then the land is grazed in the fall. The fall grazing was converted to an equivalent amount of meadow hay using a factor of 800 pounds of hay per one animal unit month (AUM) of grazing.

The increased production of meadow hay amounted to 0.2 tons or 0.5 AUM per acre on 28,000 acres. This would increase the net return per acre by $5.94 for a total of $213,800 per year, which, when capitalized over a 50 year period at a discount rate of 4 7/8 percent, would amount to $4,000,000. The discount rate of 4 7/8 percent is used by the Utah Division of Water Resources in economic analysis of projects built by the Utah Water Conservation and Development Fund. Based on a capital cost of $1.835 million for repairing and enlarging the dam and reservoir, the benefit/cost ratio is 2.18 for the agricultural portion of the project.

6.3 POWER MARKETING STUDY

Several potential users in the area were contacted to see what price they would be willing to pay for the energy to be developed at the Woodruff Narrows Low Head Hydroelectric Power Project (WN LHHPP). Those contacted were: The Utah Power and Light Company of Salt Lake City; Utah State University in Logan, Utah; Bountiful City, Bountiful, Utah; Bridger Valley Electric Association, Fort Bridger, Wyoming; and the Intermountain Consumer Power Association in Sandy, Utah.

6.3.1 PATTERN OF ENERGY PRODUCTION

The energy generated by the WN LHHPP would be available only on a seasonal basis in the spring and summer since the winter flow of the Bear River is small and would not justify keeping the power plant operating through the winter months. Under alternative 1, an enlarged reservoir at the existing site, the mean annual energy produced as discussed in Chapter 5 would be 5 GWH and would be available as shown in the table below. Momentary peak power production would be about 3 megawatts.

	April	May	June	July	August	Total
Mean Energy Gen. (GWH)	0.9	1.3	1.6	0.9	0.3	5.0
Mean Energy Gen. (%)	18	26	32	18	6	100
Max. Power Gen. (MW)	2.7	2.8	2.9	2.6	1.8	

This pattern of energy production is dictated by the irrigation released from the reservoir. Unfortunately all the energy is non-firm, since nothing is produced in the wintertime. Furthermore, the peak production does not coincide with the peak demands on the potential users' systems. Thus, the energy simply replaces the equivalent amount of fossil fuel and there is no reason for potential customers to pay a premium price.

6.3.2 WHEELING CHARGES

While the Utah Power and Light Company is not very interested in purchasing the energy from the project, the company is willing to wheel the power to potential users on their system. The wheeling charges would be divided into two parts. The "backbone" charge provides for use of the transmission lines from the Naughton Plant near Kemmerer, Wyoming, to the rest of the UP & L system and is set at $9.95/KW-year. The other "local" wheeling charge pertains to those transmission lines going from the Naughton Plant to the vicinity of the Woodruff Narrows Dam. This charge is set nominally at $5.70/KW-year but might be negotiated at a lower rate. For further use in this report a total wheeling charge of $15/KW-year will be assumed.

If the peak power generation came at the same time the local or backbone lines were called on to deliver the yearly maximum, the Woodruff Narrows project would require an increased transmission line capacity. Under this assumption it might be argued that the full wheeling charges for the entire year should be charged even though power was wheeled only five months of the year. Accordingly the cost of wheeling would be 9 mills/KWH for a 3 MW plant generating 5 GWH of energy. However, the peak generation at WN LHHPP occurs in June and is well ahead of the peak summer demand on the system. Thus the WN LHHPP probably would not add to the required transmission line capacity and it could be argued that wheeling charges should be paid only for the five months of use. Under this assumption the wheeling costs would be only 4 mills/KWH.

The project would have to bear the cost of constructing a 46 KV line from the WN LHHPP to the 46 KV Sage/Evanston line of UP & L. Estimated cost of this 5 mile long connecting line is $180,000.

6.3.3 REVENUE FROM ENERGY

The amounts the various possible users of the project energy would be willing to pay at Woodruff Narrows are summarized below.

Utah Power and Light Company. The UP & L company has expressed a willingness to pay 6 mills/KWH at current cost levels if the Woodruff Narrows Reservoir release pattern is the same as in the past. If the project included a re-regulating pond so the releases and generation could be tailored to meet the daily UP & L peak demand, UP & L would pay 12 mills/KWH. If the project could be combined with other small projects so as to delay the construction of a major unit one year, then UP & L would pay up to 30 mills/KWH.

Utah State University. USU already operates a small low head hydroelectric plant located in the mouth of Logan Canyon at State Dam. The 200 KW plant is tied to the UP & L system and its production is used to offset part of the costs of energy purchases from UP & L. The University buys the balance of its power under a negotiated rate schedule. At present level of use USU pays about 22 mills/KWH to UP & L. With wheeling charges as given above, USU could pay between 13 and 18 mills/KWH for energy at Woodruff Narrows Dam.

Bountiful City. Bountiful, Utah, is a medium sized community just north of Salt Lake City which distributes power to city residents. The city has its own diesel generating plant and also purchases power as needed from UP & L and other sources. In recent months they have paid over 18 mills/KWH solely for the diesel fuel. Some operation, maintenance, and replacement costs should also be included in the price for the power. Thus, the city would probably be willing to pay up to 25 mills/KWH less wheeling costs of 4 to 9 mills.

Bridger Valley Electic Association. BVEA is the closest potential buyer of Woodruff Narrows power and serves a rural area near Fort Bridger, Wyoming. BVEA would be willing to buy Woodruff Narrows power at a competitive price, but unfortuately there is not now a connection between the UP & L system and BVEA. Such an intertie may be built in the not-so-distant future and then Woodruff Narrows power could be wheeled by UP & L to the Naughton Plant and thence to BVEA over Pacific Power and Light Company lines to the probable intertie at Hams Fork.

No further investigation of prices was made, but based on distances alone, the wheeling charges should be less than to the UP & L system. The price paid would probably be similar to the ICPA.

Intermountain Consumer Power Association. This consumer association serves the electric power needs of its members (including BVEA) by purchasing power and energy from DOE and from UP & L. At a future date they plan to have their own generating facilities.

At the present time ICPA would not pay any more for supplemental power than the 18 mills they now pay to UP & L. However, by 1980 they estimate they will be paying 28 mills and by 1985, 34 mills.

Under the most optimistic conditions it thus appears that Woodruff Narrows power would bring up to 24 mills/KWH at today's prices at the dam. If combined with our small projects, the price might be as high as 30 mills. For the purposes of this study a net current value of 21 mills/KWH at the dam site was assumed.

6.4 FINANCIAL FEASIBILITY

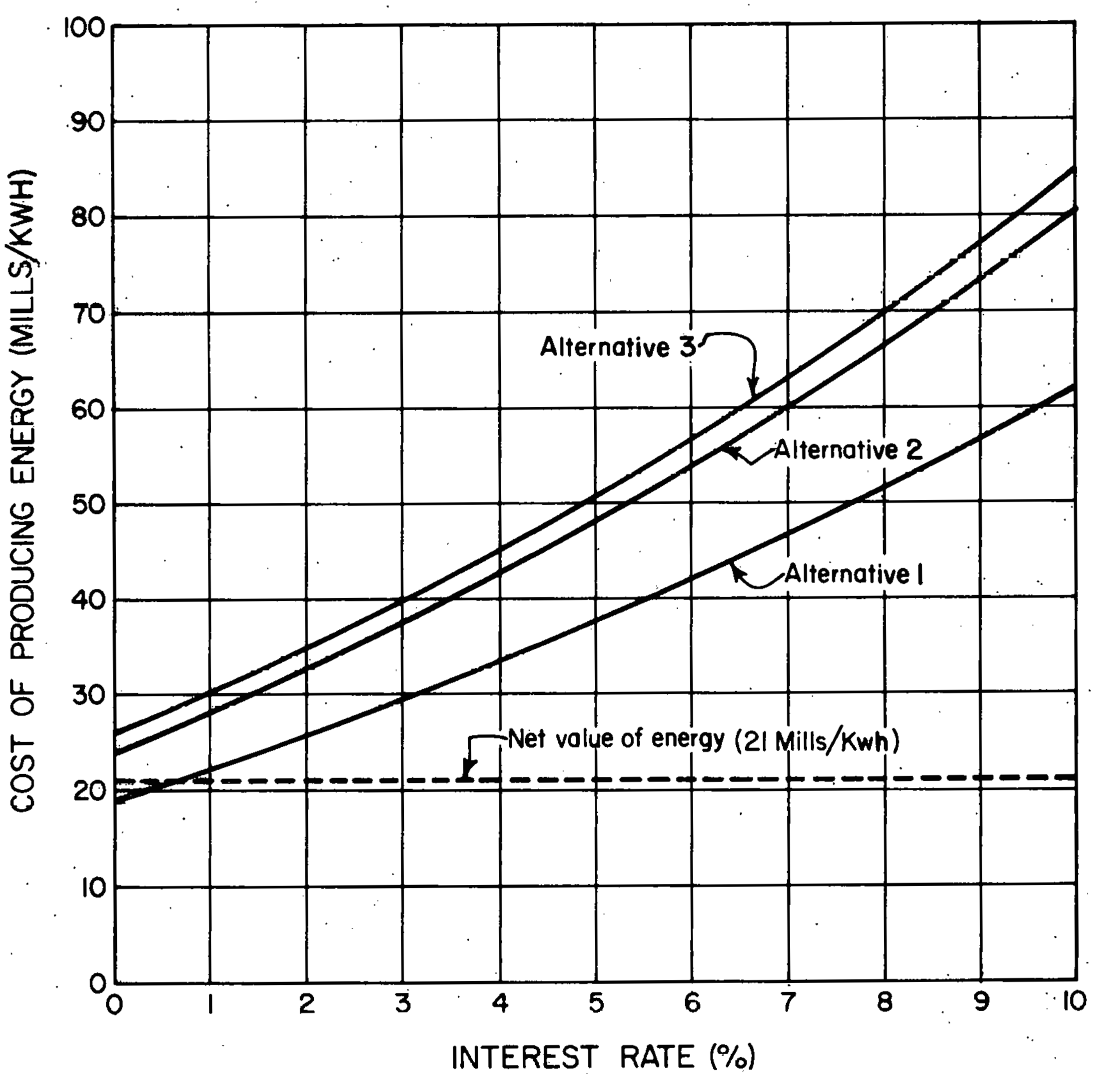
6.4.1 COST OF PRODUCING ENERGY

The cost of producing energy for the three alternatives on a mills/KWH basis was computed using a 50 year repayment period for amortizing the power facilities for various interest rates and adding the annual operation and maintenance costs. Figure 6.1 shows these costs as a function of interest rate for the three alternatives. A shorter repayment period such as 35 years would increase the cost about 2 to 5 mills/KWH depending upon the interest rate. The wheeling costs are not included in Figure 6.1. The net value of energy (21 mills/KWH) shown on Figure 6.1 is the current value of the energy (30 mills/KWH) less the wheeling cost (9 mills/KWH). As can be seen from Figure 6.1, the cost of producing energy by alternatives 2 and 3 is greater than the net value of the energy produced even with no interest. The cost of producing energy from alternative 1 is greater than the net value of the energy produced for any interest rates greater than 0.75 percent. It is obvious from Figure 6.1 that it is not financially feasible to pursue any of the three alternatives with the current market value of the energy. To be feasible at an interest rate of say 8 percent, the cost of producing energy by alternative 1 would be 51 mills/KWH. With the wheeling cost of approximately 9 mills/KWH, the total value of the energy produced would have to be at least 60 mills/KWH. This is at least double the current value of the energy.

6.4.2 FINANCING ARRANGEMENTS

None of the alternatives for developing hydroelectric power at the Woodruff Narrows site are economically or financially feasible to construct at this time. The financing strategy most likely to be used if a project was feasible would be as illustrated below for (alternative 1) the enlargement of the existing dam with a hydroelectric power component included.

Figure 6.1



Cost of Producing Energy at Woodruff Narrows Site

The total construction cost of this alternative is estimated to be $4.46 million. Of this amount, $1.835 million will be required for repair and enlargement of the dam, and $2.625 million for the hydropower generating facilities.

A previous cost estimate (1975) prepared by the Utah Division of Water Resources to enlarge and repair the existing dam for irrigation storage only, amounted to $1 million. This amount was to be financed by $800,000 from the Utah Board of Water Resources Revolving Construction Fund with the balance of $200,000 being provided by the Woodruff Narrows Reservoir Company. Financing of the $1.835 million for repair and enlargement of the dam would probably be available from these same sources, with most of the money coming from the Utah Board of Water Resources Revolving Construction Fund. The amount advanced by the fund would be returned without interest under a long-term purchase contract with the reservoir company.

The $2.625 million required for building the power generation facilities at the dam if it were both economically and financially feasible would probably be financed by the Water Conservation and Development Fund established by the State of Utah in 1978. Power revenues from the project would be used to repay with interest the money received from this fund. The interest rate of this fund is set by the Utah Board of Water Resources on a project by project basis.

6.4.3 RECOMMENDATIONS

As shown above, none of the three basic alternatives for hydroelectric power development are economically or financially feasible at this time. However, enlargement of the existing Woodruff Narrows Dam and Reservoir for agicultural purposes is both economically and financially feasible to construct. It is, therefore, recommended that enlargement of the existing dam and reservoir be pursued at this time without the addition of hydroelectric power development.

If the market value of electrical energy (as affected by fuel costs) escalates faster than the construction costs of hydroelectric facilities, the Woodruff Narrows Low Head Hydroelectric Power Plant could rather quickly become economically feasible. With the unstable worldwide petroleum supply situation, such a rapid escalation of fuel costs will likely take place. Furthermore, as crude oil and gas become more scarce, conservation of these valuable resources should be encouraged by all reasonable means. Therefore, public subsidy of marginal hydroelectric projects at this time might be a wise public policy leading to future conservation of hydrocarbon fuels. With such subsidy, hydroelectric plants could be built now with lower construction costs and the repayment could be accelerated by the increased market value of the electrical energy in the future.

Cost Estimate Woodruff Narrows - Upper Site Raised Dam

Item	Unit	Quantity	Unit Price	Total Cost
Land and Land Rights		-		-
Clearing and Grubbing			L.S.	1,000
Foundation Preparation			L.S.	10,000
Embankment				
Removal of structures			L.S.	5,000
Earth fill	c.y.	37,000	1.50	55,500
Rock rip-rap	c.y.	2,780	6.00	16,680
Spillway				
Excavation	c.y.	98,500	2.00	197,000
Concrete	c.y.	3,760	180.00	676,800
Filters and drains			L.S.	75,000
Outlet Works				
Steel pipe (installed)	lbs	125,000	2.50	312,500
Grouting	ft^3	2,500	20.00	50,000
Concrete in drop structure	c.y.	170	200.00	34,000
Modifications to intake			L.S.	5,000
Spillway Bridge			L.S.	20,000
Chain Link Fence	l.f.	1,100	10.00	11,000
Access Road and Bridge			L.S.	50,000
Subtotal				1,519,480
Contingencies (15% ±)				227,920
Total Field Cost				1,747,400
Engineering (5% ±)				87,600
Total Construction Cost				1,835,000
Interest During Construction (zero interest)				
TOTAL CAPITAL COST				1,835,000

Cost Estimate Woodruff Narrows Repair of Existing Dam

Item	Unit	Quantity	Unit Price	Total Cost
Embankment				
Work in existing spillway channel			L.S.	15,000
Embankment backfill	c.y.	4,000	2.00	8,000
Spillway				
Assume 90% of cost with raised dam = 90% of $948,800 =				853,920
Outlet Works				
Steel pipe	lbs	110,000	2.50	275,000
Grouting			L.S.	45,000
Concrete in drop structure	c.y.	150	200.00	30,000
Modifications to intake			L.S.	5,000
Spillway Bridge			L.S.	20,000
Chain Link Fence			L.S.	11,000
Subtotal				1,262,920
Contingencies (15% ±)				190,080
Total Field Cost				1,453,000
Engineering (10% ±)				147,000
Total Construction Cost				1,600,000
Interest During Construction (no interest)				-
TOTAL CAPITAL COST				1,600,000

Cost Estimate Woodruff Narrows - Upper Site Raised Dam - Power Features

Item	Unit	Quantity	Unit Price	Total Cost
Intake and Penstock				
Excavation, channel	c.y.	7,100	4.00	28,400
Excavation, penstock	c.y.	1,300	10.00	13,000
Concrete in intake	c.y.	140	200.00	28,000
Concrete culvert	c.y.	300	200.00	60,000
Concrete, penstock cover	c.y.	300	150.00	45,000
Steel penstock	lbs	100,000	1.60	160,000
Trashrack	lbs	12,000	1.40	16,800
Powerhouse				
Clearning and securing hillside			L.S.	50,000
Excavation	c.y.	7,200	6.00	43,200
Concrete	c.y.	1,200	250.00	300,000
Miscellaneous			L.S.	60,000
Turbine and Generator (2000 mm tube turbine)			L.S.	700,000
Accessory Electrical Equipment			L.S.	93,000
Miscellaneous Power Plant Equipment			L.S.	75,000
Substation Structures			L.S.	5,000
Substation Equipment			L.S.	70,000
Access Road			L.S.	10,000
Transmission Line	mi.	5	36,000	180,000
Subtotal Power Features				1,937,400
Contingencies (15% ±)				292,600
Total Field Cost				2,230,000
Engineering (12% ±)				270,000
Total Construction Cost				2,500,000
Interest During Construction (5%)				125,000
TOTAL CAPITAL COST				2,625,000

Cost Estimate Woodruff Narrows - Lower Site Low Dam Alternative

Item	Unit	Quantity	Unit Price	Total Cost
Land and Land Rights	ac	600	75.00	45,000
Clearing and Grubbing	ac	8	1000.00	8,000
Foundation Treatment			L.S.	100,000
Excavation thru Existing Dam	c.y.	15,000	2.00	30,000
Access Road and Bridge			L.S.	50,000
Spillway				
Excavation, common	c.y.	32,000	2.00	64,000
Excavation, rock	c.y.	35,000	5.00	175,000
Concrete	c.y.	3,900	180.00	702,000
Filters and drains			L.S.	40,000
Chain Link Fence			L.S.	10,000
Embankment				
Excavation, common	c.y.	30,000	2.00	60,000
Excavation, rock	c.y.	6,000	6.00	36,000
Earth fill	c.y.	340,000	2.50	850,000
Rip-rap	c.y.	8,000	6.00	48,000
Subtotal				2,218,000
Contingencies (15% ±)				332,000
Total Field Cost				2,550,000
Engineering (10% ±)				255,000
Total Construction Cost				2,805,000
Interest During Construction (zero interest)				-
TOTAL CAPITAL COST				2,805,000

Note: Estimate does not include outlet works which are included with power features.

Cost Estimate Woodruff Narrows - Lower Site Low Dam
Alternative - Power Features

Item	Unit	Quantity	Unit Price	Total Cost
Intake and Penstock				
Excavation, intake	c.y.	2,700	4.00	10,800
Excavation, penstock	c.y.	8,200	6.00	49,200
Concrete in intake	c.y.	220	200.00	44,000
Concrete conduit	c.y.	300	200.00	60,000
Penstock steel	lbs	105,000	1.60	168,000
Concrete, penstock cover	c.y.	320	150.00	48,000
Intake gate and hoist	lbs	13,000	2.00	26,000
Trashrack	lbs	12,000	1.40	16,800
Powerhouse and Bypass				
Clearing			L.S.	2,000
Excavation, rock	c.y.	2,700	6.00	16,200
Concrete	c.y.	1,700	250.00	425,000
Miscellaneous			L.S.	60,000
Bulb Turbine (2000 mm)			L.S.	1,400,000
Accessory Electrical Equipment			L.S.	100,000
Miscellaneous Power Plant Equip.			L.S.	75,000
Bypass Gate and Valve			L.S.	50,000
Substation Structures			L.S.	5,000
Substation Equipment			L.S.	90,000
Transmission Line	mi	5	36,000	180,000
Subtotal				2,826,000
Contingencies (15% ±)				424,000
Total Field Cost				3,250,000
Engineering (12% ±)				390,000
Total Construction Cost				3,640,000
Interest During Construction (5%)				180,000
TOTAL CAPITAL COST				3,820,000

Cost Estimate Woodruff Narrows - Lower Site High Dam Alternative

Item	Unit	Quantity	Unit Price	Total Cost
Land and Land Rights	ac	800	75.00	60,000
Clearing and Grubbing	ac	10	1000.00	10,000
Foundation Treatment			L.S.	120,000
Excavation thru Existing Dam	c.y.	15,000	2.00	30,000
Access Road and Bridge			L.S.	50,000
Spillway				
Excavation, common	c.y.	33,000	2.00	66,000
Excavation, rock	c.y.	38,000	5.00	190,000
Concrete	c.y.	4,100	180.00	738,000
Filters and drains			L.S.	40,000
Chain link fence			L.S.	11,000
Embankment				
Excavation, common	c.y.	35,000	2.00	70,000
Excavation, rock	c.y.	7,000	6.00	42,000
Earthfill	c.y.	440,000	2.50	1,100,000
Rip-rap	c.y.	10,000	6.00	60,000
Subtotal				2,587,000
Contingencies (15% ±)				388,000
Total Field Cost				2,975,000
Engineering (10% ±)				300,000
Total Construction Cost				3,275,000
Interest During Construction (zero interest)				-
TOTAL CAPITAL COST				3,275,000

Cost Estimate Woodruff Narrows - Lower Site High Dam
Alternative - Power Features

Item	Unit	Quantity	Unit Price	Total Cost
Intake and Penstock				
Excavation, intake	c.y.	3,100	4.00	12,400
Excavation, penstock	c.y.	9,200	6.00	55,200
Concrete in intake	c.y.	220	200.00	44,000
Concrete conduit	c.y.	330	200.00	66,000
Penstock steel	lbs	115,000	1.60	184,000
Concrete, penstock cover	c.y.	355	150.00	53,250
Intake gate and hoist	lbs	13,000	2.00	26,000
Trashrack	lbs	12,000	1.40	16,800
Powerhouse and Bypass				
Clearing			L.S.	2,000
Excavation, rock	c.y.	2,500	6.00	15,000
Concrete	c.y.	1,400	300.00	420,000
Miscellaneous			L.S.	70,000
Kaplan Turbine (4400 KW)			L.S.	1,400,000
Generator			L.S.	420,000
Accessory Electrical Equipment			L.S.	175,000
Miscellaneous Power Plant Equipment			L.S.	80,000
Bypass Gate and Valve			L.S.	50,000
Substation Structures			L.S.	5,000
Substation Equipment			L.S.	90,000
Transmission Line	mi	5	36,000	180,000
Subtotal				3,364,650
Contingencies (15% ±)				504,350
Total Field Cost				3,869,000
Engineering (12% ±)				464,000
Total Construction Cost				4,333,000
Interest During Construction (5%)				217,000
TOTAL CAPITAL COST				4,550,000

Cost Estimate Woodruff Narrows Reregulating Dam at Lower Site

Item	Unit	Quantity	Unit Price	Total Cost
Land and Land Rights	ac	160	75.00	12,000
Clearing and Grubbing	ac	1.5	1,000.00	1,500
Embankment				
Foundation excavation	c.y.	8,000	3.00	24,000
Earthfill	c.y.	40,000	3.00	120,000
Rip rap	c.y.	800	6.00	4,800
Spillway				
Excavation	c.y.	21,500	4.00	86,000
Concrete	c.y.	900	200.00	180,000
Gate and hoists	ea	3	15,000.00	45,000
Bypass			L.S.	5,000
Chain link fence	ft	500	10.00	5,000
Access Road			L.S.	20,000
Subtotal				503,300
Contingencies (15% ±)				75,700
Total Field Cost				579,000
Engineering and Adm. (10% ±)				59,000
Total Construction Cost				638,000
Interest During Construction (5%)				32,000
TOTAL CAPITAL COST				670,000

CHAPTER 7

OTHER ALTERNATIVES CONSIDERED

7.1 GENERAL

In addition to the three basic run-of-river developments discussed above, the following alternatives were also given consideration:

1. Power at the existing dam
2. Peaking installations
3. Head development by pipeline
4. Pumped storage

From rough evaluations of costs and benefits, the first three alternatives were excluded from detailed study. A power development with the existing dam would have lower head and less output than with the raised dam, whereas the cost would not change significantly. The net result would be higher unit costs of both power and energy and an even less favorable benefit/cost ratio. Providing additional capacity for peaking purposes would have no merit. Costs would be much higher than corresponding benefits, primarily because the plant would still produce no firm power and energy. The gross head for power could be increased by about 20 feet by locating the power plant about 6000 feet downstream from the dam. This would require the construction of a pipeline to supply water under pressure from the reservoir to the turbine. The cost of such a pipeline is estimated to be at least $3,000,000 which is more than the estimated cost of the entire plant at the raised dam. Average gain in net head is estimated to be only 14 feet. Therefore, this alternative also can be dismissed from further consideration. The basic reason is that the river has a relatively flat gradient of 0.35 percent in the reach below the dam so that the gain in head is small compared to the length of the pipeline. The only alternative which appears to merit a more detailed study is a pumped storage arrangement as described below.

7.2 PUMPED STORAGE

7.2.1 GENERAL

The basic concept of this alternative is to provide the power plant with a reversible unit which would permit peaking operation throughout the year. The proposed development would be similar to Alternative 1 described in Chapter 4 except that the unit would be a pump-turbine and that a downstream reservoir would be required. No additional generating capacity would be provided, but firm power would be produced throughout the year. However, the net energy produced by this type of development would be less than by a run-of-river energy plant.

7.2.2 POWER AND ENERGY

Estimates of power and energy production and requirements for pumped storage were made on the basis of the following assumptions which represent average operating conditions:

Generating Cycle	
Average power	2000 KW
Overall efficiency	0.85
Daily duration	8 hours
Average discharge	700 cfs
Average daily energy	16,000 KWH
Pumping Cycle	
Average discharge	500 cfs
Overall efficiency	0.80
Power requirement	2200 KW
Daily duration	10 to 12 hours
Daily energy requirement	25,000 KWH

The resulting energy balance is shown in the table below (1,000 KWH):

Month	Output (8 hrs/day)	Run-of-River Energy	Secondary Energy	Pumping Requirement
Jan	496	-	-	775
Feb	448	-	-	700
Mar	496	-	-	750
Apr	480	890	410	-
May	496	1,313	817	-
Jun	480	1,542	1,062	-
Jul	496	886	390	-
Aug	496	312	-	288
Sep	480	-	-	750
Oct	496	-	-	775
Nov	480	-	-	750
Dec	496	-	-	775
Total	5,840	4,942	2,679	5,563

7.2.3 CAPITAL COST

Conversion of the run-of-river plant at the Upper Site (Alternative 1) to a pumped storage development will require the addition of a downstream reservoir and some modifications to the tube turbine unit.

The minimum downstream storage requirement would be equal to the volume of water discharged during 8 hours of power generation, or about 465 acre-feet. This requirement would be met by the construction of a dam at the Lower Site for a reservoir to elevation 6400. A drawdown of 5 feet, to elevation 6395, would provide about 700 acre-feet of active storage. A layout of this dam is shown on Exhibit 11. Releases for irrigation will be made by partial opening of one of the three spillway gates. The opening will be controlled automatically by a float. A bypass for low discharges during the winter months will be provided through one of the spillway abutments. The general design of this dam is less conservative than the design of the higher dams discussed previously because a failure would cause no serious damage downstream since the storage is quite small. A cost estimate of this dam showing a total capital cost of $670,000, is presented in Table 6.1, sheet 8.

Conversion of the tube turbine to serve also as a pump would require as a minimum that the generator be equipped to operate also as a motor. Other modifications such as different draft tube shape and deeper setting of the unit also may be required. For the purpose of this study it was assumed that the modifications would add about $300,000 to the direct cost of the unit and power plant, or about $400,000 in total capital cost.

The total capital cost of the pumped storage development would then be as follows:

Power Plant Alt 1	$ 2,625,000
Reregulating Dam	670,000
Modifications for Pumping	400,000
Total Capital Cost	$ 3,695,000

7.2.4 ECONOMIC EVALUATION

The economic evaluation of this alternative is based on a comparison of annual costs and benefits for the case of no inflation. The annual costs, using similar assumptions as outlined in Chapter 6, would then be as follows:

O & M Costs	$	55,500
Wheeling Charges		36,000
Energy purchase (10 mills/KWH)		56,000
Subtotal		147,500
Capital Recovery (4% - 50 yrs)		172,420
Total Annual Costs	$	319,920

The annual benefits will consist of a capacity value of the firm power and an energy value of the energy produced. For an alternative coal fired plant, these values were assumed to be about $50/KW/year and 10 mills/KWH. For a combined cycle plant using No. 2 Diesel Oil as fuel, the values should be about $30/KW/year and 25 mills/KWH.

Thus, the total annual benefits will be:

	Coal Plant Alternative	Combined Cycle Alternative
Capacity Value	$ 100,000	$ 60,000
Energy Value	85,000	212,000
Total Annual Benefits	$ 185,000	$ 272,000

The above estimates indicate that the annual costs would be considerably higher than annual benefits. The benefit/cost ratio compared to a coal fired plant is 0.55 and compared to diesel plant 0.85. Furthermore, the above estimates are based on many assumptions which in general tend to favor the pumped storage alternative. More detailed studies would be required to determine if cheap energy would be available for pumping and if the estimates of firm power and energy are realistic.

It is concluded that a combined run-of-river pumped-storage development as described above is not economically feasible. However, the estimates indicate that adding the pumped storage feature would enhance the overall economics of the project.

7.2.5 FINANCIAL FEASIBILITY

For a financial feasibility comparison with Alternative 1, the pumped storage alternative was evaluated using an interest rate of 8 percent. When the capital costs are amortized over a period of 50 years and added to the above operation and maintenance costs including wheeling charges and energy purchases, the resulting cost of producing the energy is 60 mills/KWH. This value is identical to the cost of producing energy by alternative 1, and at least double the current market value of energy in the project area.

CHAPTER 8

INSTITUTIONAL ASSESSMENT

8.1 INTRODUCTION

8.1.1 INSTITUTIONAL SETTING

The Woodruff Narrows Dam has a rather complex institutional setting because of its location on the Bear River, an interstate stream which meanders through three states making five state line crossings in its course. The picture includes an interstate compact and compact commission; water planning and regulatory agencies of three different states; numerous local organizations-irrigation companies, municipalities, industries, and utilities; a downstream wildlife refuge; and numerous contracts and agreements concerning the allocation and storage of the water in the river.

8.1.2 SUMMARY OF GEOGRAPHIC SETTING

Bear River, shown on Figure 3.1, is the largest tributary to the Great Salt Lake. It has its source in the Uinta Mountains of north-eastern Utah and flows north into southwestern Wyoming past the city of Evanston, then back into northeastern Utah, for a short distance. It reenters Wyoming and then turns abruptly west near the community of Cokeville and enters Idaho. It continues to the northwest past the cities of Montpelier and Soda Springs, then turns south and flows through Gentile Valley and Oneida Canyon and into Cache Valley in southern Idaho and northern Utah. The river continues south through Bear River Canyon, past Brigham City and empties into the Great Salt Lake near the federal Bear River Migratory Bird Refuge.

Bear Lake, straddling the Utah-Idaho state line, once had a natural outlet to the river but this was changed to make the lake a storage reservoir for spring runoff. Bear River water now is diverted to Bear Lake through the Rainbow Inlet Canal and water from the lake is returned to the river through the Outlet Canal. Releases to the river are made through Utah Power and Light Company's Lifton pumping plant at the north end of the lake.

8.1.3 WATER USES

Water uses are primarily agricultural, irrigating approximately one-half million acres of land, although Utah Power and Light Company maintains five power plants with a total generating capacity of 125.5 MW on the river below Bear Lake. Three of the five power plants have small regulating pools for peaking purposes. There are several small storage reservoirs above Bear

Lake but these are used only for local needs. The two relatively large reservoirs on the river are Woodruff Narrows, with a capacity of 28,000 acre-feet and Bear Lake with an active storage capacity in excess of one million acre-feet. Uses, other than for agriculture and power, remain minimal, although demands for fish and wildlife and by home owners and recreationists on Bear Lake are increasing.

8.2 THE BEAR RIVER COMPACT

8.2.1 ORIGINAL PROVISIONS

The Bear River compact, agreed to by the States of Idaho, Utah, and Wyoming in 1955, which became effective 17 March 1958 after consent of Congress and signature by the President, establishes the rights and obligations of these states with respect to the waters of the Bear River. The compact provides for apportionment of direct flows of the river and its tributaries among separate sections of the states above Bear Lake, as well as establishing and limiting additional storage rights above Bear Lake. It reserves a portion of the storage capacity in Bear Lake for primary use by, and protection of, irrigation uses and rights downstream from Bear Lake, and provides that water delivery between Idaho and Utah will be based on priority of rights without regard to state boundary lines.

Storage rights existing in reservoirs upstream from Bear Lake in 1955 amounted to 324 acre-feet in Idaho, 11,850 acre-feet for Utah, and 2,150 acre-feet for Wyoming. Article V of the compact granted additional storage in this upper division of the river in the total amount of 36,500 acre-feet annually. This additional storage was allocated 1,000 acre-feet to Idaho and 17,750 acre-feet to each of Utah and Wyoming. Utah subsequently has developed all of its additional storage allocation, but Wyoming and Idaho have not. It was these compact allocations to Utah and Wyoming that provided part of the storage rights for the Woodruff Narrows Dam and Reservoir.

8.2.2 PROPOSED COMPACT REVISIONS

Since 1970, formal negotiations have been underway to amend the compact. The fact that neither direct flow nor storage rights downstream from Bear Lake were divided between Idaho and Utah by the compact has hampered water development in this area. Furthermore, residents upstream from Bear

Lake in all three states have expressed an interest in having more water allocated for use in their areas. Hydrologic studies have shown that additional amounts could be allocated without affecting downstream irrigation rights. Negotiations have attempted to resolve these issues as well as to include in the compact the allocation of groundwater which was omitted originally.

On December 22, 1978, an agreement to revise the Bear River Compact was formally approved by compact commissioners representing the three states. If it is ratified by the legislatures of the three states and receives federal approval by Congress and the President, it will divide water rights between Idaho and Utah in the lower Bear River Basin, and authorize additional upstream storage in Idaho, Utah, and Wyoming.

Upstream from Bear Lake, Utah, and Wyoming will each receive an added storage allocation of 35,000 acre-feet of water and Idaho will receive an additional 4,500 acre-feet. However, these additional upstream entitlements including groundwater will allow the three states to deplete only 28,000 acre-feet of water annually. These allocations are limited also by the level of water in Bear Lake. If the surface of Bear Lake drops below elevation 5,911 feet, this additional storage allocation would not be allowed.

8.3 IMPACTS OF THE PROPOSED PROJECT ON WATER RIGHTS AND INSTITUTIONS

8.3.1 DESIGN ALTERNATIVES

Several design configurations were considered in the engineering-economic feasibility studies for adding hydropower to the Woodruff Narrows Dam. These were described previously in Chapters 4 and 7. Tailwater regulating pools were considered for each of the hydropower alternatives to smooth out peaking flows over a 24 hour period. However, the engineering economic studies revealed that producing power for peak loads is not economically feasible due to high wheeling costs and other factors.

8.3.2 EFFECTS ON LOCAL WATER USES

A basic constraint observed in the feasibility studies was that the existing pattern of flows to irrigation uses would be maintained. Whether this is accomplished by a downstream regulating pool or by scheduling power generation only at times when water is flowing to irrigation uses, the effect on local irrigation uses and institutions is negligible.

8.3.3 STORAGE RIGHTS ISSUES

The major water rights issue in the study pertains to increased storage rights required for the enlarged impoundments included in some of the alternative designs. The question is, how will these additional storage rights be provided?

For the purpose of considering the storage rights question and other social-institutional implications, the alternatives listed above may be narrowed to three. Alternatives 2 and 3 may be combined with alternative 1 for further consideration of storage questions because the increments of storage provided by the new dam downstream over and above the amounts of storage proposed in the upstream alternatives will be dead storage. Since the Bear River Compact provides for an annual allocation to storage, if by agreement among water users, an increment of the storage allocation were held over each year in the new impoundment proposed under alternatives 2 and 3, the extra dead storage capacity would be filled in a few years time. Once filled, any new reservoir would be operated with exactly the same flows as contemplated for alternative 1. Thus, only alternative 1 is considered further in this assessment.

Storage in the existing impoundment, amounting in total to 28,000 acre-feet, come in part from allocations to Utah and Wyoming under the Bear River Compact and in part through a contract with Utah Power and Light Company for rights in Bear Lake. The Utah Fish and Game Department provided part of the construction funds in return for minimum water releases from the reservoir, and the Wyoming Game and Fish Department provided funds in return for maintenance of a dead pool in the reservoir as a fishery resource. Thus, the storage capacity in the reservoir is allocated as follows:

18,240	acre-feet irrigation storage
4,260	acre-feet irrigation hold-over
4,000	acre-feet fishery storage
1,500	acre-feet dead storage
28,000	acre-feet TOTAL

The irrigation storage is divided with 15,240 acre-feet to the Utah Woodruff Narrows Reservoir Company and 3,000 acre-feet to the Wyoming Woodruff Narrows Reservoir Company.

If the Amended Bear River Compact is ratified, as it appears that it will be, the additional storage rights (estimated to be 25,200 acre-feet) could be provided within the 70,000 acre-feet of new storage granted to Utah and Wyoming in the revision.

Should the amended compact fail to be ratified, the problem of obtaining additional storage rights for the enlargement becomes potentially more difficult. Most of the 25,200 acre-feet required for the enlargement (alternative 1) would have to come from the conversion of existing direct flow rights to storage rights. In this situation, the Utah Woodruff Narrows Reservoir Company, the major operating entity of the dam and reservoir, would probably request the Utah State Engineer to approve the conversion of 10,000 acre-feet of prior direct flow rights (prior to the original Bear River Compact) to be converted to storage rights. An additional 10,000 acre-feet of Bear Lake rights might be purchased by the reservoir companies from Utah Power and Light Company, and the remaining 5,200 acre-feet could be provided by Wyoming users partly through conversion of direct flow rights and partly from unused storage rights granted under the original compact.

All three of the aformentioned sources of storage rights that might be pursued in the absence of a compact revision, pose potential legal complications. Even if the Utah State Engineer were to approve the conversion of 10,000 acre-feet of direct flow rights to storage rights, the State of Idaho may object on the grounds that the compact is being violated. The issue could be tied up in litigation for several years. Idaho might also challenge the right of Utah Power and Light Company to sell water rights to 10,000 acre-feet in Bear Lake. And, there is uncertainty whether Wyoming users would be willing to provide the final 5,200 acre-feet increment of storage required. However, the latter could be obtained from hold-over storage if necessary.

A possible outcome of failure of the compact revision to be ratified is for the ensuing legal disputes between the states to go eventually to the U.S. Supreme Court where an adjudication of the entire Bear River could be made. In any event, it appears that considerable delay ought to be anticipated in obtaining additional storage rights for a Woodruff Narrows Dam enlargement should the current compact revision effort fail.

8.3.4 DAM CONSTRUCTION PERMIT

In as much as the dam and reservoir are located in the State of Wyoming, approval of the enlargement and additional storage in the reservoir will have to be obtained from the Wyoming State Engineer. The necessary applications have been filed with Wyoming by Utah and preliminary discussions between officials of the two states indicate that Wyoming approval will be given when the water rights issues are settled and the storage allocations are clearly defined.

8.3.5 DEPLETION LIMIT

The additional irrigation storage provided by the enlargement at Woodruff Narrows would, of course, increase depletion of the water in the river. If depletion were to go up in amount to the 28,000 acre-feet compact limit, there would be a minor loss in power production at the five Utah Power and Light Company hydroelectric plants down river. For example, at Cutler Dam, where there is approximately 1 million acre-feet of discharge annually, the 28,000 acre-feet of depletion would amount to 2.8 percent of the flow. At other dams upstream from Cutler where the flow is smaller, the percentage of depletion loss would be slightly higher. However, without the Amended Bear River Compact, groundwater development above Bear Lake may deplete the system by a greater amount than the proposed 28,000 acre-feet limitation.

Calculations made by the Bear River tri-state negotiating technical subcommittee indicate that 31,000 acre-feet could be depleted in the upper divisions of the river without interfering with downstream irrigation rights.

CHAPTER 9

SOCIAL ASSESSMENT

9.1 INTRODUCTION

9.1.1 THE NATURE OF SOCIAL IMPACTS

Social impacts of resources development projects are generally secondary and tertiary in nature. They occur as a result of other kinds of impacts, principally economic and environmental. Understanding social impacts, then, becomes largely a task of understanding the implications of the primary kinds of impacts.

9.1.2 ELEMENTS OF SOCIAL ASSESSMENT

To facilitate the identification and assessment of the social impacts of natural resources development, several agencies have proposed checklists of social, economic, and environmental variables that are subject to change induced from natural resources development projects and which may indicate potentially important social impacts, both beneficial and adverse. In response to the Principles and Standards of the Water Resources Council, several federal agencies have developed checklists for the social assessment of water resources development projects. These checklists form a starting point in the social assessment process. They are used to ensure that important social impacts are not overlooked and to guide data collection where information for assessment is lacking. Such a checklist, developed by Abt Associates, Inc. (Fitzsimmons et al., 1975), for the U.S. Bureau of Reclamation, has been used to structure the social assessment of the potential impacts of low-head hydropower development on the Woodruff Narrows Dam. As will be detailed in subsequent sections, the social assessment checklist has five major parts:

1. Individual and personal effects
2. Community and institutional effects
3. Area socio-economic effects
4. National emergency preparedness effects
5. Aggregate social effects

9.1.3 ALTERNATIVES

Due to deteriorating spillway conditions and other factors, the existing dam will have to modified in the near future. One possibility that has been considered for such modification is to change the spillway location on the existing dam and add a run-of-river hydropower generating facility. This option will be used as a baseline case for considering the effects of low-head hydroelectric development. Three alternatives to this baseline have been considered and are described in detail in Chapter 4:

1. Enlarge the present dam;
2. Construct a low dam downstream from the present dam site; and
3. Construct a high dam downstream from the present dam site.

Each of these three alternatives would include run-of-river power installations. The baseline case would produce approximately 3.4 gigawatt-hours, would inundate no additional land, and would provide 18,240 acre-feet of active storage for irrigation. The first alternative above would produce approximately 5.0 gigawatt-hours, would inundate about 620 acres more than the baseline, and would provide approximately 34,000 acre-feet of active storage for irrigation. The second alternative would provide about 7.1 gigawatt-hours, would inundate an additional 760 acres, and would supply about 34,000 acre-feet of active storage for irrigation. Finally, the third alternative would produce about 8.3 gigawatt-hours, would inundate an additional 1,440 acres, and would provide about 34,000 acre-feet of active storage for irrigation.

9.2 PRESENT SOCIAL CONDITIONS

9.2.1 GENERAL

Rich County, Utah, the county to be affected most by the proposed development, is a rural area with a present population of approximately 1,600. The major towns in the area are Woodruff and the county seat, Randolph. The county population has been declining at an average annual rate of about 0.4 percent for two decades. More than 70 percent of the population is native to the state, and less than 1 percent is non-Caucasian. The median family income in the county ($8,051 in 1970) typically runs 10 to 15 percent less than the state figure. There are approximately 170 farms in the county, and most of these had a gross income of less than $40,000 in 1974. Most are involved in livestock production. The per acre value of farmland in the county is among the lowest in the state.

9.2.2 HISTORY.

The early history of Rich County saw substantial influence on the part of explorers and trappers in the early 1800s and Mormon pioneers in the

1860s and 1870s. From the beginning, the major economic focus and use of the land in the county was livestock grazing. A more complete review of the history of the area can be found in a document prepared by Planning and Research Associates (1972).

9.2.3 REGIONAL RELATIONSHIP

As indicated by Planning and Research Assoicates (1972), Rich County is isolated from the major interstate lines of transportation and traffic except along the extreme southern portion of the county. At the present time there are no regularly scheduled airline stops and railroad service is available only indirectly through Wyoming or along the county's extreme southern boundary.

Most consumer goods are trucked into the area in exchange for agricultural products which are exported. The major metropolitan areas, while indirectly accessible, have little influence on the economy of Rich County except in providing the homes for the people who have contributed to the increasing recreational trade in Bear Lake area. While improvements are constantly being made to the agriculture and livestock sectors of the local economy, the greatest economic changes are expected to be those related to the development of recreation homes and water sports in the Bear Lake area.

9.2.4 EMPLOYMENT

The principal incentive for permanent settlement of Rich County was agricultural interest. However, in recent years the number of jobs provided by the agricultural sector in the county has declined. At the same time, the mining industry and government have increased in importance as sources of employment (though mining employment has fallen since 1970). This is illustrated in Table 9.1.

Table 9.1: Rich County Population and Employment Characteristics for selected years.

		Employment			
Year	Population	Agriculture	Mining	Government	Total (all sectors)
1950	1673	350	6	80	583
1960	1985	260	59	87	600
1970	1615	140	120	120	490

9.2.5 POPULATION

As indicated in Table 9.1 (much better documentation can be found in the reports by Planning and Research Associates (1972); the Resource Conservation and Development Project Executive Board (1974); the County Economic Facts of the Utah Industrial Development Information System; and census documents published by the Bureau of the Census), the county population has been decreasing over the last two decades. A major cause of this decline is the low availability of jobs. This decrease in county employment is attributed to increasing farm labor and equipment cost which have lead to fewer but larger and more mechanized farms employing fewer people. In addition, the county has experienced a leveling off of phosphate mining in recent years, a factor which has also aggravated the employment situation.

This decline in population has shifted the age distribution toward the older age classes. This means that the younger population has been leaving the county in the prime of their occupational life. Presently, recreational development at Bear Lake is the single most important element in the county's population and economic outlook, with the populations of Randolph and Woodruff on the other side of the county expected to remain at approximately present levels.

9.2.6 AGRICULTURE

As indicated in the report by Planning and Research Associates (1972), the number of farms in the county has shown a decreasing trend since 1935 (274 farms in 1935 versus approximately 170 presently). At the same time, total farm acreage has increased. Over 90 percent of total farm income is from livestock production, with the principal emphasis on beef cattle, especially calf production.

9.2.7 RESOURCE PROBLEMS AND OPPORTUNITIES

As indicated by the Resource Conservation and Development Project (RCDP) Executive Board (1974), the aggregate annual shortage of irrigation water for the county is approximately 40,000 acre-feet. In addition, soil surveys show an additional 130,000 acres of land in Rich County suitable for irrigation if water could be made available. On this basis, the RCDP Executive Board (1974) recommended enlargement of the Woodruff Narrows Reservoir by approximately 30,000 acre-feet to provide supplemental irrigation. They could provide no information, however, on the county population and economic impacts that would result from the proposed enlargement.

9.3 ASSESSMENT

9.3.1 INTRODUCTION

As discussed above, the basis for the social impact assessment is the checklist and procedures outlined by Abt Associates, Inc., as adopted by the U.S. Bureau of Reclamation. The following assessments were based on categories supplied from the Abt checklist, which can be found on pages 203 to 240 of that document. The social impact categories in Tables 9.2 through 9.5 are numbered as they are in the checklist.

9.3.2 INDIVIDUAL AND PERSONAL EFFECTS

The first component of the social well-being account is concerned exclusively with the impacts of the baseline and alternative plans as they are experienced at the most basic level, that of the individual and family. This component focuses on how each alternative plan will affect the personal health and well-being of members of the community and whether various aspects of the plan will contribute to or detract from the quality and stability of family life. There are five major categories in this component:

1. Life, Protection, and Safety encompasses the effects of natural disasters on life and property and the possible diminution of such effects by alternative development plans.

2. Health encompasses both the health of individuals in the community and the services and facilities available to deal with health problems.

3. Family and Individual deals with the potential direct and indirect impacts of alternative water plans on the health, well-being and personal satisfaction of individuals in the community and on the structure and stability of family life.

4. Attitudes, Values, and Beliefs discusses the attitudes of individuals in the community towards alternative water plans and the extent to which these plans affect people's attitudes towards other concerns, including their community, the environment, government agencies, etc.

5. Environmental Contributions deals with community members' interaction with their environment and the extent to which alternative plans may affect this interaction; e.g., by contributing to or detracting from individuals' enjoyment of their environment.

Table 9.2 summarizes the expected impacts under this component. The impacts center around the provision of supplemental irrigation supply in alternatives 1 to 3, the contribution toward repayment of construction costs which hydropower would make, and the potential loss of grazing land to inundation in alternatives 1 to 3. In general, the addition of hydropower generating facilities would be looked upon very favorably by area water users if it would enhance the development of supplemental irrigation water. The major potential drawback from this positive benefit would be the loss of some grazing land under each of the alternatives.

9.3.3 COMMUNITY AND INSTITUTIONAL EFFECTS

The Community and Institutional Effects component of the Social Well-Being Account contains 11 categories which are concerned with the impacts which might occur at a higher level of aggregation than those in the first component, but which are still limited to the confines of the community (or communities) which will potentially be affected by the alternative plans. Here the focus is on groups of people, there activities as members of different groups, the various aspects of the community which affect their lives, and the informal and formal institutions which serve them. Equally important is the nature of the community itself as an entity, its composition, its internal structure, etc. The 11 evaluation categories which characterize the Community, Institutional Effects component of the Social Well-Being Account are as follows:

1. Demographic relates to the structure of the community in terms of size, ethnicity, marital status, age/sex distribution, etc.

2. Education deals with educational institutions within the community (primary, secondary, and post-secondary academic education as well as vocational training), and with their activities and capacity.

3. Government Operations and Services deals with the structure, size and complexity of local government, and the services which government provides to members of the community.

4. Housing and Neighborhood concerns the quality and quantity of housing in the community, as well as the condition of its neighborhoods.

5. Law and Justice deals with the criminal justice system in the community and the possible impacts in terms of criminal and civil violations which might result, either directly or indirectly, from the implementation of a water resource plan.

Table 9.2

Description of Impacts for the Individual and Personal Effects Components

Category	Description of Impacts			
	Baseline	Alternative 1	Alternative 2	Alternative 3
A. Life, Protection, and Safety 2. Property loss due to water-related natural disasters	No change from present conditions	All alternatives would provide substantially increased flood control with the addition of about 34,000 acre-feet of active storage		
D. Attitudes, Beliefs, and Values 1. Resident expectations of what will be the impacts of the plan; attitudes about the effects a. hydropower	Local support for potential hydropower production is indicated in the resolution of support for a hydropower feasibility study passed by the stockholders of the Woodruff Narrows Reservoir Company, January 31, 1977. Hydropower production could be seen as a positive benefit of the baseline and all alternatives in its contribution to repayment of dam construction costs depending on the revenue from power production.			
b. augmented water supply	No change from present conditions	Provision of additional active storage for irrigation will be seen by water users as a positive benefit, but inundation of some grazing lands might be viewed negatively by a few area ranchers		

6. Social Services concerns the public and private sector services available to various population groups within the community (e.g., children, youths, elderly persons, etc.).

7. Religion deals with the religious structure of the community and the extent to which religion affects the lives of community members.

8. Culture concerns the ethnic composition of the population and its associated values and folkways, as well as cultural "materials" (e.g., archeological sites, artifacts, etc.) found in or near the community.

9. Recreation relates to public recreational facilities, and land and water areas in or near the community used for lpublic recreation, and to changes in recreational uses which might occur as a result of the implementation of a water-related plan.

10. Informal Organizations and Groups discusses community groups which are not a part of the local governmental or institutional structure, including fraternal organizations, advocacy groups, religious or ethnic societies, environmental groups, etc.

11. Community and Institutional Viability focuses on the capacity of a community's institutions to meet demands for a range of services, on the inter-relationships among community institutions, and on the members' views of their community.

No significant social impacts are expected for any of the three alternatives for this component. As indicated in Table 9.3, no demographic effects are anticipated.

In addition, since the area is not one of high recreation demand as compared to more accessable sites in the area (the report by Planning and Research Associates, 1972, ranks the Woodruff Narrows facility as only fair for nearly all water-based recreation activities), very marginal impacts (if any) on water-based recreation access and use will be likely to result.

9.3.4 AREA SOCIO-ECONOMIC EFFECTS

The Area Socio-Economic Effects componet contains seven evaluation categories which exist at a higher level of aggregation than either the individual/family or the community levels. Although several categories seem to contain aspects which may be applicable at the community, institutional level, the categories have been grouped under this particular component because their consideration may involve more than one community, or because they are important enough to pervade several aspects of community life at once; i.e., consideration of transportation, for example, cannot be limited

Table 9.3

Description of Impacts for the Community and Institutional Effects Component

Category	Description of Impacts			
	Baseline	Alternative 1	Alternative 2	Alternative 3
A. Demographics				
1. Changes in general demographic makeup of the population	No substantial, long-term changes in the demographic make-up of the area are anticipated from the baseline or any of the three alternatives			
I. Recreation				
1. Annual use of public recreation facilities	Little if any increase in use of water-based recreation is expected	Water-based recreation potential (especially fishing) will be augmented under each alternative. However, due to the abundant supply of high-quality recreation opportunities elsewhere in the region, increased use will be slight at most.		
2. Types/Condition of roads to and from recreation facilities	Access to the immediate area at and below the dam sites will likely improve under all three alternatives. This will probably have little impact on recreational use in the area.			
10. Area in miles of water-related recreation areas	No change from present conditions	Moderate increase in total lake surface area (from about 1600 acres to approximately 2300 acres)		Large increase in total lake surface area (from about 1600 acres to approximately 3100 acres)

to the community level alone, since transportation by definition frequently relates to exchanges among communities. Likewise, a discussion of the economic base of a community and the changes which might occur in the economic base as the result of a water resource plan's implementation, must give consideration to the more far-reaching effects which accompany changes in the economy, such as changes in housing, public and private sector services, etc. The categories discussed here are thus of a fairly broad, comprehensive nature, although their focus will sometimes be within the community context. The seven evaluation categories which make up the Area, Socio-Economic Effects component of the Social Well-Being Account are as follows:

1. Employment and Real Income deals with the means by which people in the area earn their living and the amount of income which they receive.

2. Welfare and Financial Compensation deals with the quality and quantity of benefits (including money and services) provided to people who, for various reasons, are unable to support themselves.

3. Communications discusses various inter- and intra-community methods of communications, including personal and media methods, and considers how a water-related plan may affect communciations and may be affected by them.

4. Transportation deals with public and private transportation, both within and between communities, as well as with the condition and location of roads and waterways used for various types of transport.

5. Economic Base deals with the overall economy of the area, including types of industry (and/or agriculture) which exist in the community, the changes which might occur in industry and agriculture as a result of a water-related project, and the extent to which these changes will have a social impact in the community.

6. Planning deals with the period during which alternative plans are formulated and analyzed, and the effects which the planning period might have on the community(ies) under consideration for plan implementation.

7. Construction concerns the potential short- and long-term effects of construction, ranging from temporary noise and other annoyances to long-range economic and social impacts.

As documented in Table 9.4, the most significant social impacts in this component will be the income and employment effects. Especially significant will be the increased income realized by irrigation users. All three alternatives would allow them supplemental late-season irrigation water for providing additional fall grazing. This will probably result in the creation of a few agricultural sector jobs. Some grazing land will be inundated under each alternative, however.

Minimal impacts are expected from short-term construction effects. Workers required for the construction phase of the three alternatives will never number more than 20, and this will be only a short time period. This will result in minimal physical disruption and changes in local demand on public and private services.

9.3.5 NATIONAL AND EMERGENCY PREPAREDNESS EFFECTS

The National and Emergency Preparedness Effects component deals with the way in which the changes brought about by the plan would have selected national impacts. In many cases, these changes will, in fact, be limited to the geographical area covered by the plan; in others, however, changes could contribute to (or detract from) national viability, especially in the case of emergencies such as drought, floods, or attacks by hostile forces. There are nine evaluation categories in this component:

1. Water Supplies deals with questions of the quantity, stability, distribution, etc., of water.

2. Food Production concerns provision of reserve food production potential, as well as questions of exportability of crops.

3. Power Supplies deals with questions concerning the quantity, stability, and responsiveness of available power.

4. Water Transportation discusses tonnage support capacity and network location characteristics, as well as the area covered by water transportation routes.

5. Scarce Fuels concerns the use of abundant fuels to conserve scarce ones and the use of alternative power supplies.

6. Population Dispersion relates to potential for settlement of areas in the event of a national emergency.

7. Industrial Dispersion is concerned with the potential for dispersion and relocation of industry in the event of a national emergency.

Table 9.4

Description of Impacts for the Area Socio-Economic Effects Component

Category	Description of Impacts			
	Baseline	Alternative 1	Alternative 2	Alternative 3
A. Employment and Real Income 5. Mean income by class of worker or recipient	No change from present conditions	In general, area incomes will not be appreciably affected by any of the alternatives. An exception to this would be increased income to irrigation users. Most of the supplemental water provided by each alternative would be used in July and August to provide additional grass forage after the meadow hay is harvested. This would generate fairly substantial income to the area as shown in Chapter 6. Some income losses might result, however, from loss of grazing to inundation.		
25. (Other) Number of jobs in area	The addition of hydropower will result in the creation of one new full-time equivalent	The addition of hydropower will result in the creation of one new full-time equivalent. Additional income to irrigation users will likely result in fewer than 10 new jobs.		
E. Economic Base 12. Land used for grazing and farming	No change from present conditions	Each alternative will provide supplemental irrigation water for approximately 5,000 to 8,000 full-service acre equivalents. Alternatives 1 and 2 will result in moderate loss of grazing land (ranch land inundated by Alternative 1 has already been purchased); Alternative 3 will inundate substantially more grazing land.		
G. Construction 1. Short-term effects	The short-term construction impacts (in terms of physical disruption, transient housing requirements, and change in demand for public and private services caused from an influx of workers) will be minimal under the baseline and all three alternatives. There will be a maximum of 20 workers at the site for a three-month period; peak employment will be between 10 and 20 workers during construction of the spillway, only.			

8. Military Preparedness relates primarily to the potential of a given area to house military bases and/or support military operations in a national emergency.

9. International Treaty Obligations deals with the questions of boundaries, use of common bodies of water, treaty obligations governing quantity and/or quality of water crossing international boundaries, etc., among neighboring nations.

The social impacts in this component of the Social Well-Being Account are all positive, though quite minimal as viewed from a national perspective. As documented in Table 9.5, the baseline and all alternatives will have slight impacts on the supply and stability of power and the use of scarce fuels. The power generated at the site would be wheeled over UP&L transmission lines and used outside the area of production. Altogether, the nominal power production estimates represent positive but very slight impacts on the national scale.

9.3.6 AGGREGATE SOCIAL EFFECTS

The Aggregate Social Effects component involves the aggregation of potential impacts of water resource projects as they relate to social effects as a whole. While the previous components focus on more practical concerns for the most part, it is also desirable to be able to consider the more general social implications of alternative water resource plans. The measures of impact for this component are almost entirely qualitative in nature. Three evaluation categories are of interest here:

1. Quality of Life deals with the physical and mental well-being of the individual and family and with their perceptions of the opportunities for further development of individual and family life in the future.

2. Relative Social Position concerns the extent to which the various social benefits and adverse effects of plan implementation would be equitably distributed among various individuals or groups in the community and the capacity of individuals and groups to bear social costs.

3. Social Well-Being refers to the overall impacts on the character and capacities of the community and its institutions, both formal and informal.

On the aggregate, the social impacts of the three alternatives are negligible. No substantial positive or negative effects are expected for

Table 9.5

Description of Impacts for the National and Emergency Preparedness Effects Component

Category	Description of Impacts			
	Baseline	Alternative 1	Alternative 2	Alternative 3
C. Power supplies 1. Changes in the amount of power produced	Increased power production: 3.4 gigawatt-hours	Increased power production: 5.0 gigawatt-hours	Increased power production: 7.1 gigawatt-hours	Increased power production: 8.3 gigawatt-hours
2. Changes in the stability of power supply	All power generated at the site will be sold outside of the local area. The amount of power produced will not be very significant from the standpoint of the stability of national or regional power supply.			
E. Scarce Fuels 1. Changes in the amount of scarce fuels consumed	Hydropower production under the baseline and the three alternatives would result in a savings of up to approximately 1250 barrels of oil per year.			

any of the three alternatives in terms of Quality of Life or Social Well-Being. From the standpoint of Relative Social Position, very slight decreases in public grazing acreage will have to be absorbed under alternatives 2 and 3. All owners of private land that would be inundated in alternative 1 have already been compensated. Under each of the alternatives, fairly significant income benefits would accrue to irrigation water users, who would, of course, be partially responsible for repayment of the costs of dam construction. Very modest increases in agricultural employment would be expected for each of the alternatives. This would benefit the entire county.

9.4 SUMMARY

In summary, neither the baseline nor any of the alternatives under consideration will have very significant negative social impacts. The proposed alternatives will result in little or no change in present patterns of water and land use, income, population, and employment. The very slight positive impacts from any of the three alternatives will not result in any significant changes of the social structure or character of the area. The most significant social and economic trade offs will be in the provision of additional late-season irrigation water versus inundation of some grazing land in alternatives 2 and 3. The inclusion of low-head hydropower in a Woodruff Narrows storage facility, such as envisioned in alternatives 1 to 3, might contribute to the economic viability of the project. If the project proves feasible, fairly substantial local economic benefits could be realized from increased agricultural productions. This would be a desirable social impact to the local community, especially if grazing losses could be compensated.

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CHAPTER 10

ENVIRONMENTAL ASSESSMENTS

10.1 NATURE OF ECOLOGICAL IMPACTS

The analysis of the impact of the proposed Woodruff Narrows Low Head Hydroelectric Power Plant (WN LHHPP) depends on the particular proposed changes in the Bear River system and their significance in terms of magnitude and qualitative effects on the stream ecological systems. Impacts of stream alterations on aquatic ecosystems have been assessed in many different projects and provide some generalizations as suggested in Figure 10.1. It is apparent from the relationships described in Figure 10.1 that the impact in a specific situation depends greatly on the magnitude of the proposed actions. As a means of developing a logical environmental assessment of the proposed action, the WN LHHPP impacts will be approached in the following steps: 1) a description of the proposed site and action, 2) an analysis of important variables, and 3) a specific assessment of the Bear River in the immediate and downstream areas of the project.

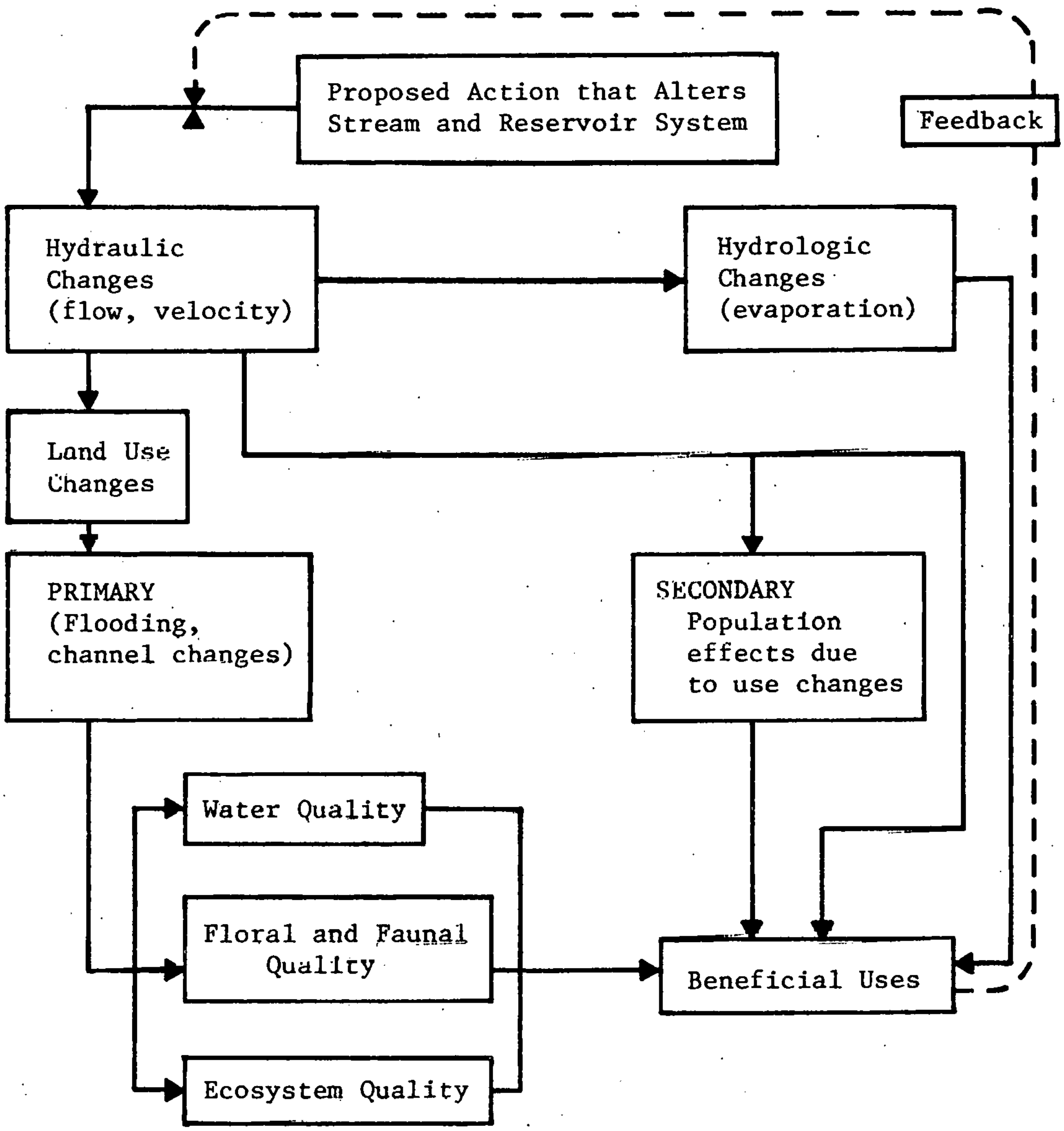
10.2 GENERAL DESCRIPTION

A general description of the Bear River has been given previously in Chapter 3 and will not be repeated here. Some general comments related to water quality follow.

Because much of the mountain land in the headwaters of the Bear River is wilderness area, the water is nearly pristine. Some recreational use by hikers in the Uinta wilderness area and the presence of grazing animals in the area upstream from Evanston may have had some minimal effects on water quality, but it is not possible to detect them. The first noticeable changes apparently occur after the river passes through the Wyoming portion of Bear River Valley prior to entering Woodruff Narrows Reservoir. Several large feedlots, an old oil-coal mining development just north of Evanston, and other agricultural activities begin to affect the quality of the Bear River significantly. A state recreation area is located adjacent to the reservoir, but the reservoir is primarily for irrigation not recreation.

After leaving the Woodruff Narrows Reservoir the Bear River continues its course through mostly agricultural areas until it eventually reaches the Bear River Migratory Bird Refuge and the Great Salt Lake. The water quality at that point has been seriously impaired, but most of the change has taken place below the Woodruff Narrows Reservoir.

Figure 10.1



Assessing environmental impacts of stream flow alterations such as dams, power plants, diversions (import and export).

In its 500 mile journey to the Great Salt Lake, Bear River drains 4,778,000 acres having annual precipitation of 8-40 inches/year, loses about 8,500 feet in elevation, achieves flow near 12,000 cfs, accumulates significant quantities of specific pollutants, and journeys through mountain lands, cold northern deserts and fertile river valleys important to the area's economy. The Bear River accumulates flows from six major tributaries and forms four reservoirs including Woodruff Narrows and many small diversion dams along its route; in addition, Bear Lake is utilized as a reservoir.

In the immediate area of the proposed WN LHHPP there is some recreational activity (camping, fishing, boating, bird and deer hunting), grazing, and residences. Otherwise use and resource interference is minimal.

Throughout the length of the Bear River, flow and power requirements are closely controlled; irrigated acreage is stable and flood control, irrigation, and recreational use are additional multiple uses of the basin waters. A major advantage of WN LHHPP would be its minimal impact on these uses.

10.3 BEAR RIVER WATER QUALITY STANDARDS

Because the major impact of actions in Woodruff Narrows Reservoir would be expressed in the immediate downstream reaches which are in Utah, only Utah water quality standards were assessed.

The Utah State Division of Health has described standards (dated August 2, 1971) which have been applied to the Bear River System (June 23, 1972) and which have been accepted by the Environmental Protection Agency. These standards are defined as the class "C" Water Quality Requirements. The standards state:

"It shall be unlawful to discharge wates resulting in:

Objectionalbe deposits
Floating debris, oil, scum, and other matters
Objectionable color, odor, taste, turbidity
Interference with class "C" water uses

Uses of class "C" waters:

Municipal
(following complete treatment)
Aesthetics
Irrigation
Stock watering
Fish propagation
Wildlife

Recreation
(except swimming)
Industrial supplies
Other (as determined by the Utah State Board of Health and Utah Water Pollution Committee)

The standards listed in Table 10.1 shall not be violated." In addition specific reaches of the Bear River system have been further classified for thermal discharge to prevent undue heating of the water and the resultant significant effects on fish and other aquatic life. Also, these requirements further limit the minimum level of dissolved oxygen (DO) in the stream. The reader should be aware that the amount of oxygen capable of being held by water descreases as the temperature of the water increases. These modifications are noted by the appending of "C" for cold and "W" for warm waters as follows:

Class "CC" -- 2°F incremental increase and not above 68°F; DO is 6 mg/l minimum.

Class "CW" -- 4°F incremental increase and not above 80°F; DO is 6 mg/l minimum.

Class "CCR" -- 2° F incremental increase and not above 68°F; DO is 6 mg/l minimum; MPN coliforms 1000/100 ml upper limit (average).

As shown on the schematic drawing of the Bear River on Figure 10.2, reaches of the river have been defined to meet one or the other of these three classifications. Those reaches not so classified are in the general classification of "C" which has no temperature requirement and a lower dissolved oxygen minimum of 5.5 mg/l. The downstream reaches are CW reflecting the greater warming of the water but not the quality degradation which has taken place with distance from the headwaters of the Bear in the Uintas.

In the Woodruff Narrows reach the water is classified as CC. Because the LHHPP is not a water quality degrading process, the only variables that might be affected are those which respond to physical changes. Reservoirs and power plants tend to increase water temperatures of streams; however, the change in water temperature due to the proposed activity will be minimum and no effects of LHHPP on water quality variables are expected.

10.4 PROPOSED CONSTRUCTION OF WN LHHPP

The proposed WN LHHPP is designed to be located at or within approximately two miles of the existing Woodruff Narrows Dam. Impacts of the several alternatives considered would probably be contained within a ten mile reach of the river (Figure 3.1) except those downstream effects that might result from alterations of flow. Essentially, three alternative situations must be

Table 10.1

Utah class "C" stream standards for specific constituents and pollutants

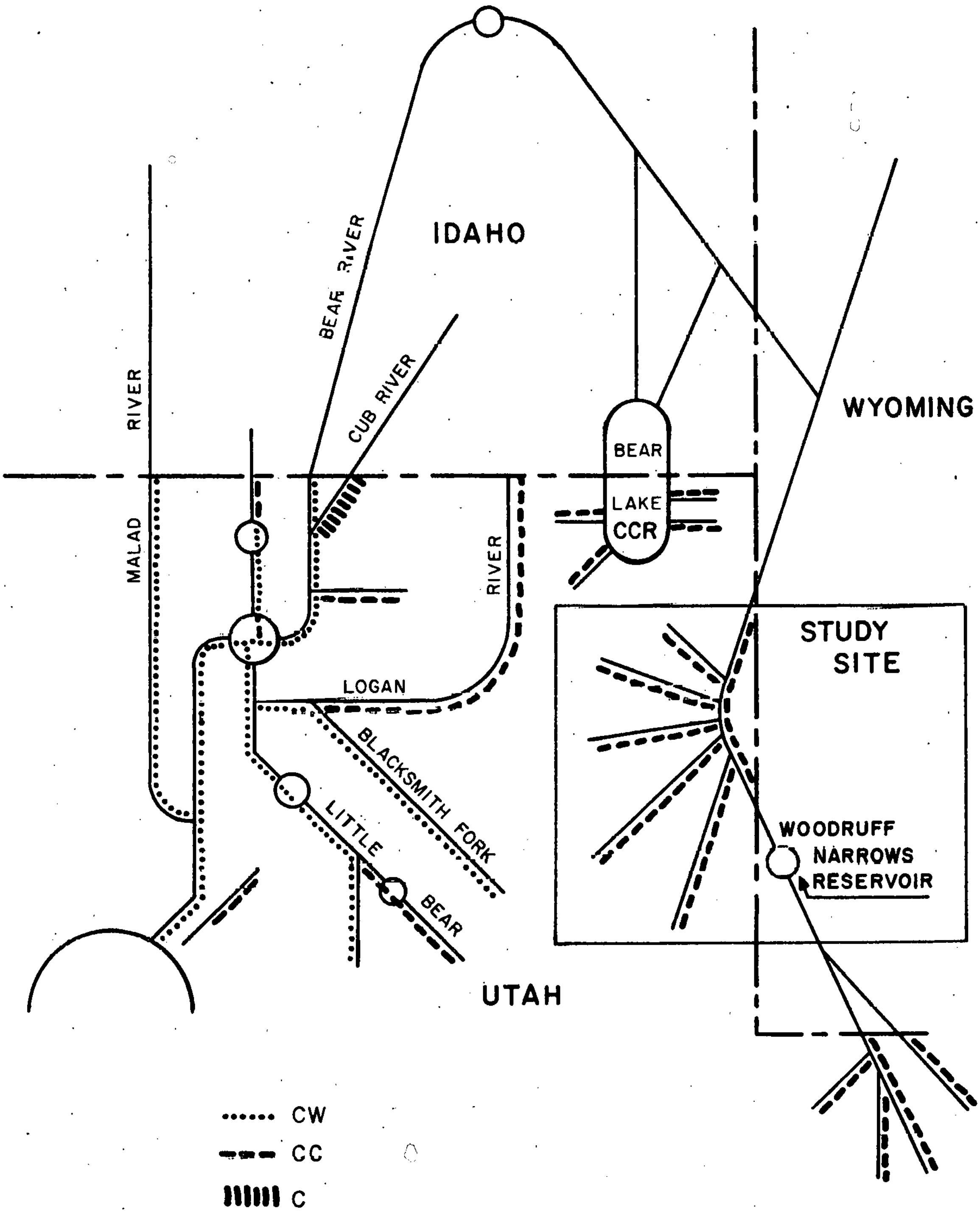
Item	Limit: Recommended mg/l	Limit: Mandatory mg/l
TDS	500	-
As	0.01	0.05
Ba	-	1.0
CCe	0.2	-
Cd	-	0.01
Cl	250	-
Cr	-	0.05
Cu	1.0	-
CN	0.01	0.02
F	1.0	2.0[a]
Fe	0.3	-
Pb	-	0.05
Mn	0.05	-
NO_3	45	-
Phenol	0.001	-
Se	-	0.01
Ag	-	0.05
SO_4	250	-
MBAS	0.5	-
Zn	5.0	-

MPN Coliforms 5,000/100 upper limit (average)
BOD_5 5 mg/l upper limit
DO 5.5 mg/l lower limit
Radionuclides not to exceed 1/30 of the MPC_w[b] values as defined in National Bureau of Standards Handbook 69

[a]Dependent on climate.

[b]Maximum permissible concentration in water.

Figure 10.2



Stream water quality classification in Utah's portion of the Bear River Basin.

considered in comparison with the existing system (Table 10.2). A higher dam could be constructed at the existing site or a dam at the lower site; at the lower site two alternatives were considered, a lower and a higher dam. These dams would cover additional areas of about 620 acres, 760 acres, and 1,440 acres respectively. Inflow to the present and planned reservoirs has averaged 157,000 acre-feet/year and the flow actually used for power generation for the different alternatives ranges between 128,000 and 134,000 acre-feet/year. Increased capacity gives larger surface area so that evaporation increases to 0.6 percent of the inflow. Flow changes for the alternatives downstream of the dam show minimal effects other than a slight decrease in peak values and slight displacement into early spring and to later summer (Figure 10.3). These flow impacts are minimal.

The specific structural and other changes involved in these alternatives are described in Chapters 4 and 7. Generally, the effects of the WN LHHPP would be to increase the amount of land flooded as a result of dam construction and perhaps alter flow patterns within the system. It is perceived that the flow will not be changed significantly because of the requirement for a 10 cfs minimum as required by contract for the Utah Division of Wildlife Resources or the selection of a peaking power option. In other words there would at the most be 8 hours of release for power production within each 24 hour period. This might occur twice a day for periods of 2 to 4 hours.

In general, there would be sufficient release to guarantee 10 cfs over approximately 24 hours. The construction of the WN LHHPP with peaking capacity might require re-regulating ponds and some alteration of the stream and the present dam site. The possible re-regulating reservoir(s) would be essentially diversion ponds and would flood some of the lower lying land in the area and increase the residence time of the water within those specific reaches. Those reaches would be 0.5 to 1 mile in length.

Stream flow requirements for downstream water rights essentially would be unaffected. There is no obligation beyond Pixley Dam (Figure 3.2) and the 10 cfs of the Utah Division of Wildlife Resources would be adequate to meet other requirements (irrigation, etc.) within the region.

Since most stream and reservoir impacts occur as a result of low flows, stream flows were evaluated for the 1977 water year, the minimum observed low flow during the period 1942-1977. The effects of the low flow were to decrease significantly the annual inflow to the reservoir, 157,000 as an

Table 10.2

Woodruff Narrows proposed LHHPP alternatives and their effects on the hydrologic regime

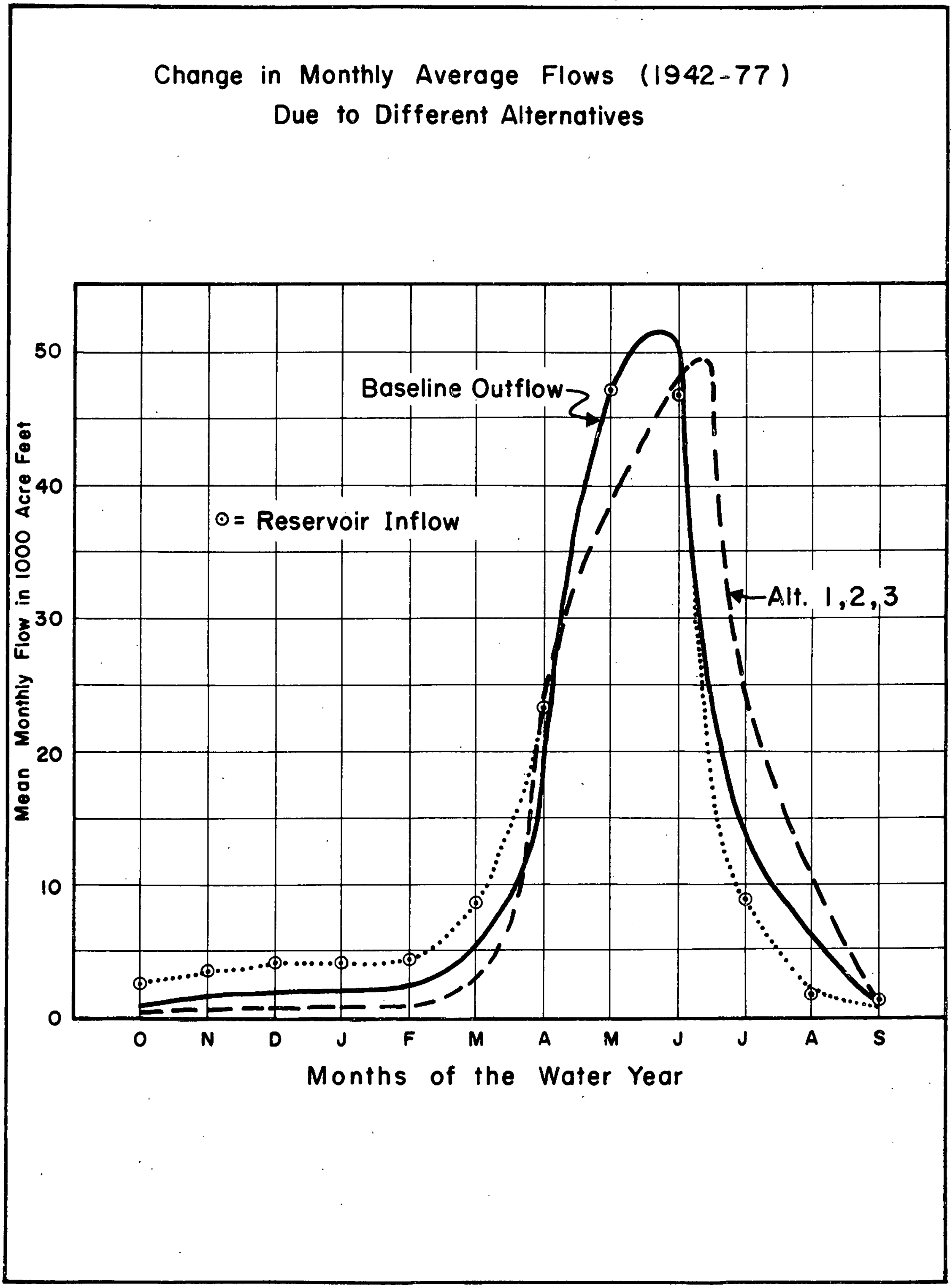
	Maximum WS elev., ft.	1,000 acre-ft/year Capacity	1,000 acre-ft/year Evaporation[a]	1,000 acre-ft/year Average End-of-Year Storage[b]	1,000 acre-ft/year Used for Power	Power Produced GWH	Typical flow Peak, cfs	Generating Capacity MW
Existing Upper Site (Baseline)	6,439.38	28.0	2.07	11.5	0	3.4[c]	0	2.1[c]
Raised Dam, Upper Site (Alt. 1)	6,452.5	53.2	1.94	18.1	128	5.0	600	3.0
Low Dam, Lower Site (Alt. 2)	6,442.5	52.0	2.85	18.4	134	7.1	600	3.9
High Dam, Lower Site (Alt. 3)	6,452.5	76.9	3.02	37.5	134	3.3	600	4.5

[a]mean annual.

[b]Mean end-of-water year storage. See Chapter 5 for hydrologic analysis.

[c]Potential if a generator were added to present dam.

Figure 10.3


Change in Monthly Average Flows (1942-77)
Due to Different Alternatives
Baseline Outflow
⊙= Reservoir Inflow
Alt. 1,2,3
Mean Monthly Flow in 1000 Acre Feet
0
10
20
30
40
50
O
N
D
J
F
M
A
M
J
J
A
S
Months of the Water Year

average' to 33,000 acre-feet for 1977. However, the pattern remained similar even for the different alternatives (Figure 10.4). In the cases of alternatives 1, 2, and 3, the outflow was increased by using previously stored water. Also the peak flows during the runoff season (Figure 10.4) were considerably reduced compared to the average situation (Figure 10.3). Because of flow pattern similarity and the similarity between base flows and alternative flows, the additional impact at minimum flow of a LHHPP was judged insignificant.

10.5 IMPORTANT ASSESSMENT VARIABLES

To identify and assess ecosystem impacts of natural resources development, federal agencies, and others have used checklists of environmental variables that are subject to change due to development projects. Potentially important aquatic ecosystem impacts, both beneficial and adverse, serve as a starting point in the assessment process and ensure that important impacts are not overlooked, and guide data collection where information for assessment is lacking (USBR, 1972; Ross et al., 1978; Cicchetti et al., 1973; Martel and Lackey, 1978).

As Leopold et al. (1971) pointed out for the USGS, these impacts can be divided into two broad categories: 1) Existing characteristics and conditions of the environment, and 2) proposed actions which may cause environmental impact. Within each of these categories several logical groupings have been defined. A selected list of the specific attributes within each category was applied to the Bear River and impact of the proposed WN LHHPP (Table 10.3) was evaluated in terms of a generalized list of specific variables that would apply to other river systems as well as to WN LHHPP. The list of variables was not completely site specific to the Bear River.

10.6 ASSESSMENT CRITERIA

The proposed actions will have impacts on aquatic ecosystems that include 98 listed items grouped as follows: modifying the typical regime, land use transportation and construction, resource extraction, processing, land alterations, resource renewal, changes in traffic, waste emplacement and treatment, chemical treatment, and accidents. Similarly, existing characteristics include 86 specific attributes grouped into earth, water, atmosphere, biological conditions, cultural factors, and ecological relationships. Others are permitted in both categories if identified.

Figure 10.4

Changes in Monthly Flows During the Driest Year (1977) Due to Different Alternatives.

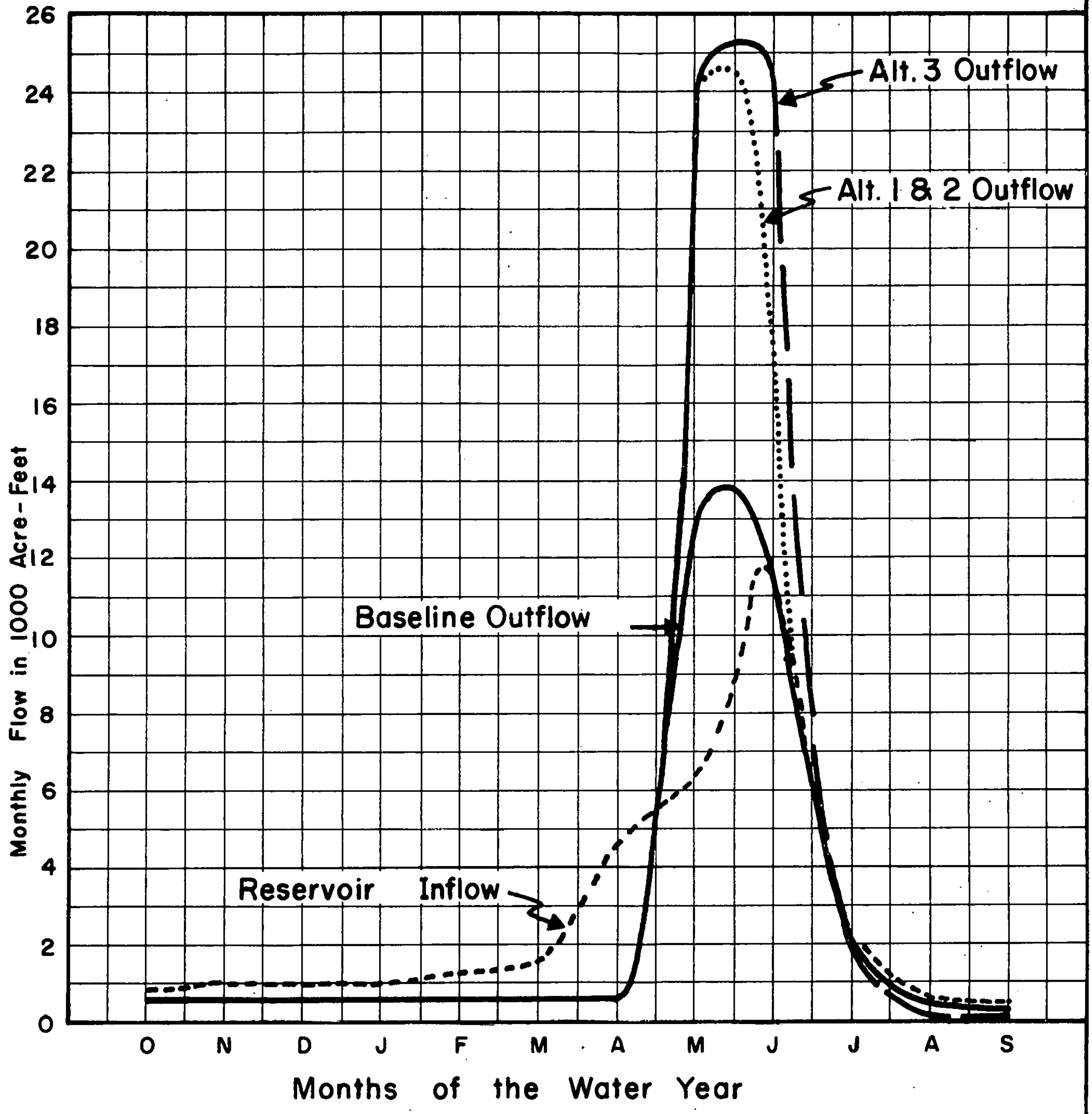


Table 10.3

The potential impacts of changing an existing dam and reservoir system to add low-head hydropower

	Major Actions with Potential Impacts[a]						
	Habitat Modification	River control of flow, etc.	Channel changes	Dams and impoundments	Energy generation	Operational failures	Estimated total measurable impact of proposed WN LHHPP for different alternatives
Water Quality	0	0	0	±	±	0	0
Water Temperature	+	+	0	+	+	0	0
Flooding Characteristics	+	+	0	+	0	-	+ but small
Aquatic plants	+	+	0	+	0	0	0
Terrestrial plants	-	-	0	-	0	0	- but small
Endangered species	±	0	±	±	±	0	0
Fish	±	±	±	±	±	0	+ but small
Macrofauna	±	±	±	±	0	0	0
Migratory Fauna	0	0	0	±	0	0	0
Land uses	0	0	0	-	0	0	- but small
Recreation - Hunting	±	0	0	±	0	0	0
Recreation - Fishing	±	0	0	±	0	0	0
Recreation - Boating	0	0	0	+	0	0	0
Recreation - Misc.	0	0	0	±	0	0	0
Scenic Views	0	0	0	±	0	0	0
Landscape design	±	0	0	±	0	0	0
Health and Safety	0	0	0	±	±	0	0

[a]Potential Impacts: + is positive change (an increase or improvement*)
- is negative change (a decrease or degradation*)
± is either depending on site and specific variable
0 is no effect

*improvement is (+)
degradation is (-)

Those variables most relevant to LHHPP impacts (construction and operation) were identified in Table 10.3. The variables were selected from lists compiled for the USGS (Leopold et al., 1971), the Canadian government (McKee et al., USU, unpublished), the USBR (USBR, 1972), and recent attempts to analyze aquatic ecosystems using computer approaches (Ross et al., 1978; Martel and Lackey, 1978).

The potential impacts generated by developing a LHHPP on an existing dam and reservoir site must be assessed in relation to those produced by the existing conditions. Because quantitative functional relationships frequently do not exist between ecological variables and physical and chemical changes, a subjective evaluation is often used. Although some ambiguity exists when using a + to show increase as well as improvement, the system allows for obtaining a quantitative evaluation for those cases where it is not possible at present to relate increase or decrease to improvement (temperature change). The impact evaluation scheme as noted approximates the USGS system (Leopold et al., 1971). The fact that a potential impact could occur does not mean that the magnitude of the action is sufficient to cause a measurable impact.

In the case of the WN LHHPP, the magnitude of the activity is insufficient to cause any significant impacts. Two factors lead to this conclusion: 1) the magnitude of habitat change of the reach is too small; 2) other factors mask any impacts within the reach.

Essentially about 0.5 percent of the river would be impacted by the action (<2 miles out of more than 400) and very little impact on river flow pattern would occur (Figure 10.3). Additional flooded land could amount to as much as 1.2 square miles but this amounts to only 0.016 percent of the total land area in the basin. Rare and endangered species are not in the immediate area and effects of adding LHHPP would be minimal anyway because the existing dam provides a barrier to migration. The other impacts are in total judged to be negligible.

Although changing of peak flows have been shown to produce changes in habitat in Intermountain streams (Grenney and Porcella, 1976a), the flow changes that are produced by LHHPP are inadequate to cause those changes. Stalnaker (1979) has shown that stream habitat is a good means to evaluate instream flow needs. Again, the effects of WN LHHPP are too insignificant to produce habitat changes of the magnitude suggested by Stalnaker.

Previous attempts using a water quality model to evaluate water quality impacts of alternatives in applying wastewater treatment processes to a region of the Green River in Utah indicated little impacts of the alternatives (Grenney and Porcella, 1976b). Because the relative magnitude of impact was less for the LHHPP on the Bear River, this approach was not applied to Woodruff Narrows. Similarly the EIS evaluation model developed by Martel and Lackey (1978) was not applied because of the insignificance of impacts generated by the proposed action.

The fact that other activities have environmental impacts in the river system and mask LHHPP is insufficient to ignore LHHPP impacts. However, it would be impossible to measure those LHHPP impacts because ecological "noise" would prevent assessment of those impacts. An example is the change in macrofauna (Table 10.4) between a station located upstream of Evanston, Wyoming, and a station downstream of Woodruff. The change in stream character and impact of point and nonpoint waste materials decreased diversity and biomass. Quality variables, stream hydrodynamics, and geomorphic factors all react to cause these changes in the stream macrofaunal community.

10.7 CONCLUSION

Based on an assessment of ecological vairables that would reflect stream ecosystem integrity, it is judged that the Woodruff Narrows LHHPP would have negligible impact on the Bear River ecosystem over and above existing structures and stream operations. Flow patterns, quality and quantity would be essentially unchanged. Sensitive ecological factors appear non-existent for that segment of the Bear River system. Also based on this one example, it appears that WN LHHPP would be a low impact technique for producing hydropower.

10.8 SOURCES OF ECOLOGICAL DATA

Most data were obtained from water quality studies (Sorensen et al., 1976; UWRL, 1974). Other data were reviewed subjectively as needed. Typical EIS data have not been compiled nor collected in this region. Significant collection and analysis would be required to develop such a pool of data and the proposed action is judged to be too insignificant to require such data collection because of low magnitude of impact and low sensitivity of the specific environment.

Table 10.4

A comparison of macrofauna community variables for sampling stations upstream and downstream of the proposed WN LHHPP

USGS Station and River Mile	Diversity[a]	Number of Recorded Taxa	Number Per ft^2	gm biomass Per ft^2
10011500 Rm 401.5	1.90	18	228	1.51
10020500 Rm 334.	1.73	18	2,452	1.07

[a] $d = -\left(\frac{n_i}{N} \Sigma \ln \frac{n_i}{N}\right)$; d is diversity, n_i is the number of individuals recorded in taxon, i, and N is the total number of individuals in the community sampled.

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CHAPTER 11

REGULATORY REQUIREMENTS

11.1 STATE OF WYOMING

11.1.1 WYOMING STATE ENGINEER'S OFFICE

The following information and permits would be required for adding hydro-electric power generation at the Woodruff Narrows Reservoir:

1. A secondary application must be filed for the water stored in the Woodruff Narrows Reservoir under Permit No. 6556 Res., and the enlargement of Woodruff Narrows Reservoir, T.F. No. 22 2/84. This would allow water from both filings to be utilized for power generation in addition to the existing uses.

2. A direct flow filing, S.W. 1 Form, must be filed for water that would be passed directly through the reservoir, and utilized for power generation.

3. A map, certified to by a licensed engineer in Wyoming, must accompany the filings.

11.1.2 WYOMING PUBLIC UTILITY ADMINISTRATION

An application must be filed for the proposed transmission line from the power house to the Utah Power and Light Company 46 KV transmission line.

11.1.3 WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

An application must be filed for the water and waste water disposal from any rest room facilities and for the tailwater discharge at the power house.

11.1.4 WYOMING OFFICE OF INDUSTRIAL SITING ADMINISTRATION

An application must be filed in conformity with rules and regulations of this office.

11.1.5 WYOMING DEPARTMENT OF GAME AND FISH

A set of plans for the proposed development with an appropriate application form must be submitted to the Wyoming Department of Game and Fish.

11.2 FEDERAL AGENCIES

11.2.1 U.S. ARMY CORPS OF ENGINEERS

An application is required for construction of the permanent foundation of the power plant in the river bed below the high water surface.

11.2.2 U.S. BUREAU OF LAND MANAGEMENT

An application has been filed for an easement for the proposed enlargement of the present dam (upper site) for additional land that would be inundated by raising the dam. No additional permits would be required for the upper site since the proposed power development would be built on land owned by the Utah Board of Water Resources and the proposed power transmission lines would be constructed on land either owned by the Utah Board of Water Resources or the stockholders of the Woodruff Narrows Reservoir Company.

If the proposed power development were constructed on a dam at the lower site, an application for additional easements to the U.S. Bureau of Land Management would be required for both inundation of land between the upper and lower sites and for a short distance for the power transmission lines.

11.2.3 FEDERAL ENERGY REGULATORY COMMISSION

If power features are to be added to the Woodruff Narrows Reservoir, it would be necessary to obtain a license from the Federal Energy Regulatory Commission prior to start of construction. At the present time this would require submittal of an application with complete documentation of the proposed project. Since it is larger than 1.500 kw, a total of 20 exhibits must be prepared including statements on water rights, proposed financing, project operation, and an environmental impact statement. A proposal to establish a short-form application or projects of less than 15,000 KW capacity is under consideration by the Congress. If the proposal is enacted, the procedure for obtaining an FERC license for a power development at Woodruff Narrows would be much simplified.

CHAPTER 12

CONCLUSIONS AND RECOMMENDATIONS

12.1 GENERAL CONCLUSIONS

A summary of the results and conclusions reached from this feasibility study are reported below for each item of information required by Cooperative Agreement Number DE-FC07-78ID01767 as listed in Chapter 2 under Scope of Study.

1. Hydropower Configuration and Capacity. Run-of-river hydroelectric power installation was considered for three alternatives which included an intake, penstock, powerhouse, turbine, accessory elecrical equipment, miscellaneous mechanical equipment, access roads, substation equipment, and transmission line. Alternative 1 is the most economical alternative with hydropower development at the existing dam at the upper site raised to provide a reservoir with normal maximum water surface at elevation 6,452.5 feet. Hydropower installation at a low dam and a high dam at the lower site were also considered as alternatives 2 and 3 respectively. The maximum capacities of the hydropower installations for alternatives 1, 2, and 3 respectively are 3,000 KW, 4,000 KW, and 4,500 KW.

2. Hydroelectric Power Characteristics and Production. The power production for the above three alternatives would occur during the 5 month period of April through August with June as the maximum production month. Over 85 percent of the flow of the Bear River at the Woodruff Narrows site occurs during this 5 month period. Peaking power production and a pumped storage alternatives were also considered at the upper site. Peak power production was clearly less favorable than run-of-river alternatives. The pumped storage alternative appeared to be more economical than the run-of-river alternatives when compared to generating power from coal or diesel oil. However, from an analysis of costs and the current market value of energy in the area the pumped storage alternative is no better than alternative 1. The average annual energy production for the pumped storage alternative was 7.6 GWH with a pumping requirement of 5.6 GWH resulting in a net average annual energy production of 2.0 GWH. An estimate of the average annual energy production for alternatives 1, 2, and 3 respectively are 5.0 GWH, 7.1 GWH, and 8.3 GWH.

3. <u>Hydropower Impact on Other Uses</u>. Woodruff Narrows Reservoir is used primarily for irrigation. Hydropower production would be subject to river flows and reservoir releases for irrigation purposes and fish conservation and would not have any significant negative effects. Hydropower development would have a positive effect by providing better regulation for irrigation and flood control during the 5 month period of April through August.

4. <u>Power Marketing Potential</u>. A number of potential users in the area were contacted concerning the marketing of the potential energy that could be developed at the Woodruff Narrows site. The current value of the energy that could be produced is approximately 30 mills per KWH. The power company in the area did not show much interest in purchasing the power but is willing to wheel the power at approximately 9 mills per KWH for a maximum plant capactiy output of 3.0 megawatts based on a charge of $15 per KW-yr and production of 5 GWH per year. Therefore, the net value of the energy produced at the Woodruff Narrows site is approximately 21 mills per KWH.

5. <u>Regulatory Requirements</u>. Hydropower development at the Woodruff Narrows site would require a Federal Energy Regulatory Commission License, a U.S. Army Corps of Engineers permit for construction, water right approvals from the Wyoming State Engineer, and applications filed as required by the following agencies of the State of Wyoming: Public Utility Administration, Department of Environmental Quality, Office of Industrial Siting Administration, and Department of Game and Fish. Alternatives 2 and 3 would require easements from the U.S. Bureau of Land Management.

6. <u>Economic Analyses</u>. None of the three basic run-of-river alternatives or the pumped storage alternative are economically or financially feasible at this time. Alternative 1 is the most favorable alternative. The capital investment per installed kilowatt is $1,094 for this alternative with an average plant capacity of 2,400 KW. The capital investment costs per installed kilowatt for alternatives 2 and 3 respectively are $1,370 and $1,498. The total cost of energy produced by alternative 1 is 51 mills per KWH based on an 8 percent return on investment. If the wheeling charges are added, the total cost of producing the energy is 60 mills per KWH. The rate of return on investment for alternative 1 is less than one percent based on the current net market value of 21 mills/KWH for the energy. Alternatives 2 and 3 are even less favorable than alternative 1. The cost of producing power by alternatives 2 and 3 based on a rate of return on investment of 8 percent including wheeling charges is over 75 mills per KWH.

7. Annual Operation and Maintenance Costs. The annual operation and maintenance (O&M) costs of each alternative were estimated at 1.5 percent of the total capital cost of the project. This resulted in annual O&M costs for alternatives 1, 2, and 3 respectively of approximately $40,000, $72,000, and $90,000. These costs do not include wheeling charges which are estimated at $15 per kilowatt of plant capacity. The wheeling charge could amount to approximately 9 mills per KWH.

8. Anticipated Project Life. The anticipated life of the project was estimated to be 50 years for all alternatives considered.

9. Institutional, Social, and Environmental Assessment. The only institutional problem of any magnitude is the water right problems associated with the tri-state Bear River Compact. The Bear River Commissioners of each state have recently signed an Amended Bear River Compact that would alleviate this problem. The Amended Compact is now before the legislatures of each of the three states for ratification. None of the alternatives under consideration would have significant negative social impacts. The proposed alternatives would result in little or no change in present patterns of water and land use, income, population, and employment. The very slight positive impacts from any of the alternatives would not result in any significant changes of the social structure or character of the area. The most significant social and economic trade offs would be in the provision of additional late-season irrigation water versus inundation of some grazing land in alternatives 2 and 3. Based on an assessment of ecological variables that would reflect stream ecosystem integrity, it is judged that hydropower development at the Woodruff Narrows site would have negligible impact on the Bear River ecosystem over and above existing stuctures and stream operations. Flow patterns, quality, and quantity would be essentially unchanged. Sensitive ecological factors appear nonexistent for that segment of the Bear River system.

10. Safety Considerations. While some safety precautions would be necessary during the construction of hydropower facilities at the site, there are no known or foreseeable safety hazards that would be introduced by the addition of a power plant at the Woodruff Narrows Dam and Reservoir site.

11. Engineering Acceptability of the Site for Hydropower Development. Both the upper site and lower site locations are geologically sound and acceptable from a geotechnical engineering viewpoint for hydroelectric power

development. However, hydroelectric power development at the Woodruff Narrows site is not economically sound at this time.

12. Turbine Availability and Suitability. For alternative 1, with a maximum net head of 48 feet, a standardized pre-designed ready-made tube turbine was selected on the basis of cost, availability, simple installation and easy maintenance. For alternative 2, which has a maximum net head of 65 feet, a horizontal bulb type turbine was selected because the operating head of more than 60 feet is beyond the range of a standard tube turbine and also because a vertical Kaplan type turbine would be more costly. For alternative 3, which has a maximum net head of 75 feet, a vertical Kaplan turbine was selected because the operating head is higher than the normal range for a bulb turbine. It should be noted that as the maximum power head is increased the cost of the turbines that are suitable for the corresponding heads rises faster than the value of the additional energy generated by the additional head.

13. Development Scheduling for Putting Power On-Line. Since it was concluded that it is not economically feasible at this time to develop hydropower at the Woodruff Narrows site, a detailed schedule for putting power on line was not developed. However, if it were economically feasible to develop hydropower at the site, it is estimated that it would take approximately six months to complete final design of the project. In addition, it is anticipated that it would take an additional 18 months to complete an Environmental Impact Statement and the regulatory requirements for obtaining the necessary licenses and permits. Construction of the project could be completed in a 1 year time period. The resulting time required to put power on-line would be at least 3 years. From experience in development of other state and local water projects involving numerous regulatory approvals, a more realistic estimate for putting power on-line is 4 years.

12.2 RECOMMENDATIONS

None of the three basic run-of-river or the pumped storage alternatives for hydroelectric power development are economically or financially feasible at this time. However, enlargement of the existing Woodruff Narrows Dam and Reservoir for agricultural purposes is both economically and financially feasible to construct. It is, therefore, recommended that enlargement of the existing dam and reservoir be pursued at this time without the addition of hydroelectric power development. If the market value of electric energy in the project area should rise at a rate much faster than inflation of construction costs, it may be feasible in future years to add hydroelectric power generation facilities at the Woodruff Narrows Dam and Reservoir site. However, at the present time, it would not be economically sound to construct hydropower facilities at the site.

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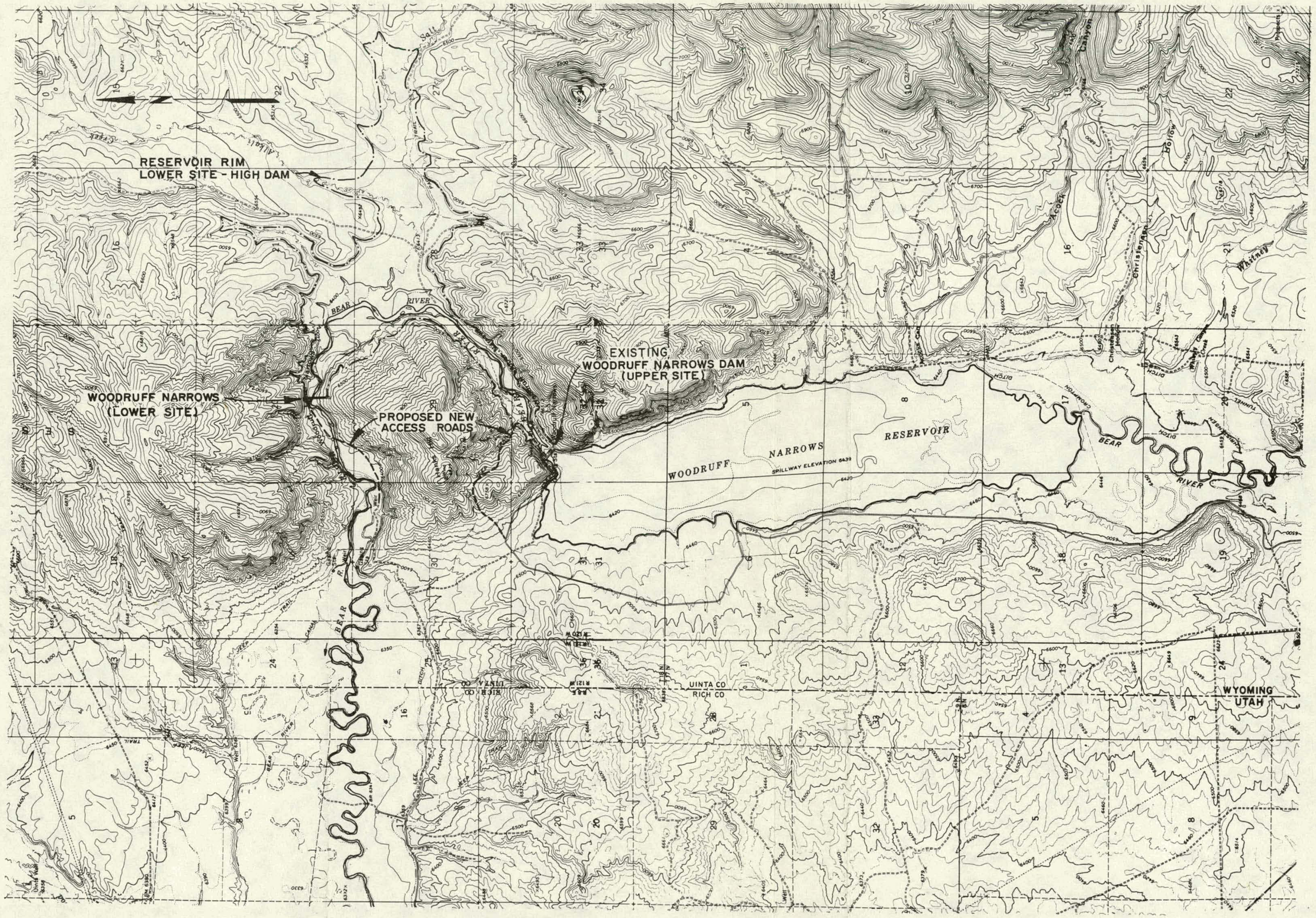
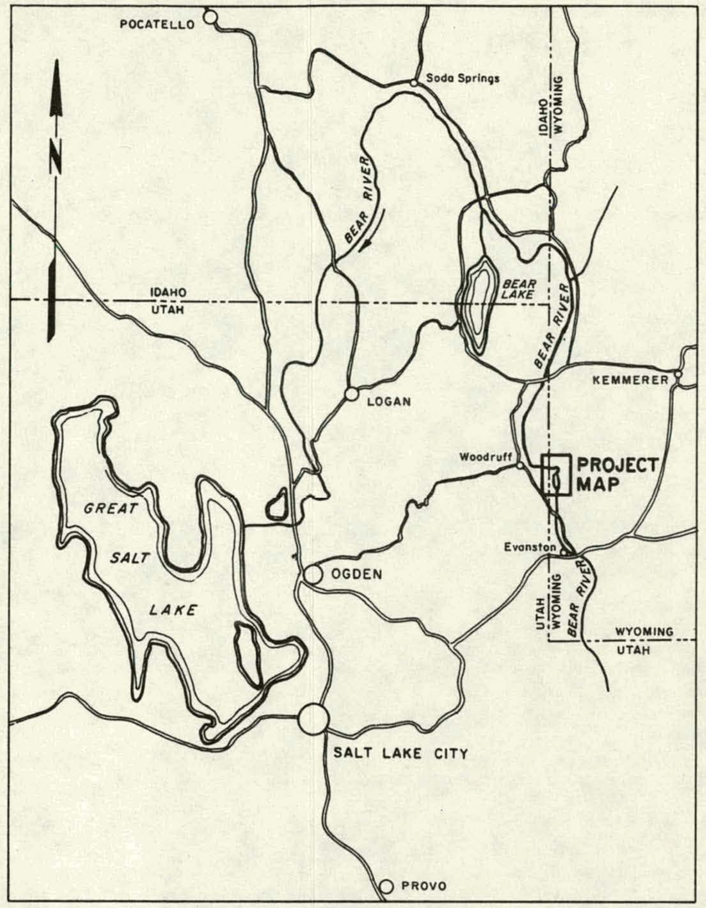


PROJECT MAP

SCALE 0 20,000 40,000 60,000 80,000 100,000 120,000 FEET



LOCATION MAP

SCALE 0 10 20 30 40 50 MILES

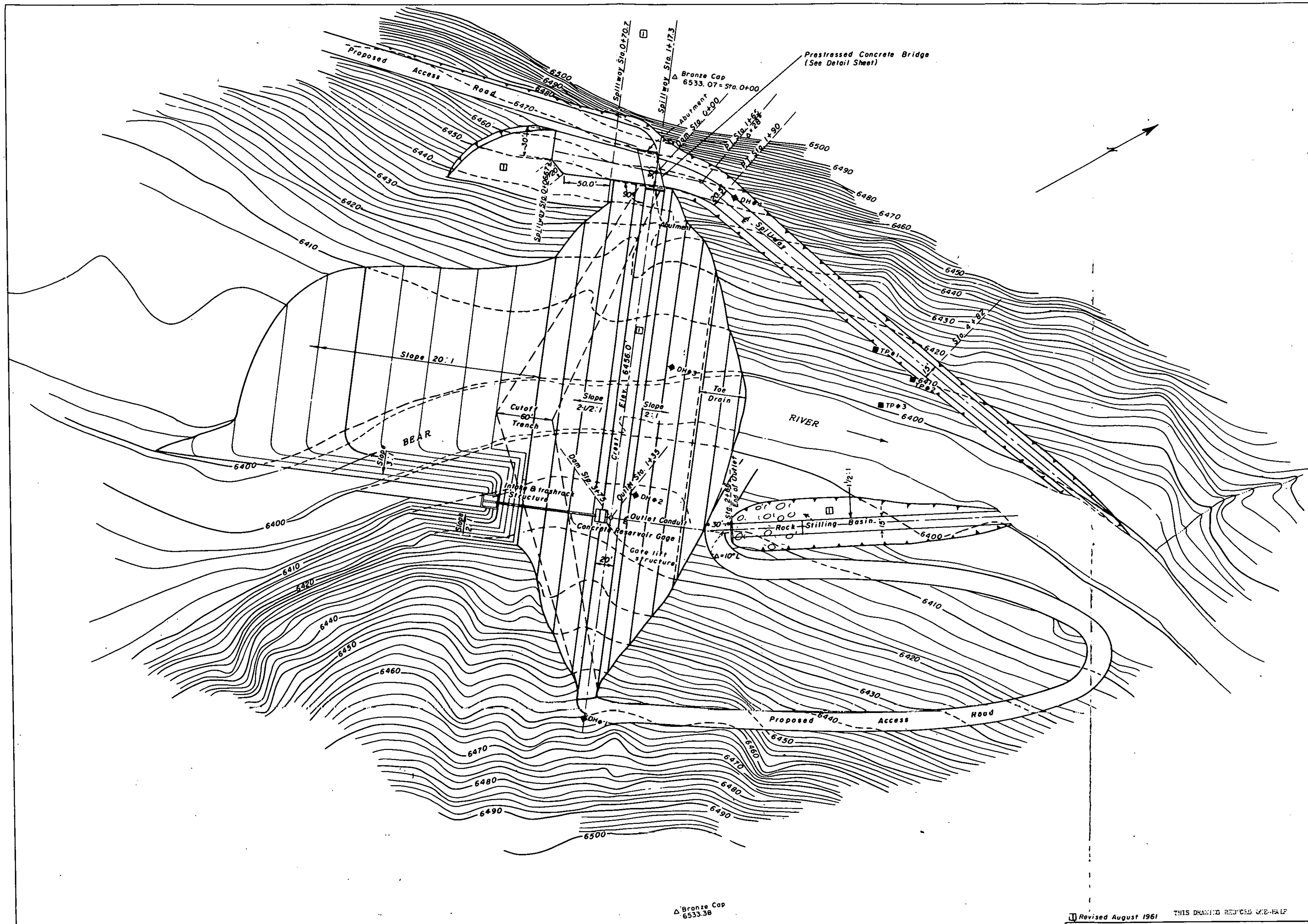
STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
POWER DEVELOPMENT

LOCATION MAP AND PROJECT MAP

CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104

EXHIBIT 2



PLAN
Scale: 1" = 50'

Revised August 1961

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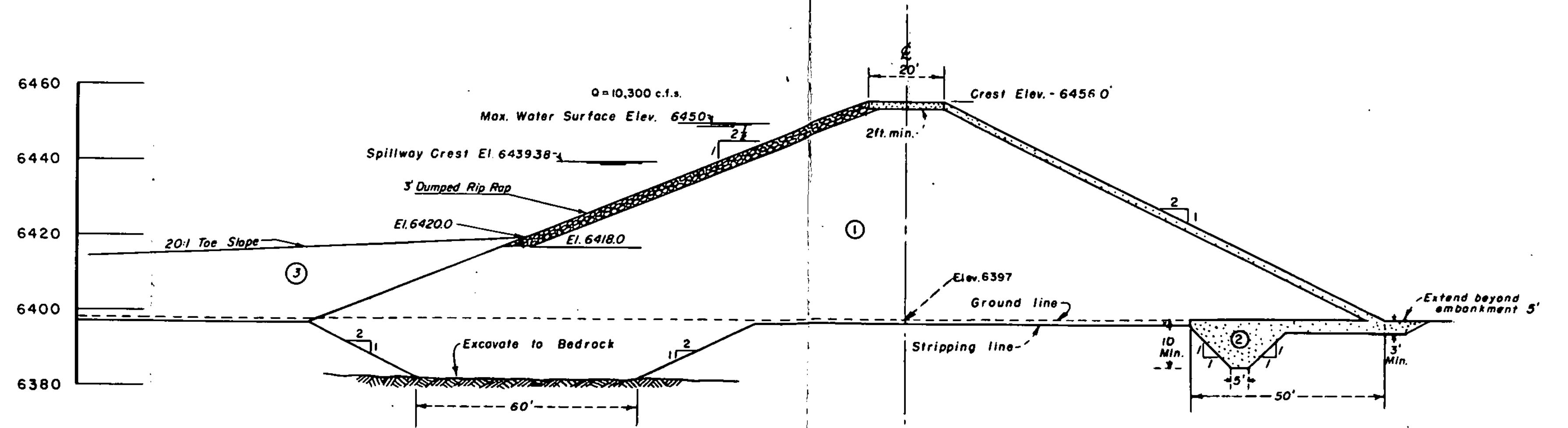
STATE OF UTAH UTAH WATER AND POWER BOARD	
WOODRUFF NARROWS DAM **GENERAL PLAN**	
SCALE: As shown	COUNTY UINTA, WYO.
DRAWN L.C., E.L.B & R.H.Z.	SUBMITTED E. J. Bay
TRACED A.B.E. R.B.A.	RECOMMENDED
CHECKED	APPROVED
DATE June 1961	APPLICATION 17 1/368 Wyoming — SHT. 2 OF 8

EXHIBIT 3

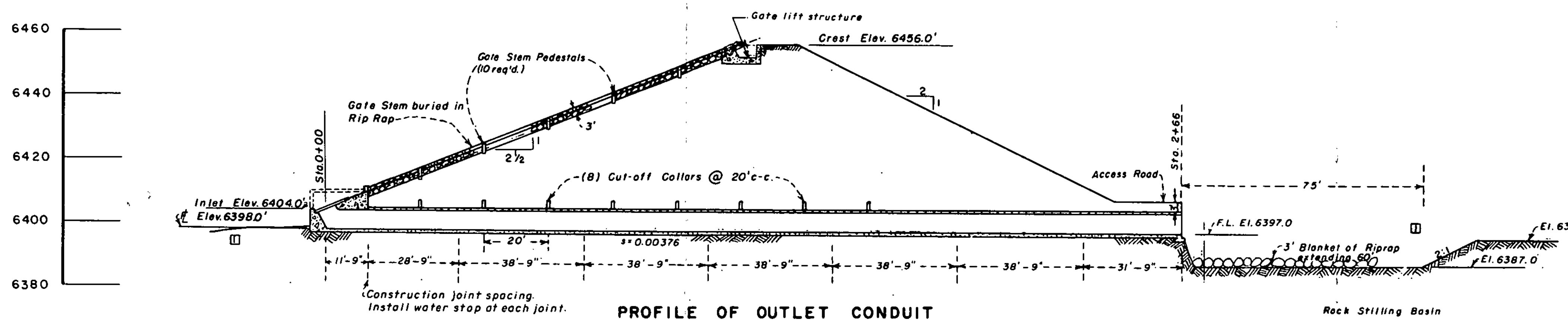


① Impervious

② Pervious & erosion resistant

③ Excavated material

DAM
MAXIMUM SECTION
Scale - 1" = 20'-0"



PROFILE OF OUTLET CONDUIT
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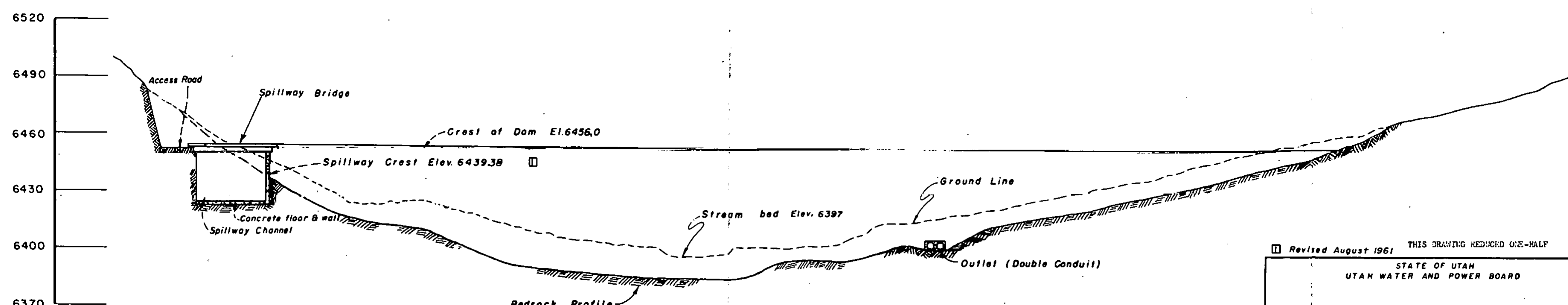

PROFILE OF CUT-OFF TRENCH
Scale - 1" = 30'-0"

Revised August 1961

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STATE OF UTAH
UTAH WATER AND POWER BOARD

WOODRUFF NARROWS DAM
DAM SECTIONS

SCALE: as shown — COUNTY UINTA, WYO.

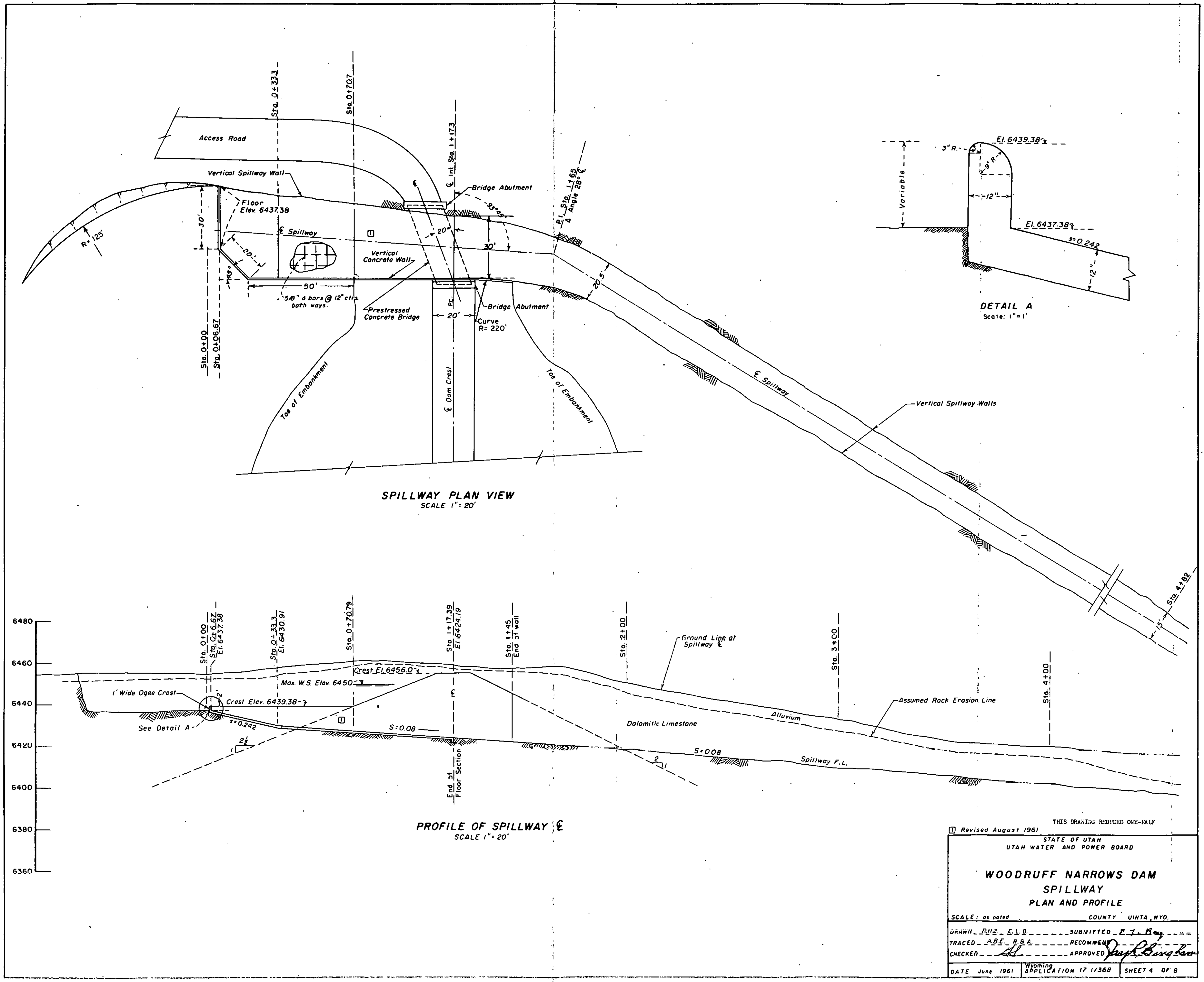
DRAWN E.L.B. R.H.Z. — SUBMITTED E.J. Bay

TRACED R.B.A. A.B.E. — RECOMMENDED

CHECKED — APPROVED

DATE June 1961 — Wyoming APPLICATION 17 1/368 — SHT. 3 OF 8

EXHIBIT 4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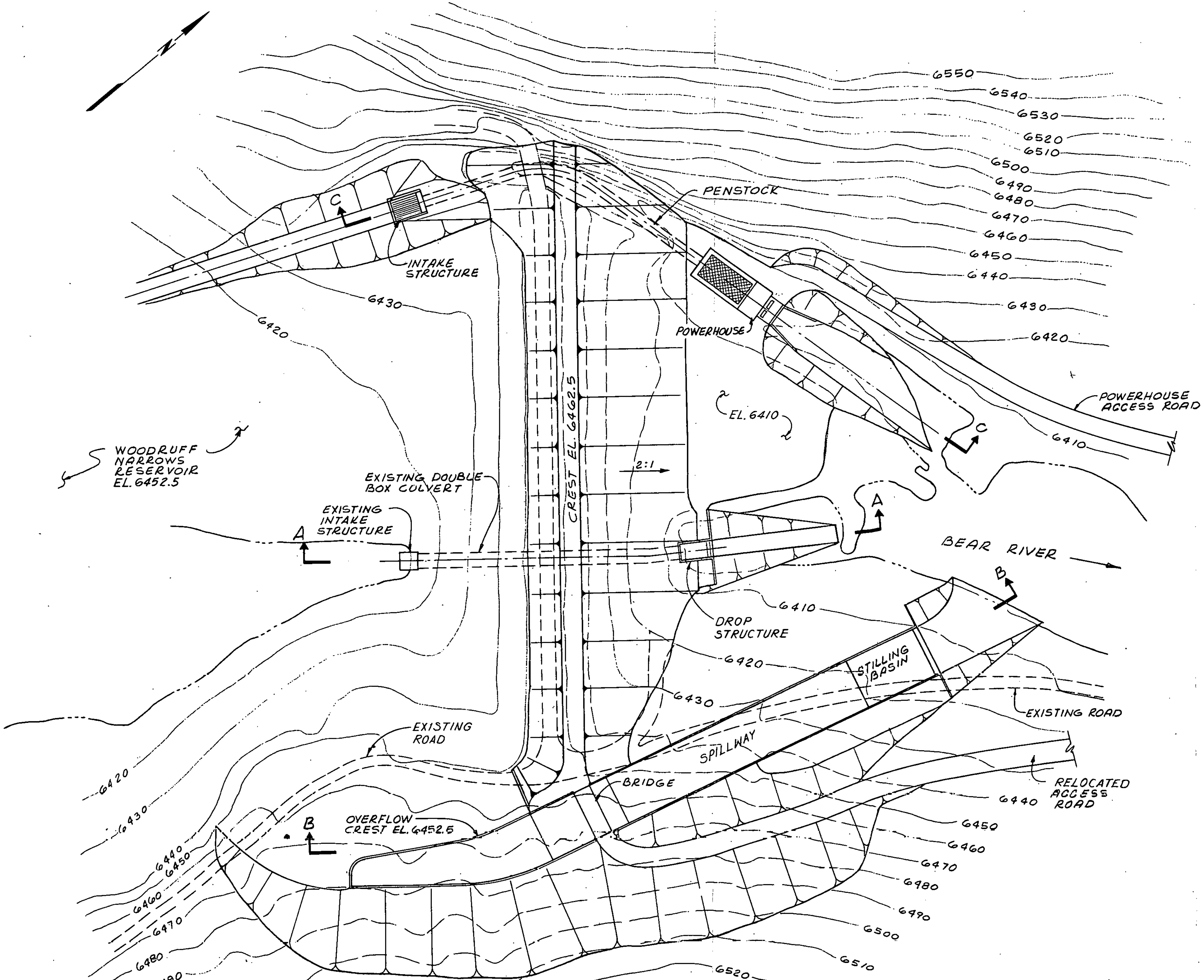
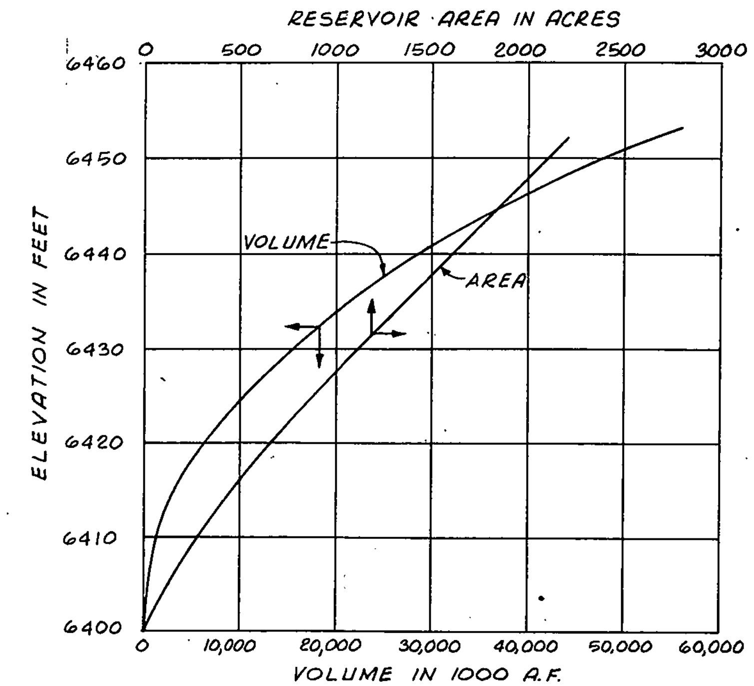
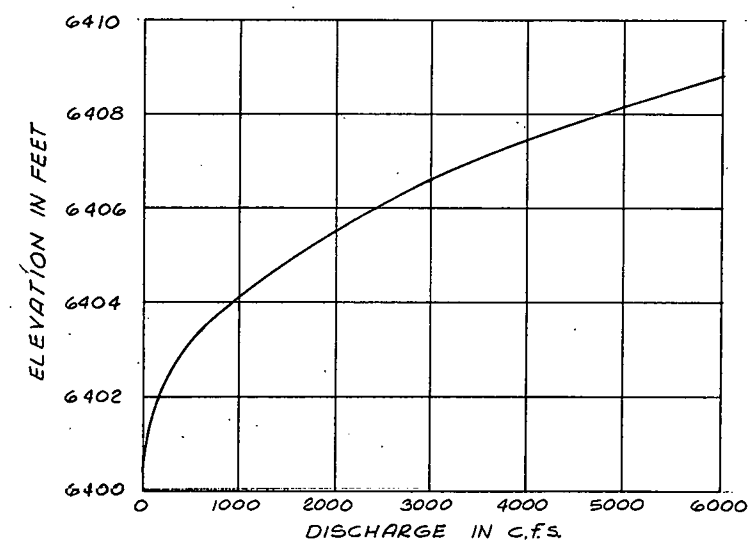
Vertical Spillway Wall
Floor Elev. 6437.38
R=125'
30'
℄ Spillway
Vertical Concrete Wall
50'
20'
5/8" ø bars @ 12" ctrs both ways.
Prestressed Concrete Bridge
Bridge Abutment
Curve R=220'
℄ Dam Crest
Toe of Embankment
Sta. 0+00
Sta. 0+06.67
Sta. 0+33.3
Sta. 0+70.7
℄ Int Sta. 1+17.3
P.I. Sta. 1+65 Δ Angle 28° ℄
20.5'
Vertical Spillway Walls
Sta. 4+82
15'
SPILLWAY PLAN VIEW
SCALE 1"=20'
El. 6439.38
3" R.
9" R.
12"
Variable
El. 6437.38
s=0.242
DETAIL A
Scale: 1"=1'
6480
6460
6440
6420
6400
6380
6360
Sta. 0+00
Sta. C+ 6.67 El. 6437.38
Sta. 0+33.3 El. 6430.91
Sta. 0+70.79
Sta. 1+17.39 El. 6424.19
Sta. 1+45 End of wall
Sta. 2+00
Sta. 3+00
Sta. 4+00
Crest El. 6456.0
Max. W.S. Elev. 6450
1' Wide Ogee Crest
Crest Elev. 6439.38
See Detail A
s=0.242
S=0.08
End of Floor Section
Ground Line at Spillway ℄
Dolomitic Limestone
Alluvium
Assumed Rock Erosion Line
Spillway F.L.
PROFILE OF SPILLWAY ℄
SCALE 1"=20'
THIS DRAWING REDUCED ONE-HALF
1 Revised August 1961
STATE OF UTAH
UTAH WATER AND POWER BOARD
WOODRUFF NARROWS DAM
SPILLWAY
PLAN AND PROFILE
SCALE: as noted
COUNTY UINTA, WYO.
DRAWN
TRACED A.B.E. R.B.A.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DATE June 1961
Wyoming APPLICATION 17 1/368
SHEET 4 OF 8

EXHIBIT 5





RESERVOIR AREA AND VOLUME



TAILWATER RATING CURVE

STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
POWER DEVELOPMENT

UPPER SITE - RAISED DAM
GENERAL PLAN

CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104

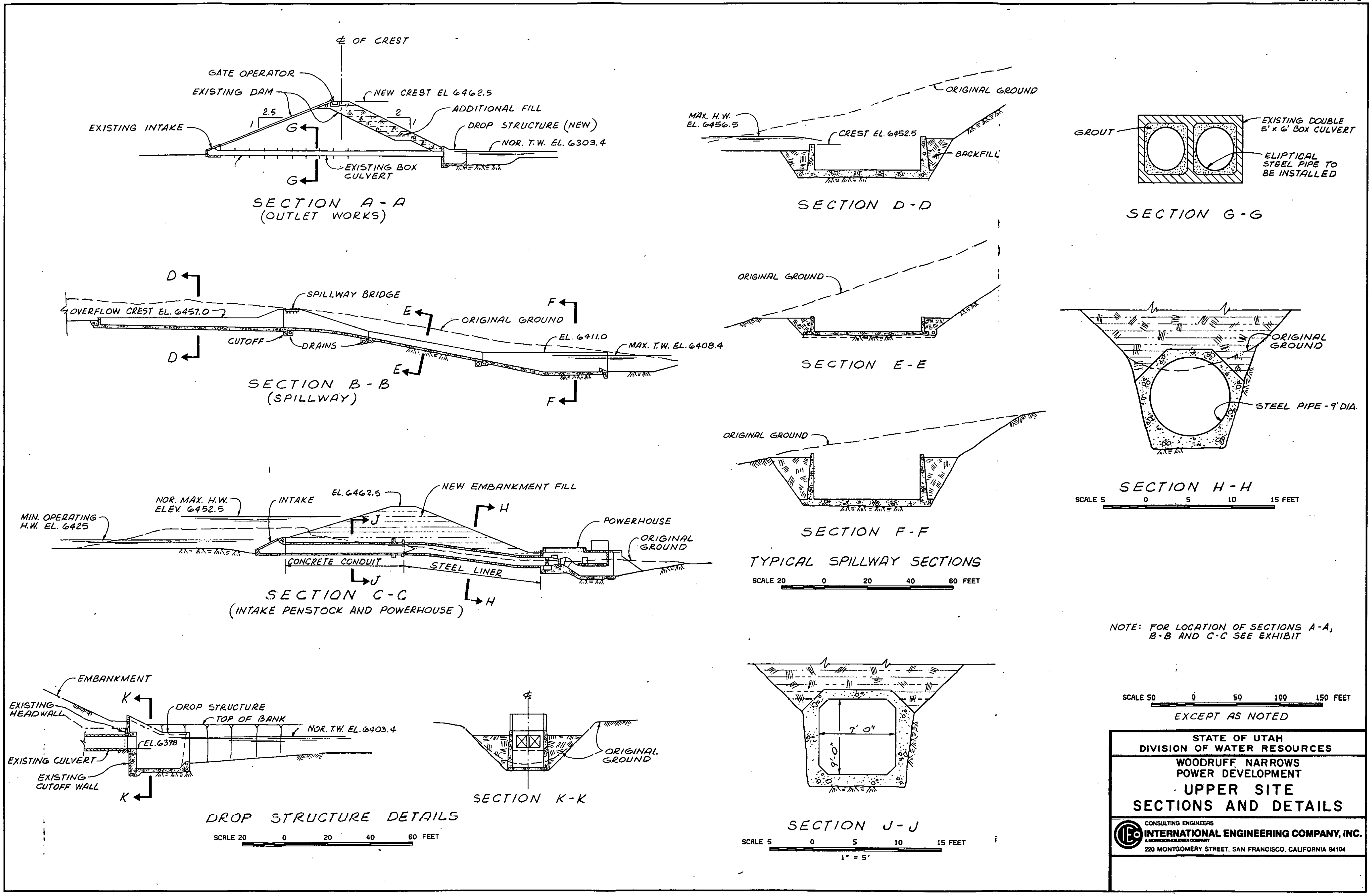
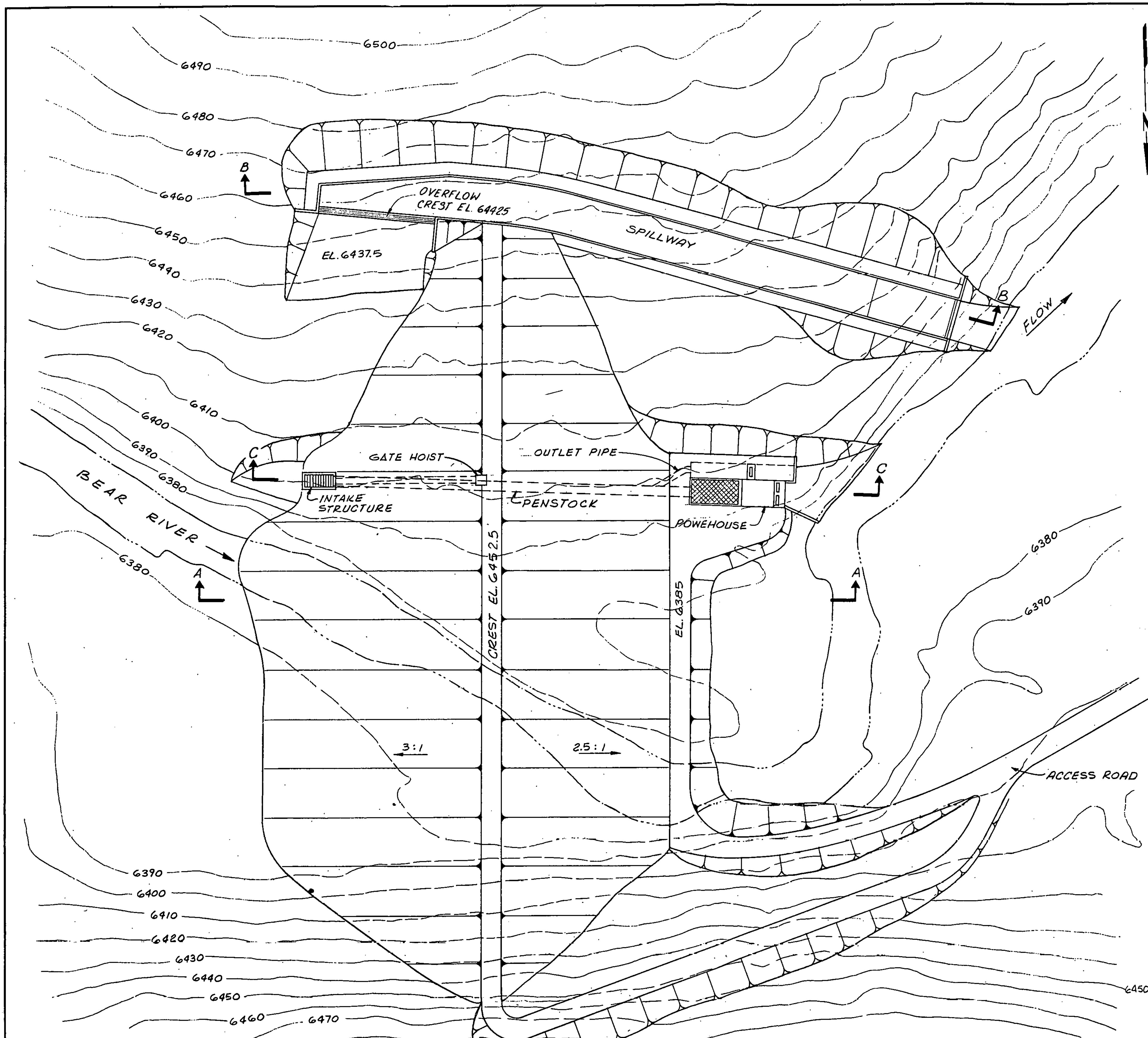
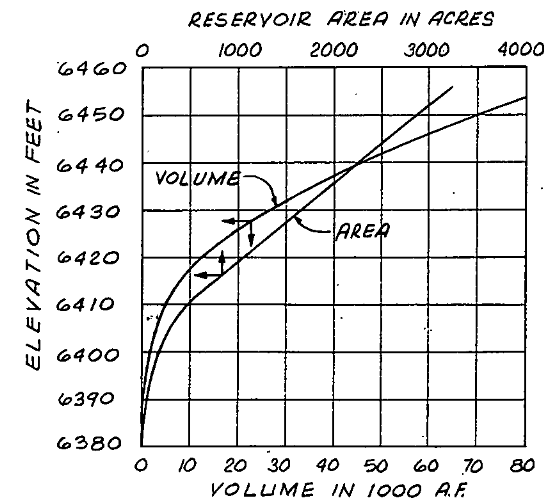
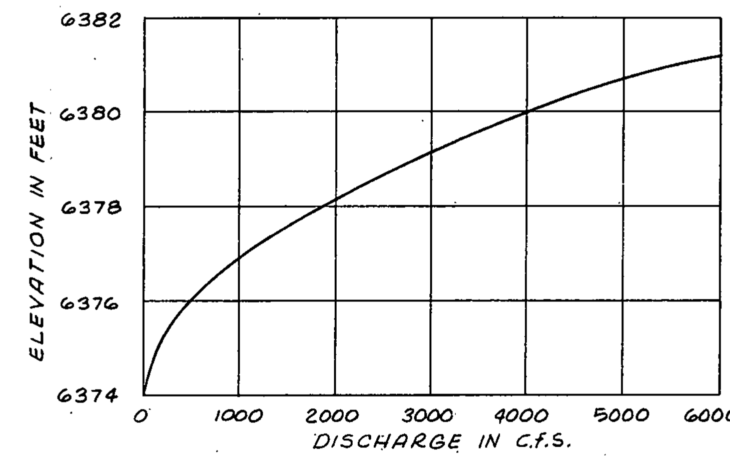


EXHIBIT 6
℄ OF CREST
GATE OPERATOR
EXISTING DAM
NEW CREST EL 6462.5
ADDITIONAL FILL
2.5
1
2
1
EXISTING INTAKE
G
DROP STRUCTURE (NEW)
NOR. T.W. EL. 6303.4
EXISTING BOX CULVERT
G
SECTION A - A
(OUTLET WORKS)
MAX. H.W. EL. 6456.5
ORIGINAL GROUND
CREST EL. 6452.5
BACKFILL
SECTION D-D
GROUT
EXISTING DOUBLE 5' x 6' BOX CULVERT
ELIPTICAL STEEL PIPE TO BE INSTALLED
SECTION G-G
D
SPILLWAY BRIDGE
OVERFLOW CREST EL. 6457.0
E
F
ORIGINAL GROUND
EL. 6411.0
MAX. T.W. EL. 6408.4
CUTOFF
DRAINS
D
E
F
SECTION B - B
(SPILLWAY)
ORIGINAL GROUND
SECTION E-E
ORIGINAL GROUND
STEEL PIPE - 9' DIA.
ORIGINAL GROUND
SECTION F-F
TYPICAL SPILLWAY SECTIONS
SCALE 20 0 20 40 60 FEET
SECTION H-H
SCALE 5 0 5 10 15 FEET
EL. 6462.5
NEW EMBANKMENT FILL
NOR. MAX. H.W. ELEV. 6452.5
INTAKE
MIN. OPERATING H.W. EL. 6425
J
H
POWERHOUSE
ORIGINAL GROUND
CONCRETE CONDUIT
STEEL LINER
J
H
SECTION C-C
(INTAKE PENSTOCK AND POWERHOUSE)
NOTE: FOR LOCATION OF SECTIONS A-A, B-B AND C-C SEE EXHIBIT
EMBANKMENT
EXISTING HEADWALL
K
DROP STRUCTURE
TOP OF BANK
NOR. T.W. EL. 6403.4
EL. 6398
EXISTING CULVERT
EXISTING CUTOFF WALL
K
℄
ORIGINAL GROUND
SECTION K-K
DROP STRUCTURE DETAILS
SCALE 20 0 20 40 60 FEET
7' 0"
9' 0"
SECTION J-J
SCALE 5 0 5 10 15 FEET
1" = 5'
SCALE 50 0 50 100 150 FEET
EXCEPT AS NOTED
STATE OF UTAH
DIVISION OF WATER RESOURCES
WOODRUFF NARROWS
POWER DEVELOPMENT
UPPER SITE
SECTIONS AND DETAILS
CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104





RESERVOIR AREA AND VOLUME



TAILWATER RATING CURVE

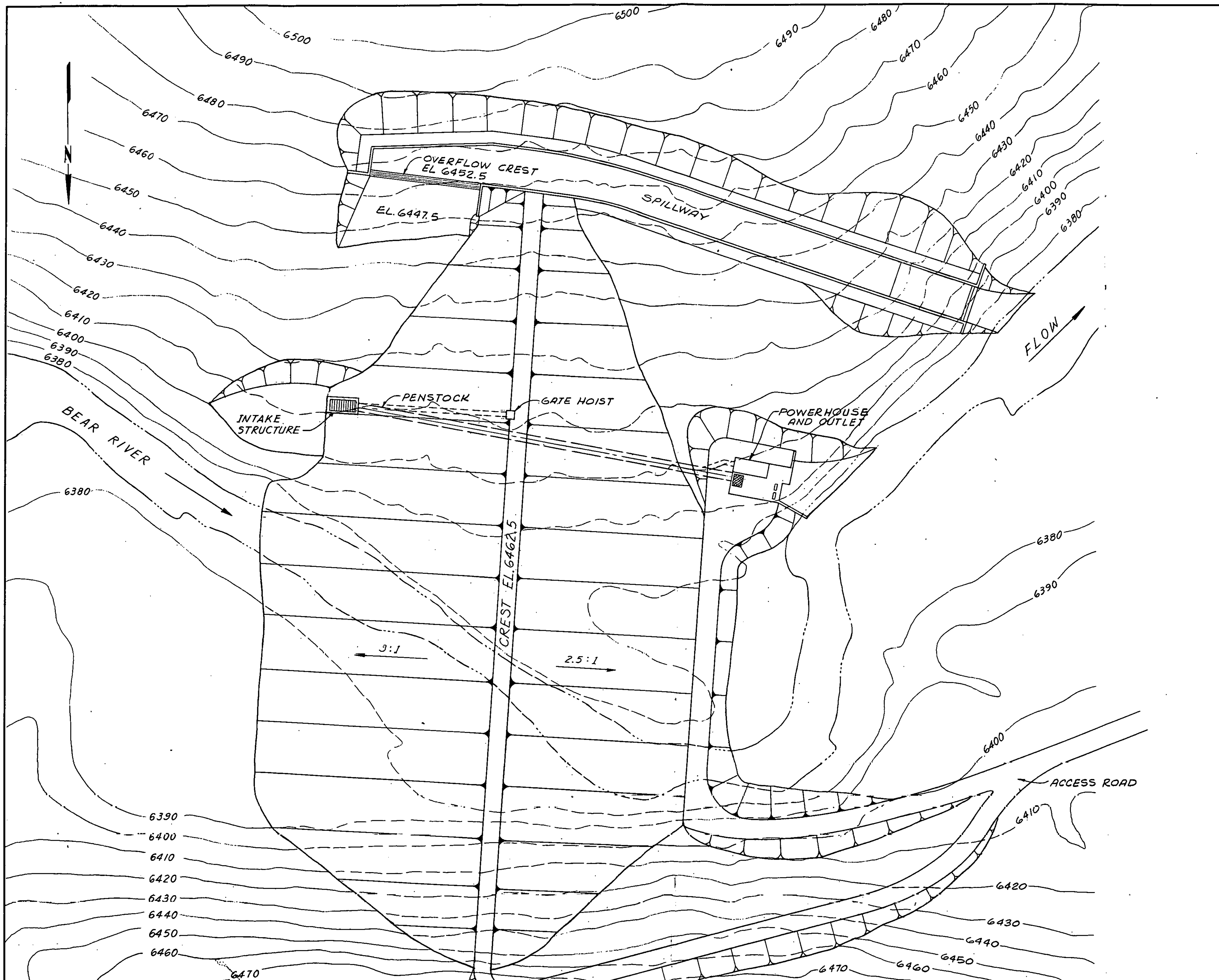
STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
POWER DEVELOPMENT

LOWER SITE - LOW DAM
GENERAL PLAN

CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104

EXHIBIT 8



SCALE 50 0 50 100 150 FEET

STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
POWER DEVELOPMENT

LOWER SITE - HIGH DAM
GENERAL PLAN

CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY
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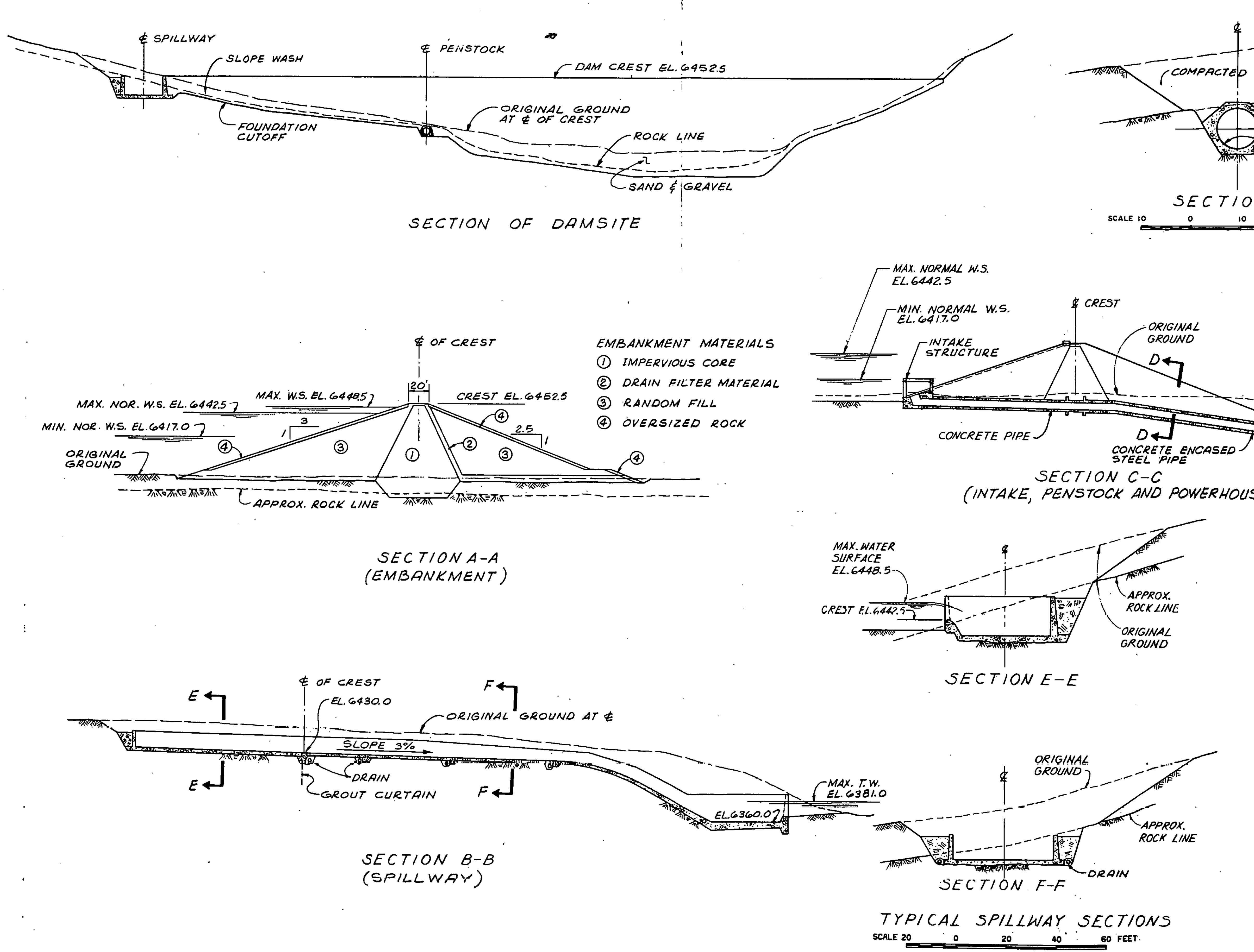

NOTE: ALL STRUCTURES SHOWN HEREON ARE FOR THE LOW DAM ALTERNATIVE (RESERVOIR EL. 6442.5) THE STRUCTURES FOR THE HIGH DAM ALTERNATIVE (RESERVOIR EL. 6452.5) ARE OF SIMILAR DESIGN.

FOR LOCATION OF SECTIONS A-A, B-B AND C-C, SEE EXHIBIT

SCALE 50 0 50 100 150 FEET

EXCEPT AS NOTED

STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
POWER DEVELOPMENT

LOWER SITE
SECTIONS AND DETAILS

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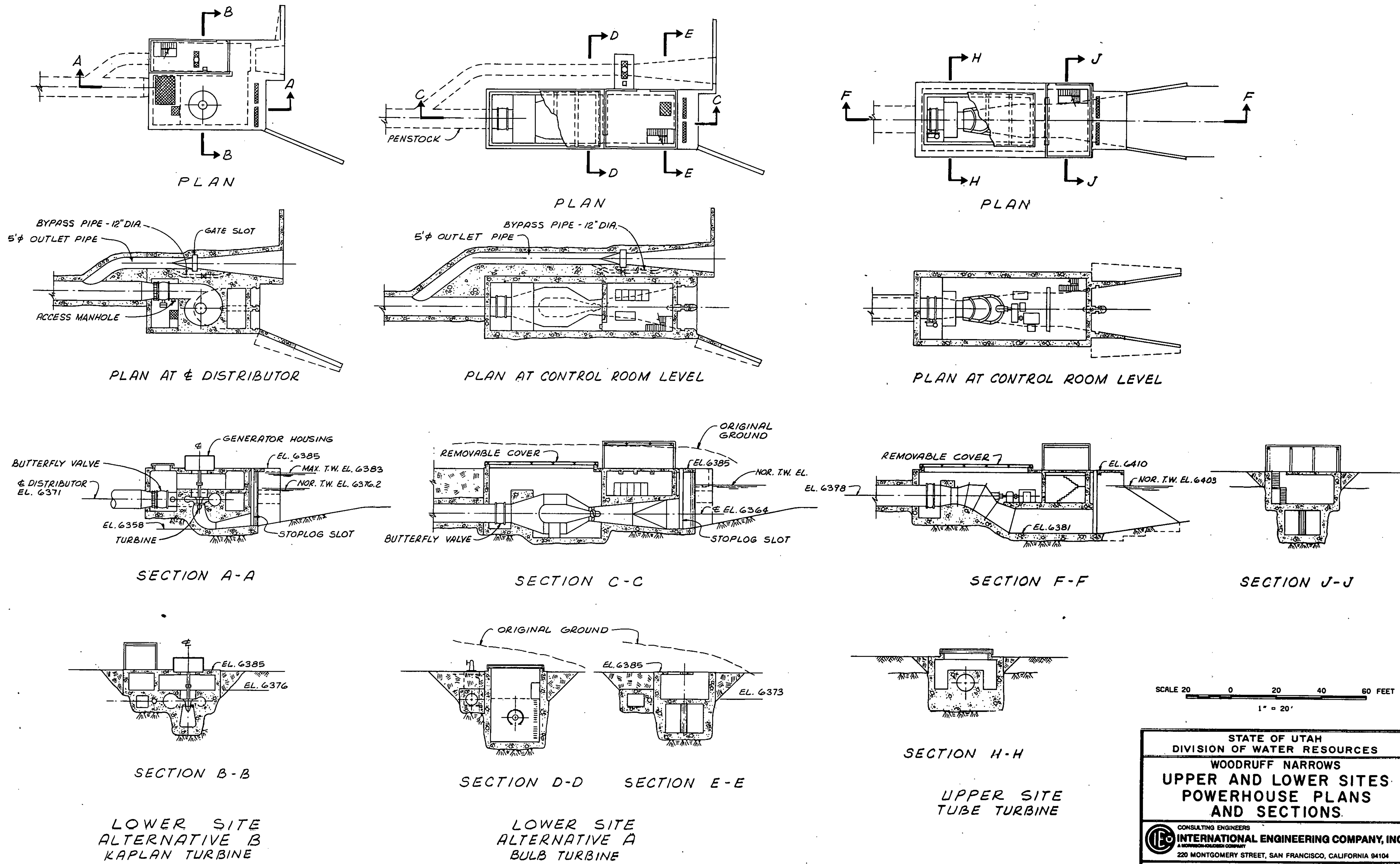

STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS

UPPER AND LOWER SITES POWERHOUSE PLANS AND SECTIONS

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A MORRISON-KNUDSEN COMPANY
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104

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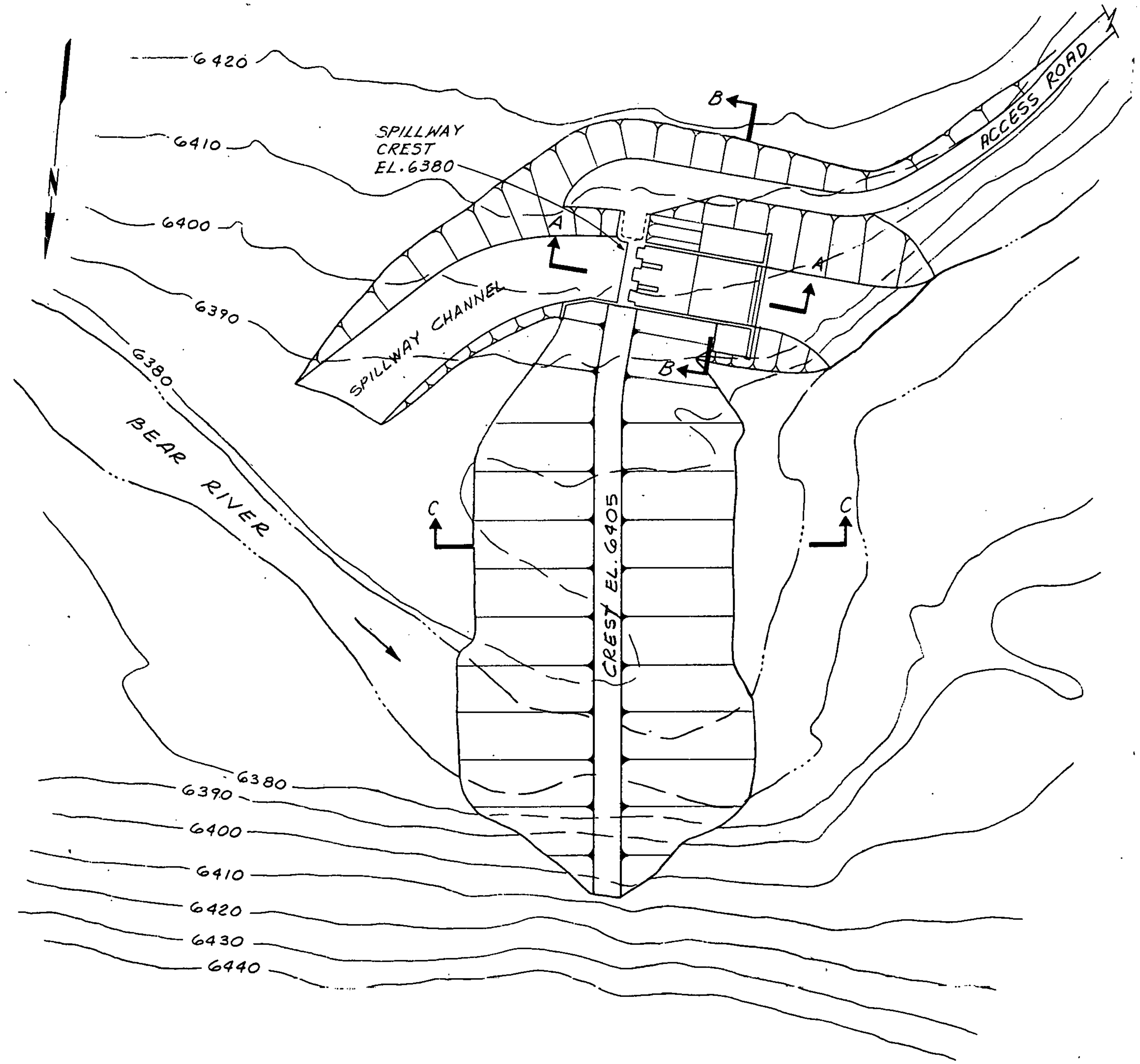
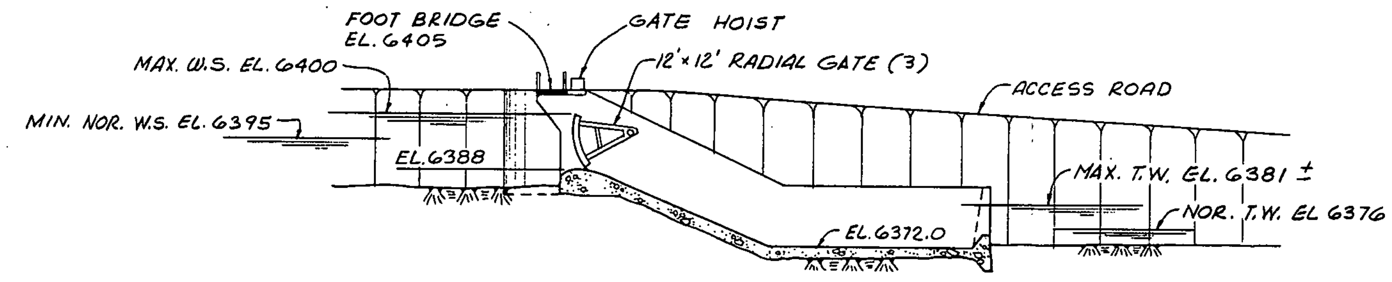
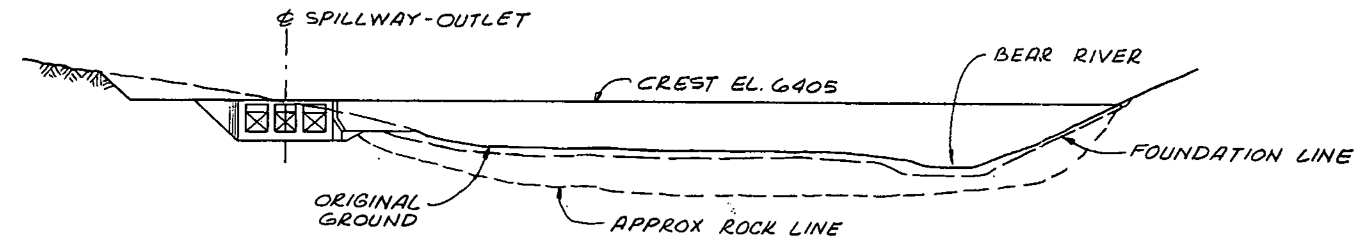


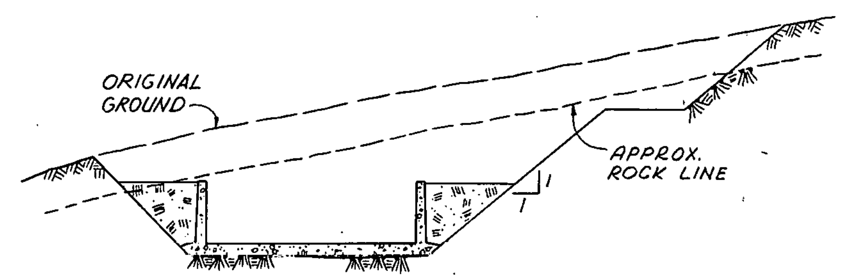


SECTION A-A

SCALE 20 0 20 40 60 FEET

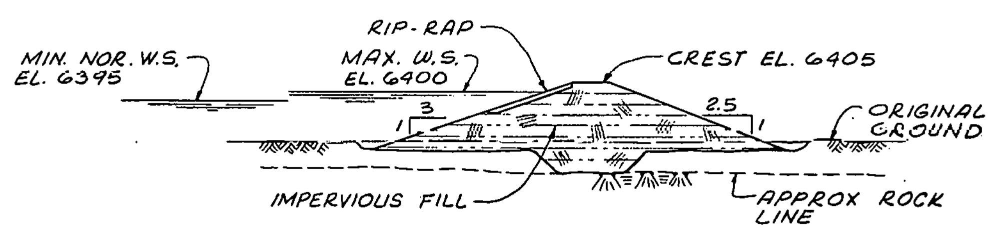


UPSTREAM ELEVATION



SECTION B-B

SCALE 20 0 20 40 60 FEET



MAXIMUM EMBANKMENT
SECTION C-C

SCALE 50 0 50 100 150 FEET
EXCEPT AS NOTED

STATE OF UTAH
DIVISION OF WATER RESOURCES

WOODRUFF NARROWS
REREGULATING DAM
GENERAL PLAN
SECTIONS AND DETAILS

CONSULTING ENGINEERS
INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY
220 MONTGOMERY STREET, SAN FRANCISCO, CALIFORNIA 94104