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CRSP Power Peaking Capacity: Generation at Outlet Glen Canyon Unit, Arizona: Concluding Report

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CRSP Power Peaking Capacity, Generation at Outlet Glen Canyon Unit, Arizona

CONCLUDING REPORT

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UPPER COLORADO REGION

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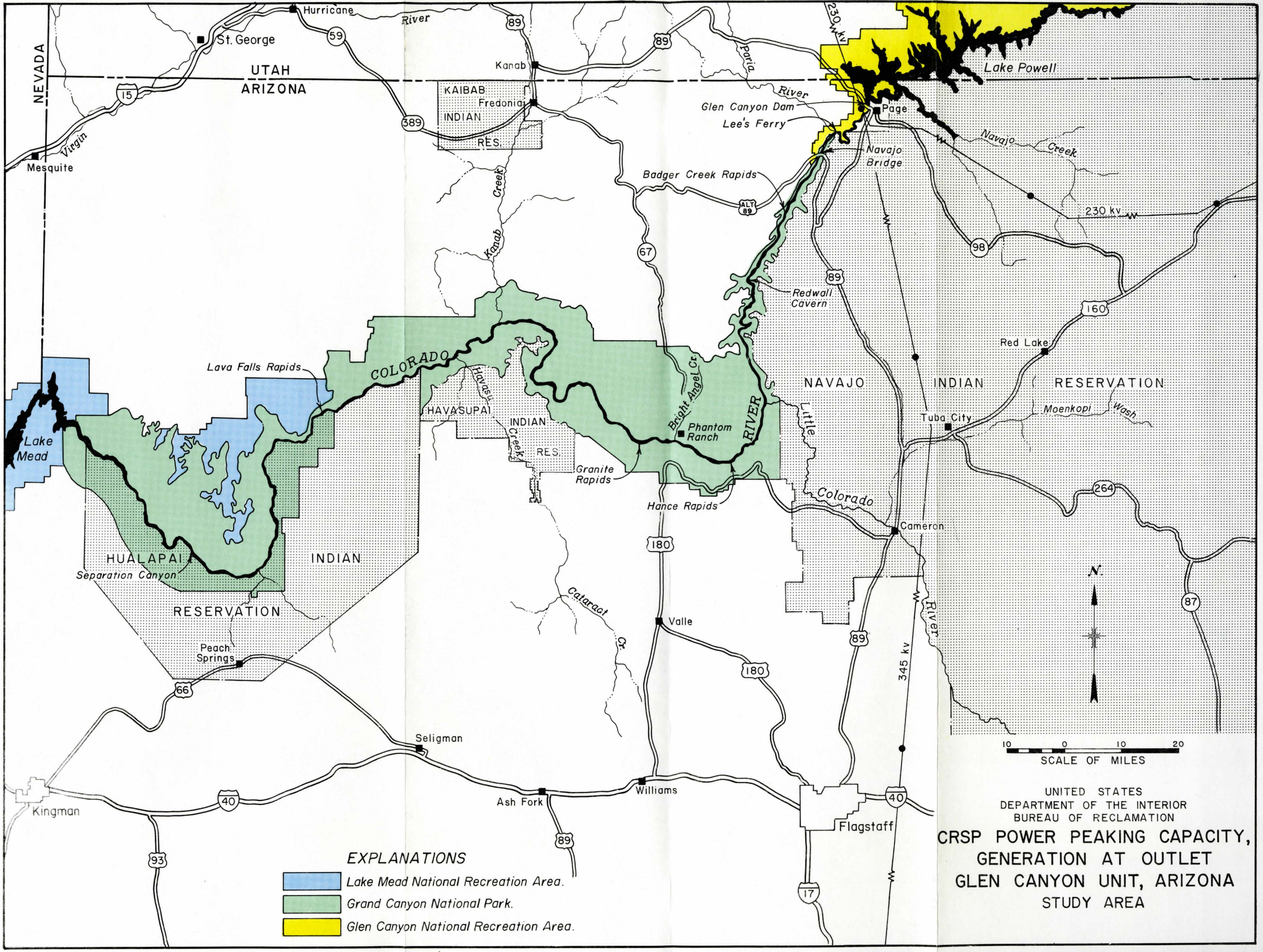

CRSP POWER PEAKING CAPACITY, GENERATION AT OUTLET GLEN CANYON UNIT, ARIZONA STUDY AREA

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SUMMARY AND CONCLUSIONS

Summary

The purpose of this investigation, known officially as the CRSP Power Peaking Capacity--Generation at Outlet, Glen Canyon Unit, Arizona, Feasibility Investigation, was to determine the feasibility of using the existing river outlet tubes at Glen Canyon Dam for increased generation capacity in the form of peaking power. The investigation resulted from a 1966 authorization by Congress (Public Law 89-561) for studies of peaking power possibilities in the Upper Colorado Region. The peaking power investigations were funded in 1975, in response to the rising costs of fossil fuel energy.

In the studies since 1975, many potential peaking power projects were identified. These projects primarily fall into one of two categories: (1) a flow-through system where stored water is released through a powerplant directly to the river in response to peak demands or (2) a pumped storage system where water is stored in an upper reservoir, released to a lower reservoir during peak demand periods, and then pumped back during low demand periods. The former type, of which Glen Canyon is an example, results in highly fluctuating flows downriver unless a regulating reservoir is incorporated. The latter requires the need for an additional energy supply to provide for pumping. This need is typically 50 percent greater than the total energy provided by the plant, but the difference in the value of peaking energy versus low demand period energy in some cases enables a pumped storage plant to be practical.

Three existing dams, of which Glen Canyon Dam was one, were subsequently selected for feasibility investigation from 150 sites identified as having potential for the production of hydroelectric peaking power. Factors originally favoring the selection of Glen Canyon Dam for feasibility investigation were the existing outlet tubes and the existing transmission facilities adjacent to the dam. Potential impacts to the downstream environment and recreation were recognized during the initial survey of potential peaking powersites.

Preliminary surveys for projected power demands up to the year 2000, conducted by Western (Western Area Power Administration), indicate a need to develop more energy resources within the CRSP (Colorado River Storage Project) marketing area by the year 2000. Additional generating capacity will be needed to help meet future requirements for power at peak demand periods even with conservation measures and with such non-structural management measures as a redistribution of existing demand patterns through a time-of-day pricing structure.

A Bureau of Reclamation survey of power needs was conducted as part of the 1975 power peaking reconnaissance study by a power resource and needs subteam, a component of the planning team organized to aid in the study process. With a projected continuation of existing patterns of demand that take conservation measures into account, the 1975 power resources and needs subteam projected about 8,000 MW (megawatts) of additional peaking power demand would exist in the CRSP market area from 1985 to 2000.

More recent inventory studies by Western have indicated that projected effects of increased energy conservation and load management programs have reduced the level of need from 8,000 MW down to 4,000 MW, which includes 1,000 MW of reserves.

A Notice of Initiation of Investigation was issued in October 1978. The plan of study was to conduct appraisal investigations leading to the selection of a preferred alternative, which would then be subjected to detailed analysis at the feasibility level. A feasibility report was scheduled for completion in 1983 and an environmental impact statement in 1984.

Planning teams were organized at the beginning of the study based upon the interest shown by other Federal, State, and local agencies, and individuals. Biology, recreation, power, and social teams were organized to determine and evaluate potential impacts and needs. The teams met whenever new information was available or when recommendations from the teams were necessary in the planning process. The teams were to recommend a preferred size based upon appraisal information which could be studied in more detail later in the feasibility investigation.

Originally, the alternatives for study were all sizes of generating units ranging up to 250 MW, the largest unit that could be installed because of the physical limits of the outlet tubes. Since the size of the generating unit is directly proportional to the size of the release from the dam, alternative sizes for study were selected that were likely to show differentiable impacts while still having a likelihood of being economically feasible. The two sizes selected for study at the beginning were the 250-MW and 125-MW units.

The most efficient of the alternative sizes evaluated was the 250-MW alternative, which would consist of two 125-MW units located at the present site of the outlet structures for the existing outlet tubes. The total cost, based on January 1981 prices, was estimated to be $196,560,000, with a total annual cost of $15,097,000 and a total annual benefit of $29,835,000. This corresponds to a B/C (benefit-cost) ratio of 1.98:1.

The 250-MW addition to the dam would increase the maximum release by 7,000 cfs (cubic feet per second). Combined maximum releases from the existing generating units, upon completion of rewinding and uprating (a project now underway which will increase releases by 1,600 cfs), and additional 250-MW units would increase the maximum release from 33,100 cfs to 40,000 cfs. The only increase proposed would be in capacity; total annual energy generated would not be increased. Impact analyses were based on that increase in the maximum release and the resulting wider range in flow fluctuations.

SUMMARY AND CONCLUSIONS

Potential impacts identified by the teams concerned flow fluctuations on the downstream environment, recreational uses of the river, and the economic repercussions reduced recreational uses and construction impacts would have on local communities. The significant issues involved the loss of riparian vegetation and wildlife, erosion, and inundation of beaches used for camping purposes in the Grand Canyon, the potential conflict in scheduling trips through the canyon due to more extreme flow variations, fishing access and productivity of the trout fishery between the dam and Lee's Ferry, the potential losses to the recreation industry and surrounding communities, and potential construction impacts on Page, Ariz.

The public reaction to the study indicated great concern over potential environmental and recreational problems which it felt could occur. The level of concern demonstrated the way many people feel about the Grand Canyon and any possible adverse effects such as might occur with increased fluctuations of the flows of the Colorado River through the Grand Canyon.

None of the preliminary studies performed to date indicated that there would be significant adverse effects over the current operation to either the biological habitat, the visual quality, archeological and historical resources, or endangered species. Based on the same preliminary studies, some potential adverse recreational impacts were identified but would not have prevented the planning process from proceeding into a feasibility-level study for a particular size of generating unit. The significance of these recreational impacts would have been determined during the feasibility studies.

Conclusions

The investigation was concluded before selection of a preferred alternative for feasibility investigations could be developed. The study was concluded for the reasons listed below.

1. Appraisal level studies indicate that construction of the maximum 250-MW unit, which is the most cost effective, with a B/C ratio of 1.98:1, would not cause significant adverse impacts on the Colorado River or the Grand Canyon over the existing operation of the Glen Canyon Unit (CRSP). Preliminary studies indicate a potential for recreational impacts. The degree of these impacts would have been determined during feasibility studies had the investigations not been concluded. Glen Canyon Dam has the advantage of being an existing facility, has the potential to provide peaking power sooner than most other sites, and would require minimum construction. The investigation, however, touched off a Nationwide response from the public who were opposed to any development that may have any detrimental effect on the Grand Canyon.

Further, while there is broad support from municipalities and other power interest for developing additional peaking power capacity in the CRSP market area, there is a lack of strong support for developing additional capacity at Glen Canyon Dam.

2. As discussed earlier, a decrease in the projected need for peaking power in the CRSP market area, led Reclamation (Bureau of Reclamation) to conduct a peaking power prioritization study to determine which potential peaking power projects in the area were most promising and should be investigated first. This study resulted in several other potential peaking power investigations receiving a higher priority than the Glen Canyon studies.

3. Based on the above considerations and because concluding this investigation at this time would help in achieving budget cuts sought by the current administration, Reclamation announced in October 1981 that the study would be concluded.

   The investigation of other potential peaking power projects will continue. If after these investigations there is a remaining need for additional capacity, the Glen Canyon study may be reconsidered. This report summarizes the results of studies made to date and will provide information for any future investigation at this site.

CHAPTER I

INTRODUCTION

Purpose and Objectives

The purpose of the Glen Canyon Dam Peaking Power Study was to determine the feasibility of generating additional electrical capacity in the form of peaking power with the addition of one or two generating units onto the existing river outlet tubes at the dam.[1/] Economic and environmental impacts were to be identified in the study as well as the engineering feasibility of using the river outlet tubes. At present, 1,150 MW of capacity and energy are produced at the site by units that have been in place since 1966. Turbines could be installed on the river outlet tubes, which would increase generation capacity by 250 MW and maximum releases by up to 7,000 cfs. The only increase proposed would be in capacity; total annual energy generation would not be increased. This report documents the reasons for terminating the study and summarizes the investigation, particularly those aspects that relate to the decision to conclude the study.

As explained in detail in Chapter IV, Problems and Needs, the purpose of the project would be to meet, in part, projected increases in requirements for peaking power in the CRSP marketing area, which includes Colorado, Wyoming, Utah, New Mexico, Arizona, and parts of Nevada and California. Significant population increases and development are expected to continue in this region.

The prime objective of the study was to evaluate the capability of Glen Canyon Dam to meet a portion of the need for additional peaking power. This need was previously determined in 1964 by a Reclamation study and is to be refined through further marketing studies by Western. Specifically, this study was to evaluate alternative sizes of generating units that could be installed on the river outlets and to select a preferred size for a detailed feasibility-level study. The "future without action" would remain as an alternative throughout the study.

Authority for the Study

Public Law 89-561, September 1966, authorized the Secretary of the Interior to engage in feasibility studies of potential peaking

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1/ Hydroelectric power has a significant advantage in meeting peak electricity demands that occur during certain times of the day, week, and year. Use of fossil fuels is reduced, thereby conserving this resource; hydropower generation creates no waste products; the fuel (water) is readily available, so no extraction costs are involved; control is relatively simple, and the response to control is immediate.

power capacity in the Upper Colorado River Basin and the eastern part of the Bonneville Basin along the Wasatch Mountains in Utah. Reclamation has the leading role in these studies because of its responsibility for CRSP hydroelectric plants.

Previous Investigations

The Bureau of Reclamation issued a preliminary report on pumped storage investigations in the Upper Colorado Region in March 1964.[1/] The results of those investigations led to the 1966 authorization and 1975 appropriation of funds for an appraisal-level study of the potential of developing peaking power in the Upper Colorado Region. In April 1975, a planning team was formed and subteams were created to study resources and needs relating to the development of peaking power.

In Reclamation's peaking power studies since 1975, many potential peaking power projects have been identified. These projects primarily fall into one of two categories: (1) a flow-through system where stored water is released through a powerplant directly to the river in response to peak demands or (2) a pumped storage system where water is stored in an upper reservoir, released to a lower reservoir during peak demand periods, and then pumped back during low demand periods. The former type, of which Glen Canyon is an example, results in highly fluctuating flows downriver unless a regulating reservoir is incorporated. The latter requires the need for an additional energy supply to provide for pumping. This need is typically 50 percent greater than the total energy provided by the plant, but the difference in the value of peaking energy versus low demand period energy in some cases enables a pumped storage plant to be practical.

The study identified about 150 potential peaking powersites in the region and subsequently narrowed that number to 26 sites, of which 20 were pumped-storage and six were flow-through facilities. These sites were presented to the public in a series of six public meetings held in different locations within the region. Three sites--Flaming Gorge in Utah, Blue Mesa Dam in Colorado, and Glen Canyon Dam--were then recommended for feasibility study for fiscal year 1979. Since that time the Blue Mesa Project has been concluded, and the Flaming Gorge Project is on hold while further investigations are conducted.

The planning team noted that Glen Canyon Dam had the advantage of being an existing facility, that a minimum of construction would be required, and that power could be generated sooner than most other sites to meet projected needs. The team recognized that recreational and environmental impacts could be significant. The Peaking Power Status Report of September 1978 summarized the recommendations for feasibility studies.

1/ U.S. Department of the Interior, Bureau of Reclamation, Pumped Storage Investigations, Preliminary Reconnaissance Report, Upper Colorado Region, Salt Lake City, Utah, March 1964.

Participating Agencies and Individuals

Late in 1978, Reclamation established a multidisciplinary planning team led by the Durango Projects Office and four subteams to assist in the study. Other government agencies, such as the National Park Service, the U.S. Fish and Wildlife Service, Western Area Power Administration, State and local agencies, and the public were invited to join any of the subteams established for the study. Public members of the subteams represented environmental organizations, public and private utilities and other power customers, university scientists, commercial rafting companies and trade organizations, and concerned members of the public. The subteams and the general planning team, which consisted of subteam leaders, met periodically to review problems and issues, make recommendations, and plan the course of the study.

The only Federal agency funded by Reclamation to participate in the study was the U.S. Fish and Wildlife Service under authority of the Fish and Wildlife Coordination Act (1958).

CHAPTER II

SETTING

Location

Glen Canyon Dam on the Colorado River is located in extreme north-central Arizona, immediately south of the Utah-Arizona border. Its reservoir, Lake Powell, extends approximately 100 miles to the northeast into Utah. The dam lies within Coconino County, Ariz., adjacent to Page, Ariz., the largest community in the sparsely populated region around the dam. The Glen Canyon National Recreation Area surrounds Lake Powell and Glen Canyon Dam, and is bordered on the south and east by the Navajo Indian Reservation. Two U.S. Highways extend from Page--U.S. Highway 89 running south to Flagstaff, Ariz., and north to several small communities in southern Utah, and State Highway 98 running east through the Navajo Reservation. The study area includes the 255-mile section of the Colorado River from Glen Canyon Dam, to the backwaters of Lake Mead. This section of the river is located within or bordered by the Grand Canyon National Park and the Havasupai and Hualapai Indian Reservations.

Natural Environment

Climate

The climate in the study area is semiarid with a wide temperature range over the year, although precipitation and temperature vary greatly with altitude. Average annual precipitation in the Grand Canyon varies from about 9 inches at the bottom to about 16 inches along the north rim. Most precipitation in the area occurs in the summer, mainly as brief afternoon thunderstorms, and during the winter, as less intense but longer periods of rainfall. Snow occurs at higher elevations but is rare at Page's elevation of 3,700 feet. Temperatures at Page range from 103° F (Fahrenheit) in the summer to 3° F in the winter. The hottest temperatures in the area occur in the lower portions of the Grand Canyon.

Physiography

The study area lies within the western portion of the Colorado Plateau, which is characterized by mostly flat and gently sloping sedimentary formations eroded into numerous canyons, mesas, and plateaus of varying elevations. Commonly, one wide mesa bench rises above another so as to form a series of broad, irregularly outlined steps, each hundreds, or in some cases, thousands of feet in height. Interspersed throughout the area are intrusive igneous features represented in the vicinity of Glen Canyon Dam by Navajo Mountain and the Henry Mountains. The red-stepped mesas form picturesque vistas and the deeply incised canyons expose formations that cover nearly the entire period of geologic time. This phenomenon is most unique in the Grand Canyon. General elevations range from 2,000 feet to 9,000 feet. The river elevation is 3,100 feet at Glen Canyon Dam.

At Glen Canyon Dam the river flows in a 1,000-foot-deep, steep-walled canyon of Navajo Sandstone of Jurassic age. The Navajo Sandstone is a red-colored, fine-grained, and thick formation of remarkably uniform composition that also forms most of the canyon walls around Lake Powell.

Downstream from the dam, progressively older geologic formations are exposed along the Colorado River as it flows through Marble Canyon below Lee's Ferry and then through the Grand Canyon. Canyon walls are very steep at river level over much of this distance, with vertical cliffs reaching the river in places. Most of the river bank consists of talus from the overlying cliffs and river deposits of silt, sand, cobbles, and boulders.

Stream systems

The Colorado River begins in Rocky Mountain National Park in Colorado at 14,000 feet above sea level and flows southwest into Utah. Glen Canyon Dam is located over 600 miles downstream. The principal tributaries of the Colorado River above Glen Canyon Dam are the Green and San Juan Rivers. The Green River begins in western Wyoming and discharges into the Colorado River in southwest Utah about 200 miles above Glen Canyon Dam. Green River flows are controlled by Fontenelle and Flaming Gorge Dams. The San Juan River originates in the San Juan Mountains in southwestern Colorado and flows into Lake Powell. San Juan River flows are largely controlled by Navajo Dam.

From Glen Canyon Dam to Lake Mead, a distance of 255 miles, the Colorado River falls from 3,100 to 895 feet above sea level. Over 150 rapids, some having drops of up to 40 feet, account for most of the decrease in elevation, although only 10 percent of the distance. Numerous tributaries enter this stretch of river, the principal ones being the Little Colorado River, Paria River, Kanab Creek, Bright Angel Creek, and Havasu Creek. Most of the rapids are formed at points on the river where tributaries enter to form debris fans composed of large boulder- and cobble-size materials.

Sedimentation and erosion

The beaches in the Grand Canyon were formed by a process of erosion and replenishment of river sediment. Prior to construction of Glen Canyon Dam, the average annual spring high flow was approximately 80,000 cfs, with floods occasionally exceeding 100,000 cfs. The floodflows entering the canyon supplied a large sediment load transported in from the Upper Basin. As the flood peak moved through the canyon, the higher velocity flows would cause some scouring of the river bottom and banks; but as the flood receded, the river velocities would decrease and the river would deposit part of the sediment load immediately above and below the rapids in the low velocity reverse eddies, in the deeper pools, and on the talus deposits forming the banks. This way the beaches were periodically eroded and replaced with sediment.

After completion of Glen Canyon Dam, periodical erosion and replenishment ceased, and most of the river's sediment load is deposited upstream of the dam. The beaches above the current high water mark are no longer flooded, but they still erode as a result of human use of these areas for camping. Beaches below the current high water mark are continually being eroded from fluctuating flows ranging from 1,000 to over 30,000 cfs. Releases from the dam are extremely erosive since they are nearly sediment-free and have a large transport capacity. During daily low flows, there is seepage of ground water stored in the river banks, which further aggravates beach erosion by carrying sediment to the river. The winds and heavy recreational use also contribute to the process.

The sediment supply from the Paria River, the Little Colorado River, and smaller tributaries entering below Glen Canyon Dam has served in some degree to slow down the beach erosion process after discharging sediment to the river. The effect on erosion, however, is a temporary one which radically diminishes during times of low discharge from the tributaries.

Recreation

Portions of Grand Canyon National Park and Glen Canyon National Recreation Area, both administered by the National Park Service, are the recreational units located within the study area, and both have the Colorado River as a major recreational attraction. The boundary between the two units at the river is at Lee's Ferry, one of two locations where there is public vehicular access to the river in the study area (the other being at Diamond Creek in the lower reaches of the Grand Canyon).

Below Lee's Ferry, annual rafting use on the Colorado River through the Grand Canyon, the major activity impacted by the peaking power proposal, is currently limited to 169,950 user-days by the National Park Service. Commercial users, represented by 27 companies, are allotted 115,500 user-days, while noncommercial users are alloted 54,450 days. Approximately 62 percent of user-days are allotted during the summer season. Restrictions are placed upon both groups of users as to maximum group size, number of groups leaving Lee's Ferry per day, and maximum trip lengths. The current high level of recreational rafting on this section of the Colorado River has developed since Glen Canyon Dam became operational in 1963.

The 15 miles of river between Glen Canyon Dam and Lee's Ferry is used primarily for fishing and associated recreational activities. A single concessionaire operates a 1-day float trip from the dam to Lee's Ferry. River-oriented recreation within this area accounted for about 24,000 visitor-days in 1980, with more than 5,000 of these days used by the 1-day commercial float trip. Most of the remainder represents use of the trout fishery below the dam and other associated activities. Although the Park Service does not currently limit use within the area, studies are being conducted to determine the maximum use the area can withstand without suffering serious environmental damage.

River and riparian environment

The present riparian and aquatic environment of the Colorado River in the study area can be attributed to the immediate and continuing effects of the construction of Glen Canyon Dam, which allowed the formation of Lake Powell beginning in 1963. Prior to then, the downstream environment was considerably different. The fundamental changes leading to the present environment were the elimination of large spring flows, decreased water temperature, decreased suspended solids, and increased primary productivity. The downstream environment today continues to change in response to these relatively new conditions.

Pre-dam river flows consisted of a high spring runoff averaging 80,000 cfs, with a record high of about 300,000 cfs, followed by late summer and early fall low flows of sometimes less than 1,000 cfs. Water temperatures fluctuated seasonally with extremes of near freezing in the fall and winter to over 80° F in the summer. The Colorado River transported a sediment load in suspension which cyclically contributed to the deposition and scouring of the riparian zones downstream. Primary productivity was low because of the low seasonal supply of basic nutrients and low light penetration, both of which restrict photosynthesis.

Since construction of the dam, extreme seasonal flow fluctuations have been eliminated with maximum and minimum flows ranging from 1,000 to 31,500 cfs. Releases from the dam come from the lower levels of the reservoir where temperatures range between 45 to 55° F. Nutrients accumulate in the lower levels of the reservoir and are released downstream, providing the chemical basis for a lush growth of aquatic plant life. The level of suspended solids released has been to a point where there are no measurable amounts at present.

Pre-dam riparian vegetation was ephemeral and controlled by the magnitude of high flows. Plants that became established at low flows were washed away at high flows. Wildlife did not rely heavily on the riparian zone for survival but was adapted to desert conditions and used the river as an infrequent water source. Fish species in the pre-dam river were unique and highly specialized in their adaptation to the severe physical conditions.

Post-dam conditions have favored the development of a significant perennial riparian flora, regarded as disclimax or in a state of reponding to the disturbance caused by the dam. Located mostly on the pre-dam flood terrace, this community supports a wide variety of wildlife, including many species not present before the dam.

Many native fish species have been eliminated, notably the Federally listed endangered species, the Colorado squawfish. In their place, several exotic species have flourished, the most predominant being rainbow trout, which was introduced, and carp.

Vegetation and Wildlife

Plant communities in the study area are classified as riparian and are restricted to the narrow corridor along the Colorado River at the bottom of the canyons. The surrounding land supports a desert vegetation which encroaches occasionally to the river's edge. The riparian zone is dependent upon the river and thus is restricted to the pre-dam flood terraces composed primarily of fine sand and silt alluvium. The riparian zone is restricted by the size of the pre-dam flood terrace which, in many instances, extends to the sandstone and granite walls enclosing the river corridor.

River fluctuations periodically inundate portions of the riparian communities closest to the shoreline. Sharp erosion terraces with extensive amounts of exposed roots are a common occurrence. In places the vegetation acts as a trap and reduces the suspended sediment load of the river.

Initial colonization on the pre-dam flood terraces was by the exotic species tamarisk and the native species coyote willow. These two species presently are alternating in the role of the dominant species in the canyon. Seep willow and arrow weed are subdominant species in these communities. Other species include red brome, scouring rush, and dog bane.

The establishment of a perennial vegetation has created a variety of habitats in the riparian zone, resulting in an increase in number and diversity of wildlife species. Mammals are represented by rodents, bats, fur bearers, mule deer, and desert big horn sheep. Reptiles and amphibians are common within the vegetation canopy. Birds are the most conspicuous animals in the canyon, most of them being migratory species.

Fisheries

The Colorado River in the study area currently supports a high quality trout fishery of recreational significance that is made possible by the cold, clear water releases from Glen Canyon Dam. Post-dam physical conditions, however, are also responsible for the decrease in numbers of most native species.

The trout fishery exists over the entire length of the river in the study area, a distance of 255 miles, but is managed only in the first 15 miles downstream of the dam where there is suitable access. The Arizona Game and Fish Department manages the fishery, which was established in 1963 following closure of the river.

Over the years, the cold, clear releases from the dam have established conditions for the propagation of invertebrate and plant species on which trout thrive, and consequently the fishery has developed into one of "trophy" status. Fisherman pressure has increased considerably over the years causing the Arizona Game and Fish Department to consider restrictions on harvest to maintain the quality of the fishery.

Daily flow fluctuations have not affected the viability of the trout fishery. Neither extreme high flows nor low flows significantly limit the amount of usable adult habitat. During low flows, trout are found in the numerous deep pools of the river. Flows above 10,000 cfs move out laterally, creating additional habitat and therefore do not significantly alter total available habitat as average water velocity, depth, and river width increase.

Native fish have been significantly impacted by the daily flow fluctuations that have existed in the 19 years since the closure of the river. The flow fluctuations, along with the persistently cold water temperatures and competition from the new exotic fish species are the three primary reasons for the decline in numbers of native fish. Three species including the Colorado squawfish, the bonytail chub, and the roundtail chub have become extinct in the Grand Canyon below the dam.

Endangered Species

Two Federally listed endangered species occur downstream of Glen Canyon Dam, the peregrine falcon and the humpback chub. Peregrine falcons would not be impacted by the proposed increase in maximum flow. Humpback chubs are known to occur in the Colorado River but in relatively small numbers. To date, only the Little Colorado River (77 miles downstream of Glen Canyon Dam) provides suitable habitat for the humpback chub to successfully complete its life cycle. Persistent cold water temperatures in the Colorado River inhibit and probably prevent gonadal maturation of humpback chubs. The chubs that exist in the Colorado River are probable immigrants from the Little Colorado River. Aside from the apparent inability of these fish to successfully reproduce, the main river fish have adapted well to this new environment. There is no evidence that these main river fish return to the Little Colorado River, once "lost" to the Colorado. The confluence area between the Little Colorado and Colorado Rivers would be the only area of possible impact related to fluctuating flow. Although some impact to incubating spawn and young-of-the-year fish may presently occur, it is thought not to be significant in terms of adversely affecting the chub population as a whole. Investigators have confirmed that successful natural reproduction by humpback chubs occurs in the first 8 miles of the Little Colorado River upstream from the confluence. Also, chubs have been found to be one of the most common fish species in the Little Colorado River.

Cultural resources

To determine the presence and nature of the cultural resources in the project area, a Class II field survey was conducted for the area between Glen Canyon Dam and Lee's Ferry and a Class I literature search was performed for the study area below Lee's Ferry. Ten archeological and historic sites were located along the river between the dam and Lee's Ferry. Historic sites include Lee's Ferry, Stanton's Road, and a placer mine test site. Remains at the Ferry date from the 1870's to the mid-1940's, while Stanton's Road was built in 1899 to establish mining claims along the river. Archeological sites include petroglyph panels, quarry sites, campsites, and small rock shelters. Some petroglyphs are similar to styles believed to date several thousand years ago, while others belong to the Anasazi tradition (ca. 600-1400 AD). The Class II survey has revealed that the visitation, use, and occupation of the main stem of Glen Canyon was greater than is commonly recognized today.

A literature search (Class I survey) was done by the Museum of Northern Arizona. The survey contains detailed information on the hundreds of historic and archeological sites along the river below Lee's Ferry.

Social and economic conditions

Population

Based on the U.S. Census figures, the population of Page, Ariz., was 4,907 in 1980, 341 percent higher than the 1970 population of 1,439. This surge in growth primarily resulted from the construction of the Navajo Powerplant during the first half of the decade as well as a growing interest in the area's recreational opportunities. By comparison, Coconino County increased 55 percent to 75,008 in 1980, and Arizona as a State increased 53 percent to 2,718,215 in 1980.

Census figures in 1980 showed the following racial composition for Page: 4,094 whites, 673 American Indians, 21 Asians, 17 blacks, and 102 in the all others category. Of the 4,907 population in 1980, 206 were of Spanish origin.

Employment, Economic Base, and Income

Transportation, communication, and public utilities made up 30.7 percent of Page's employment structure in 1976, while wholesale and retail trade accounted for 28.2 percent of the total in that same year.[1/] Services contributed 27.1 percent. All other employment categories comprise the remaining 14 percent. Retail trade, services, and transportation sectors are significantly affected by tourism-related employment. In 1976, approximately 22 percent of the total employment in Page was attributed to tourism.

Page and its surrounding trade area, encompassing a radius of 50 miles, reveal a wide range in personal income, extending from relatively well paid government and public utility workers to consistently low income reservation residents.

Public Services

School system.--The Page school system contains a public elementary school, a public junior high school, and a public high school. Faculty size for the three schools was 36, 33, and 29, respectively; while

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1/ Page Community Profile, Arizona Office of Economic Planning and Development. Unless otherwise noted, factual information in this section is taken from this source.

enrollment was 891, 610, and 571, respectively. Not included in the faculty size are 21 additional resource teachers. The BIA (Bureau of Indian Affairs) also operates two boarding schools and one day school. At present, the elementary school is seated to capacity, according to a local school official, but the high school can accommodate more students because it is able to place students in large lecture rooms.

Health care.--Page medical facilities are adequate for accidents or general hospital care, but little specialized care is available. The city hospital has 25 acute care beds. The recent addition of another clinic and doctor has brought the total number of clinics and doctors to two and five, respectively. Medical air evacuation services to Phoenix and Flagstaff are available during emergencies. In addition, two dentists, one optometrist, and one chiropractor serve the city.

Police and fire protection.--Police protection in Page includes the city police department with 18 members, the county sheriff and two deputies, and 4 officers of the State Department of Public Safety. The municipally operated fire department consists of mostly volunteer fire and rescue divisions, which include emergency medical personnel and equipment. The Page Fire Department also provides service to facilities at Glen Canyon Dam.

Water, sewer, and utilities.--Page's municipal water comes from Lake Powell and is delivered to the city from pumps located at the Glen Canyon Powerplant. Local officials contend that the water supply is presently fully allocated, although the Page, Ariz., Community Prospectus, 1978, stated that there is enough water available to serve a population of 10,000 at a per capita use rate of 280 gallons per day.

Page achieved significant improvements in its self-operated sewer system in 1973 and, by 1978, provided more than adequate sewer service.1/ Capacity was listed as 500,000 gallons per day which would enable a daily average of 90 gallons per capita to be processed. Figures in 1976 indicated an average daily flow of 32.85 gallons per capita. In contrast to the Community Prospectus description, city officials in 1981 stated that Page sewage treatment capabilities are presently strained to such a degree that they cannot accommodate a population above 6,000 (1980 population 4,907).

The Arizona Public Service Company provides electrical services to Page and also purchases power from the city itself. Page has no plans for obtaining natural gas service in the immediate future and will continue to rely on LP gas which is available from local distributors.

Housing, transportation, and communications.--At present, 1,782 housing units are available in Page, most of which are mobile homes. There is a shortage of conventional housing. The city is served by one bus company and one regional airline. There are two small local newspapers, a radio station, and cable television.

1/ Page, Ariz., Community Prospectus, 1978.

CHAPTER III

PUBLIC INVOLVEMENT

The earliest public involvement on the Glen Canyon study occurred during the initial investigation of peaking power possibilities in the Upper Colorado Region.1/ Public involvement for that study included public meetings held in six communities in the region, including one in Page, Ariz., in May 1978. The public expressed concern at that time over possible adverse impacts to boating and fishing on the Colorado River, but Glen Canyon was subsequently chosen for feasibility investigation based on the minimal amount of new construction required and the existing transmission interties to the CRSP system. Planners felt at that time that an economically feasible project with an acceptable level of impact could be formulated.

October 1978 to November 1979

The feasibility study formally began in October 1978 at the beginning of fiscal year 1979. A Notice of Initiation of Investigation was announced in the Federal Register in December 1978. During initial planning activities over the next several months, the Durango Projects Office and the Upper Colorado Regional Office planned the first public involvement events. Public meetings were held in Page, Flagstaff, Phoenix, and Salt Lake City to inform the public about the study and to obtain initial public reaction and advise on how to conduct the study. These meetings and subsequent planning team meetings also served as "scoping" sessions, as required by the National Environmental Policy Act, to determine the issues to be addressed by the environmental impact statement.

The meetings were publicized with paid advertisements in local newspapers and radio spot announcements; the study team leader was interviewed on television in Flagstaff. Certain Federal and State agencies and other parties known to be interested were contacted directly with invitations through the mail.

The four meetings were held during the last week of July 1979. Total attendance was 90 people, including representatives of utility companies, environmental and recreational groups, government agencies, labor unions and members of the news media. The presentation covered the background of the proposal, the demand for peaking power, potential impacts, and the planning process.

1/ Described in the Peaking Power Status Report, Bureau of Reclamation, September 1978.

The major areas of comment dealt with recreational, biological, power, and social impacts and questions over the process of conducting the study. Recreational concerns dealt with the potential impacts of increased flows on camping beaches and the scheduling of rafting trips; questions were raised on how the Grand Canyon Management Plan would be affected. The major biological concern was over the potential effect of increased flows on the trout fisheries, beaches, and vegetation. There were questions concerning the need for additional peaking power and the feasibility of alternative technologies. Major social concerns were expressed about the impacts of construction on the community of Page and the economic impacts on recreation to Page and other communities. Questions related to conducting the study concerned methods of collecting and analyzing data, timing and location of public meetings, and involvement of the general public and other Federal and State agencies in the study. Approximately a third of the participants chose to join one of the four technical planning teams which were formed at that time. The comments and reactions obtained were judged as preliminary in nature due in part to the level of attendance. A mailing was later sent to all participants that summarized the results of the meetings.

The first subteam meetings were held between August and October 1979. Each subteam selected a leader who represented the team at the first general planning team meeting held in November 1979. The first activities of the subteams were to expand on the initial lists of potential impacts and to make suggestions for the future conduct of the study. The biology and recreation teams made specific suggestions on data collection needs and methodologies and reviewed available information.

December 1979 to October 1981

Data collection and analysis were the primary activities during 1980. The public was kept informed of progress through newsletters, which reached interested individuals unable to attend meetings or otherwise actively participate. The first newsletter sent in December 1979 to about 225 people, reported on the formation of the planning team, advised of the data collection activities planned for the next year, and included a response from the public to gauge interest in the newsletters and satisfaction with the public meetings held in July 1979.

Three more newsletters were sent out during 1980. Newsletter Two summarized the response results, which were very favorable toward the newsletters and mixed toward the public meetings. The lack of information available at that time to respond to the major concerns was the primary complaint. Newsletters Two, Three, and Four described ongoing data collection activities and Newsletter Four discussed the conservation alternative to the proposal. Two of the newsletters discussed the decision that had to be made in 1981 on the size of the powerplant to be studied at the feasibility level if the study were to proceed to that point.

A series of planning team and subteam meetings resumed late in 1980 and early in 1981 to analyze the data gathered the previous year and to prepare for the decision on sizing expected later that year. The recreation team met eight times, the biology team five times, and the social and power teams each met twice. The computer simulated flow data that predicted downstream flow patterns were presented at a recreation team meeting in Page in March 1981 that attracted about 80 people and at a large combined recreation and biology team meeting in Flagstaff in April 1981. Both meetings were actually public meetings since they were attended by many individuals who were not members of the two subteams and by members of the press. Newsletters Five and Six were prepared in May and September 1981 and described the computer-predicted flow patterns.

The level of public comment in mid-1981 increased tremendously, so that by September the mailing list had grown to over 1,000. The overwhelming majority of the letters were against the peaking power proposal for recreational and environmental reasons. The study was also the subject of several feature articles by major newspapers and magazines.

In September 1981, a final general planning team meeting was held to review the issues to be presented at the public meetings prior to the selection of a recommended plan. Those meetings were held during the last week of September and first week of October in Page, Flagstaff, Phoenix, and Denver to obtain public comment. The meetings were publicized through news releases sent to newspapers and radio and television stations throughout the southwest, including major newspapers in California and the National wire services. A special notice and a pre-meeting informational handout summarizing major findings were sent to everyone on the mailing list, which included several organizations with publications of wide distribution.

Attendance at each meeting was as follows: 72 in Phoenix, 167 in Flagstaff, 67 in Page, and 99 in Denver. Most groups that showed interest in the study were represented at one or more of the meetings. The format allowed for long periods of public comment following a presentation of the information developed to date.

More than 95 percent of the participants were against the proposal. The reasons most often cited were that the flow fluctuations would adversely affect recreation and the ecology of the river in the Grand Canyon; that the Grand Canyon was a great natural heritage not worth damaging for the additional capacity obtained; that the level of predicted power demand was questionable; and that there are viable alternatives that should be investigated. Throughout the course of the study there was no strong public support for additional peaking power generation from this potential project.

More than three-fourths of the participants reacted favorably to the organization and conduct of the meeting. Many people, however, felt that pertinent information should have been supplied further ahead of time to the general public.

The final public involvement activity was a newsletter released in early November 1981 that summarized the concerns expressed at the last series of public meetings and stated the reasons for concluding the study. Reclamation made the decision in October 1981 to conclude the study, which was endorsed by the Secretary of the Interior in an October 29, 1981, news release. The reasons for concluding the study were the public's concern for potential enrivonmental and recreational problems, the consideration that other sources of peaking power were available, and the need to achieve budget cuts sought by the current administration.

CHAPTER IV

PROBLEMS AND NEEDS

Demands for additional peaking power, together with the rising cost and dwindling supplies of fossil fuels have made it necessary to further develop efficient, renewable peaking power resources such as hydroelectric power facilities. Throughout the CRSP service area,1/ additional generating capacity will be needed to help meet future requirements for power at peak demand periods even with conservation measures and with such nonstructural management measures as a redistribution of existing demand patterns and a time-of-day pricing structure.

A Reclamation survey of power needs in the CRSP marketing area identified the need for increased peaking power capacity. The survey was conducted as part of the 1975 power peaking reconnaissance study by a power resources and needs subteam, a component of the planning team organized to aid in the study process. The survey and other analyses developed by the subteam are documented in detail in the 1978 Peaking Power Status Report, Appendix, Volume 2 of 2. Load and energy projections derived from the report are presented in the following table which reflects the effects of conservation measures, interregional interties, and changes in rate schedules.

CRSP marketing area load and energy projections
cumulative totals from all load centers1/

Item	Power projections 1975	1985	1990	1995	2000
Total capacity requirements (MW)2/	12,680	25,309	33,131	42,409	54,117
Annual energy (MWh x 10^6)	63.3	129.5	170.3	218.9	280.4
Maximum peaking energy (MWh x 10^6)	2.8	6.1	8.0	10.2	13.3
Minimum peaking energy (MWh x 10^6)	.8	1.7	2.2	3.1	3.9
Maximum peaking load (MW)	4,071	8,276	10,834	13,825	17,740
Minimum peaking load (MW)	2,562	5,188	6,759	8,948	11,365
Maximum peaking hours	2,200	2,320	2,300	2,300	2,340
Minimum peaking hours	800	830	810	880	880
Estimated peaking energy (MWh x 10^6)3/	1.8	3.9	5.1	6.6	8.6
Estimated percent of annual energy	2.8	3.0	3.0	3.0	3.1
Estimated peaking load (MW)	3,493	7,099	9,293	11,959	15,261
Estimated percent of annual peak demand	27	28	28	28	28
Estimated peaking hours4/	1,500	1,570	1,570	1,580	1,580
Annual load factor5/	0.57	0.58	0.59	0.59	0.59

Source: U.S. Bureau of Reclamation, Peaking Power Status Report Appendix, Volume 2 of 2, 1978.

1/ Time of occurrence for peak loads varied slightly among load centers; however, it was assumed that the variation in individual hours reported would not affect the totals estimated for annual peak demand and annual schedule changes.

2/ Total demand including base as well as peak.

3/ Average of maximum and minimum range of peaking energy.

4/ Estimated number of hours per year that peaking occurs.

5/ Ratio of average load to peak load.

1/ The CRSP service area for planning purposes includes the States of Colorado, New Mexico, Arizona, Utah, and Wyoming in their entirety; all or portions of six counties in Nevada; and the State of California east of the 115th degree of longitude.

U.S. Census projections show the CRSP area can expect a population of about 10,981,000 by 1990 and 13,492,000 by 2000, compared to 8,237,000 in 1976. With a projected continuation of existing patterns of demand that take conservation measures into account, the 1975 power resources and needs subteam projected about 8,000 MW1/ of additional peaking power load would be needed in the CRSP market area from 1985 to 2000, as shown in the table on the preceding page.

More recent inventory studies by Western have indicated that projected effects of increased energy conservation and load management programs have reduced the level of need from 8,000 MW down to 4,000 MW, which includes 1,000 MW of reserves.

This reduced projection for peaking power led to Reclamation conducting a Peaking Power Prioritization Study (June 1981) to determine which of several peaking power projects under study by Reclamation in the CRSP market area should be investigated first. This study indicated other projects in the market area may be able to provide peaking power at lower installed costs per kilowatthour than the Glen Canyon Project peaking power increment. The study recommended investigations on these other projects be completed before any further study for potential peaking power at Glen Canyon is considered.

1/ Includes rate schedule changes.

CHAPTER V

EVALUATION OF RESOURCE CAPABILITY

Water Supply

Annual release requirements

Under present operating criteria (35 FR 112, June 10, 1970) the Secretary of the Interior has been releasing 8.23 million acre-feet annually from Lake Powell1/. The Upper Division States and the Upper Colorado River Commission have rejected any implication that the release of 8.23 million acre-feet per year constitutes a definition of Upper Division States' delivery obligation under the Colorado River Compact. In years of abundant water supply and reservoir storage, quantities greater than 8.23 million acre-feet of release from Glen Canyon Dam can and have occurred.

No change in the annual volumes discharged by Glen Canyon Dam is planned for current operation of the dam nor would yearly releases change if additional units were added to the dam.

Monthly releases

Monthly releases vary according to the amount of storage in Lake Powell and energy demand. As each new water year begins in October, monthly releases are projected for the year based upon a less than favorable water supply accumulation for the coming year. As the year progresses, actual monthly discharges will differ from projected monthly releases discharges insofar as reaching the average of 8.23 million acre-feet releases each year.

The use of Glen Canyon Dam as a peaking power facility has grown since the initial operation of the dam. The effects of peaking operations at Glen Canyon Dam result with water conserved during light load demand months in the spring and fall (March, April, May, October, and

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1/ "Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994, 59 Stat. 1219), the decree entered by the Supreme Court of the United States in Arizona vs. California, et al. (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S. Code 618a), the Colorado River Storage Project Act (70 Stat. 105; 43 U.S. Code 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S. Code 1501)."

November) and greater volumes released during peak demand months in the winter and summer (December, January, July, and August). The difference in monthly releases reflects the supply and demand of available power in the CRSP area. During light load months, energy can be generated at other facilities so that Glen Canyon Dam can store water for power production at a more beneficial time. During months of large releases from Glen Canyon Dam, energy is in great demand and peak needs can more easily be met at hydrogenerating units such as those at Glen Canyon Dam. The following tabulation shows monthly release projections for the present and future operation of Glen Canyon Dam, with or without powerplant expansion.

Month	Released water (acre-feet)
October	600,000
November	700,000
December	800,000
January	900,000
February	700,000
March	400,000
April	400,000
May	400,000
June	600,000
July	1,000,000
August	1,000,000
September	730,000
Total	8,230,000

Daily releases

Diurnal fluctuations are also a function of power demand, and reflect our daily uses of energy and reservoir storage. Normally, energy demand is least during the very early morning hours of the day, increases to a peak from late in the morning to late in the evening, then drops back to early morning reduced demands. Although fluctuations have a maximum range of 1,000 to 31,500 cfs, daily fluctuations will vary according to season and reservoir elevation. Releases in the summer vary from about 5,000 to 30,000 cfs, releases in the winter vary from 1,000 to 30,000 cfs, and releases in the spring and fall vary from about 1,000 to 15,000 cfs. Exceptions to the above ranges can occur for an immediate emergency demand for energy due to mechanical failures at other sources of energy, flood control and reservoir storage needs, adverse weather conditions, or for lack of power demand. The tabulation on the following page summarizes releases during different seasons of the year.

Season	Range of release (cfs)
Fall (mid-September to mid-November)	1,000-20,000
Winter (mid-November to mid-February)	1,000-31,500
Spring (mid-February to Easter)	1,000-15,000
Rafter's Spring (Easter to mid-June)	3,000-15,000
Summer (mid-June to mid-September)	3,000-31,500

Presently, the generators at the powerplant are being rewound because of deterioration of the units. The result will be an uprating of generation capacity and an increase in the maximum release from the dam from 31,500 cfs to 33,100 cfs. The operation is being performed as a routine maintenance procedure. The rewinding and uprating was expected to be completed before the powerplant expansion would have occurred.

Releases associated with a maximum 250-MW expansion at Glen Canyon Dam would have increased the maximum discharge capacity to 40,000 cfs. This is 7,000 cfs greater than maximum releases of 33,100 cfs the dam could release if existing generators were rewound and uprated. Annual and monthly releases would not change, but following rewinding and uprating and a maximum 250-MW expansion, daily release patterns would have maximum peaks of 40,000 cfs rather than the current 31,500 cfs.

The effects of this widened range of release capacity would show up in the peak load months where there would be a longer period of minimum releases in the morning with sharper increases later in the day. Peaking operations would not last as long during the day, and the drop back to minimum releases would, likewise, be sharper. Releases during other than the peak load months would result in little change from the present operation of the dam during these months.

Minimum releases

Since the initial operation of Glen Canyon Dam, minimum release criteria have been established to preserve the downstream environment and to accommodate recreational interests. Minimum flows are set at 1,000 cfs during the year from approximately Labor Day to Easter (September through April) for environmental reasons. During the remaining year (May through August) minimum releases from the dam are 3,000 cfs. The 3,000-cfs minimum was established to accommodate river runners rafting from the dam to Lee's Ferry and through the Grand Canyon since this is the time of heaviest private and commercial use of the river. These summer minimums also aid fishermen's access to the excellent trout fishery that has developed below the dam.

Lake Powell and Glen Canyon Dam

Physical facilities

Lake Powell is a principal reservoir in the Colorado River Storage Project. The reservoir extends over 100 miles up the Colorado River from Glen Canyon Dam and 71 miles upstream from the former mouth of the San Juan River. The maximum operational elevation of Lake Powell is 3,700 feet above mean sea level and the reservoir's maximum storage capacity of 27,000,000 acre-feet of water covers an area of 161,390 acres.

Glen Canyon Dam is a concrete arch dam which rises 710 feet from its base to an elevation of 3,715 feet and spans 1,560 feet from canyon wall to canyon wall. The dam has two spillways, one in each abutment, which have a capacity to release 138,000 cfs. There are eight 15-foot steel penstocks located at an inlet elevation of 3,470 feet which are used to convey water to turbines.

The outlet works of Glen Canyon Dam consist of four 96-inch-diameter steel pipes located at an elevation of 3,374 feet to convey water to the downstream side of the dam for shutdown emergency procedures. The four outlet tubes have a combined capacity of 15,000 cfs at a reservoir elevation of 3,490 feet which is the minimum reservoir elevation for power operation.

Space is available in the switchyard, and plant control facilities exist which could accept new generating units and peripheral equipment that would be attached to the outlet works. Up to 250-MW of additional power generation could be produced using the outlet works and corresponds to additional releases of 7,000 cfs. After the existing generators are rewound and uprated, the addition of 250-MW units to the river outlet tubes would increase the total release capacity from 33,100 cfs to 40,000 cfs.

Appraisal estimates completed by Reclamation's Engineering and Research Center in Denver in June 1980 indicated that no special physical requirements for water hammer protection would be necessary for the proposed units. Also, any unit added to the outlet tubes would probably be the last unit on-line to produce power because the losses in the conveyance system would reduce the efficiency of the new unit below the efficiency of the existing units.

Transmission facilities and plant control

A transformer deck could be located on the south-southwest side of the powerplant building. Transmission lines could be connected from the transformers to points on the west canyon wall near the existing power-line towers. One or more new towers would be required. There are spare tie points in the switchyard to accommodate the additional transmission lines. The existence of the transmission system from Glen Canyon Dam to outside areas would reduce costs associated with the powerplant expansion proposal, but the capacity of the transmission system needs to be verified for carrying the increased capacity of power generation if additional powerplants were added to the outlet tubes at the dam.

Spare connection points are available in the intermediate and secondary switchgear. These points provide electrical service to the powerplant, control room, offices, and Visitor Center. Expanding the existing subsystem from the switchgear points to these areas may be necessary. Spare cable trays and electrical conduits are provided in the dam. There are spare bays in the control room for installation of the turbine generator control equipment.

Existing facilities for fire protection, service water, and unit cooling should be able to accommodate the proposed new units to some degree. Separate facilities would most likely need to be constructed to serve the additional units for gravity drainage, pressure drainage and unwatering, transformer oil, lubricating and governor oil, compressed air, and the carbon dioxide fire extinguishing system.

CHAPTER VI

PLAN FORMULATION

Glen Canyon Dam was recommended for feasibility investigation in 1978 as a result of the basinwide survey of potential peaking power resources as previously described. Harnessing existing river outlets at the dam could increase the capacity of generation significantly more than any other existing CRSP hydrogenerating facility. Benefits were seen in choosing Glen Canyon Dam as a study site since the extra generation capacity could be brought into the CRSP system earlier than other identified sites, due to the minimal construction required to modify the existing river outlet tubes, and the close proximity of a transmission system to handle the increased capacity.

Plan formulation for the investigation proceeded according to guidelines established in the Water Resources Council's Principles and Standards (Principles and Standards for Water and Related Land Resources Planning); Bureau of Reclamation Instructions and Policies; Council on Environmental Quality Regulations for Implementation of the National Environmental Policy Act; the Fish and Wildlife Coordination Act; the Colorado River Storage Project Act; and other legislation and regulations as they apply to water resources planning.

Scope of the Study

A multiobjective planning process was used to conduct the investigation, however, because the scope of the study was limited to the addition of peaking power facilities on the outlet tubes of Glen Canyon Dam, the study concentrated primarily on formulating the most feasible-size powerplant with maximum economic benefits and minimal adverse environmental and socioeconomic consequences.

Plan Formulation Process

Plan formulation for the Glen Canyon Unit followed a process outline in Principles and Standards. The problems and needs of the area were first identified and the capability of the available resources to meet these problems and needs were evaluated. This evaluation of needs and resources provided the basis for determining planning elements that would be considered in the formulation of alternative plans.

Next, alternative plans for meeting the objectives of the study were formulated and evaluated at appraisal level to determine if they met the four tests listed in Principles and Standards for identifying viable plans. These four tests include completeness, effectiveness, efficiency, and acceptability. The four tests are briefly defined as follows: (1) completeness is the extent to which an alternative plan provides and accounts for necessary investments or other actions to ensure the realization of the planned effects; (2) effectiveness is the extent to which an alternative alleviates the specified problems and achieves the desired results; (3) efficiency is the extent to which an alternative is cost effective (economically justified); and (4) acceptability is the workability and viability of the alternative in respect to acceptance by the public and adherence to existing laws and regulations.

Under the Principles and Standards alternative plans that pass all four tests become candidate plans and are subject to much more detailed examination. The next step in the plan formulation process entails subjecting each candidate plan to an analysis under each of the four accounts identified in Principles and Standards. These four accounts include (1) National Economic Development (NED), (2) Environmental Quality (EQ), (3) Regional Economic Development (RED), and (4) Other Social Effects (OSE). It is from these candidate plans and the four-account analysis that the preferred plan is identified.

In the case of the Glen Canyon study, none of the alternatives passed the four tests; however, the alternative with the best B/C ratio was evaluated according to economic, social, and environmental parameters to determine its potential if the plan were to be implemented.

Upon initiation of the investigation, a multidisciplinary group composed of interested Federal, State, and private agencies, as well as interested individuals was established to assist the Durango Projects Office with the identification of potential impacts associated with the proposal. The group recommended that four subteams be formed and leaders of each subteam meet with the study team leader from the Durango Projects Office as part of a planning team to make recommendations or exchange information between subteams. These four subteams were power, social, biology, and recreation. Interested individuals were invited to join any of the subteams. Organization of the subteams assisted in identifying issues of importance to the investigation and helped identify potential impacts to the environment and economy of the study area.

Alternative plans were formulated using appraisal-level data and procedures to evaluate the costs and economic benefits of each plan. The costs and benefits used and the data and assumptions upon which they are based are explained below.

Benefits

Appraisal-level benefit values for peaking power were based on the cost of the most likely single-purpose alternative which could deliver the same type of benefit at the same location. Considering a plant factor[1/] of 7 percent, the most likely alternative would be an

1/ Plant factor is the ratio of the average plant output to the plant nameplate rating. It reflects the amount of time per year that the plant operates. Peaking powerplants have low plant factors, usually not being greater than 17 percent.

oil-fired combustion turbine. Estimated annual cost of this alternative including fuel escalation to a 1990 plant on-line date is $120 per kW (kilowatt) of capacity. Based on this cost the benefit value of a 250,000-kW plant would be $30,000,000 annually.

A loss of recreation benefits which might result from a change in flow patterns was estimated to be about $165,000 per year to the quality of recreation experiences while rafting through the Grand Canyon. This $165,000 per year figure in lost recreation benefits may not be representative of the actual impact to the recreation resource. The figure was arrived at by using the Unit-Day Value Method. This method was used instead of the Travel Cost Method or Contingent Value Method because of a lack of base data necessary to apply these two methods and insufficient time available to collect this information. Losses were not estimated for any decrease in user-days related to changes in flow patterns or changes in river management plans by the National Park Service.

Since the National Park Service limits the number of rafters that can float through the Grand Canyon, any change in flows would not affect the number of users (man-days) that would continue to go through the canyon. The loss in economic value ($165,000) then was attributed to an annual reduction in the unit-day value through loss of quality in the rafting experience.

Costs

Cost estimates for the alternative plans were developed using the following criteria.

1. Appraisal level cost estimates for alternative plans were estimated using price levels current at the time of analysis and updated to January 1981.

2. Reclamation Instructions Series 150, Appendix A, "Estimating Data" was used to prepare all cost estimates with modifications for special conditions. Reclamation's Computer Program "PRWPLT" was used to develop cost estimates of powerplant facilities.

3. Alternative plans were compared using an interest rate of 7 3/8 percent and a useful life for facilities of 100 years. Construction costs and reimbursable interest during construction were amortized at this interest rate, and annual costs were added.

4. Operation, maintenance, and replacement costs were estimated using Reclamation Instructions Series 150, Part 154.

Development of Alternatives

Initial studies on developing the size of additional generating units led to a decision that a 250-MW unit was the maximum size that would be physically allowable. This corresponds to an additional 7,000-cfs release (maximum) from Glen Canyon Dam for a total maximum release capacity of 40,000 cfs, including releases from the existing generator units.

In order to determine the relationship between the size of powerplant and economic efficiency, powerplants of 100, 125, 175, and 250 MW were analyzed. The economic analysis of these potential powerplants is shown in the table below.

Economic analysis of various sizes of powerplants
CRSP peaking power capacity
Glen Canyon Dam

	Alternative generation unit sizes			
	100 MW (two 50 MW)	125 MW (two 62.5 MW)	175 MW (two 87.5 MW)	250 MW (two 125 MW)
Capital cost 1/				
Construction	$114,809,000	$123,100,000	$140,513,000	$165,428,000
Interest during construction 2/	21,606,000	23,166,000	26,443,000	31,132,000
Total	136,415,000	146,266,000	166,956,000	196,560,000
Annual capital cost 3/	10,069,000	10,796,000	12,323,000	14,508,000
Annual operation, maintenance, and replacement costs	212,000	232,000	407,000	589,000
Total annual cost	10,281,000	11,028,000	12,730,000	15,097,000
Annual power benefit 4/	12,000,000	15,000,000	21,000,000	30,000,000
Negative recreation benefit 5/	NA	NA	NA	-165,000
Net annual benefit	12,000,000	15,000,000	21,000,000	29,835,000
B/C ratio	1.17:1	1.36:1	1.65:1	1.98:1
Total capital cost per kW	$1,360	$1,170	$950	$790

1/ January 1981 price level.
2/ Based on 6-year construction period and 7.375 percent interest compounded.
3/ Based on capital recovery factor of 0.07381 (7.375 percent and 100 years).
4/ Based on $120/kW of capacity.
5/ Only applied to 250-MW size to represent worst case situation.

As shown in the table, as the size of the powerplant is increased, the B/C ratio increases and the capital cost per kW becomes less. This would indicate that from strictly an economic point of view, the 250-MW size would be the most favorable. Other factors remaining to be considered were potential environmental impacts that could be expected downstream with the various size units. These would include impacts on fish and wildlife, recreation, cultural and archeological resources, and socioeconomic impacts.

A consideration in powerplant size selection was the total average annual volume of water available for release at Glen Canyon Dam. At present at least 8.23 million acre-feet is released from Lake Powell annually. This quantity is exceeded in wet years and thus excess energy can be produced with the existing generating units. The average annual release would meet compact provisions when Upper Basin water development occurs.

Four alternative plans were selected to receive a complete appraisal-level analyses. These include two structural alternatives

(250 MW and 125 MW), the no-action alternative, and a nonstructural alternative.

Structural alternative

The structural alternatives are to add powerplants of either 125 or 250 MW to the dam. The physical layout of the two alternatives would be identical, both being located at the foot of the left abutment of the dam. The power units and plant housing would be located at the present site of the outlet structures of the outlet tubes. (See Artist's Concept on the following page.)

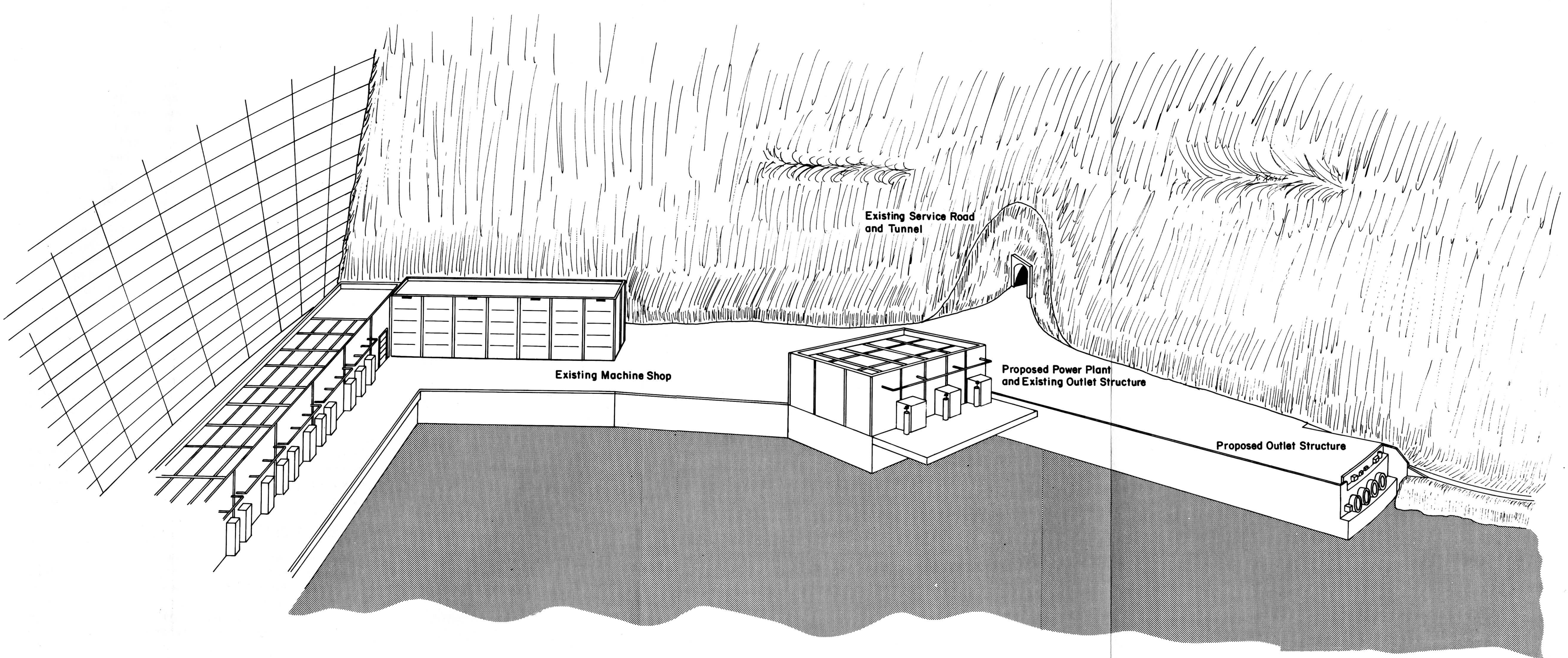
The original purpose for the outlet works was to provide for releases to meet downstream commitments when the powerplant is not in use and during final closure of the diversion tunnels. They would also be used to maximum capacity during maximum flood control releases. The outlet works would need to continue to serve these purposes with the proposed powerplant in place. The outlet tubes would, therefore, be extended and the outlet structures relocated as shown in the drawing. Valves would be installed upstream of the new powerplant, under the parking deck, to divert water into either the powerplant or through the outlet structures.

It would be possible to operate the new units when the main powerplant is inoperable because the intakes to the outlet works are at a substantially lower elevation than the intakes for the main penstocks. (See Chapter V, Evaluation of Resource Capability for a description of the existing outlet works.)

A 250-MW powerplant would require a housing with dimensions of about 115 feet by 150 feet, slightly larger than a housing for a 125-MW powerplant. Both powerplants would consist of two turbines, probably of the Francis type, lying side-by-side; the 250-MW plant would have two 125-MW turbines and the 125-MW plant would have two 62.5-MW turbines. Both alternative powerplant sizes would have plant factors of approximately 7 percent, producing peaking power for 3 to 5 hours each day for 90 days during the summer season and 60 days during the winter season. Peaking power from the additional units, and the consequent higher dam releases, would not be produced in the spring and fall.

The maximum release from the dam with the 250-MW addition would be 40,000 cfs, which would include 7,000 cfs from the addition and a maximum release of 33,100 cfs from the remaining power units on the dam after the rewinds and uprates are completed. Current maximum releases are 31,500 cfs. A 125-MW addition could require releases of up to 3,500 cfs, creating a 36,600-cfs maximum release from all powerplants on the dam.

Maximum or near maximum releases could occur almost every weekday during the operating seasons. Weekend releases would be lower, reflecting the reduced demand on those days. Minimum releases would be of longer duration increase since the total quantity of water released from the dam would remain the same as at present. The increased duration of



ARTIST'S CONCEPT OF PROPOSED
POWERPLANT ADDITION
GLEN CANYON DAM, ARIZONA

minimum releases with the 125-MW addition would be about half of that of the 250-MW addition.

Nonstructural alternative

The nonstructural alternative is a plan to reduce the need for peaking power by means other than construction of new facilities. Energy conservation measures could be instituted by legislation or through incentives to reduce or limit the need for more energy. These measures could be a result of rate structures administered on the use of energy during certain times of the day or season by the utility companies, encouraging a more even use of energy throughout the day rather than peak loading. Load management and co-generation are other means of meeting demand without construction of new facilities.

The ability of a nonstructural alternative to meet future demands is difficult to estimate, and it is difficult to establish the benefits attributed to this alternative. It is reasonable to assume that both nonstructural and some structural alternatives will be necessary to meet projected capacity demands as the CRSP area increases in population and development.

Without-plan condition

In this case, the river outlet tubes would remain as they are and Glen Canyon Dam would not be considered as a source of additional peaking power capacity, although the rewinding and uprating programs would be completed.

The effects of the proposed plans are measured against this scenario. Depending upon the significance of the measurement of this effect in the Four-Account Analysis, a decision could either be made to further study a recommended plan or discontinue study in favor of no action.

Four Tests of Viability

All four alternatives were evaluated using the four tests of viability. The following evaluation examines how each alternative fared as it relates to each of the four tests. Though none of the alternatives were able to pass all four tests at this time, the 125- and 250-MW alternatives have the potential to pass all tests if changing conditions make these alternatives more acceptable.

Completeness

Both the 125- and 250-MW units were complete in that the plans provided for the actions and investments necessary to realize fulfillment of the planned effects; i.e., installation of peaking power generation capacity from existing outlet works without increased flows.

The nonstructural alternative is not complete in that it would utilize conservation as its critical element and the actions necessary to accomplish the needed conservation have not been provided for. If methods of conservation were instituted, this alternative could become complete at a later date.

Effectiveness

Both the 125- and 250-MW alternatives would be effective in that they would provide additional peaking power capacity for the CRSP service area to satisfy the project needs discussed in Chapter IV.

The nonstructural alternative, if actually implemented, would be effective to some degree in that conservation would decrease the amount of peaking power necessary in the future. Some structural measures may, however, still be necessary.

Efficiency

Both the 125- and 250-MW alternatives were deemed to be efficient as the estimated B/C ratio was greater than unity, indicating the benefit would outweigh the costs of developments. The 250-MW unit B/C ratio, as shown previously, was estimated to be 1.98:1; while the 125-MW unit would be less effective but still economically feasible with a B/C ratio of 1.36:1.

The nonstructural alternative is efficient in that conservation efforts would make better use of already developed energy resources and would cut down on costs for new construction. Here again the degree of efficiency would depend on the amount of conservation accomplished.

Acceptability

The 125- and 250-MW alternatives were both unacceptable to the majority of the public that showed an interest in the study. This conclusion was evidenced by a large number of letters which expressed strong disapproval for any plan which it perceived as having a potential adverse effect on Grand Canyon National Park. While the peaking power capacity investigations are supported by power companies and municipalities in the CRSP market area, little support was demonstrated for developing additional capacity at Glen Canyon Dam. While either of these alternatives could be restudied at a future date, there is considerable support for investigating other potential peaking power projects in the market area before completing this investigation.

The nonstructural alternative was acceptable to the environmental community and special interest groups because it would result in no development or possible adverse environmental effects to the Colorado River and the Grand Canyon. This alternative would be acceptable to power interests only if alternative means of satisfying the projected peaking power needs were implemented.

Evaluation of Potential Project Effects

The Bureau of Reclamation conducted several appraisal-level studies to obtain information needed to perform the four-account analysis of the candidate plans. While the project investigations were concluded before the analysis was actually performed, information obtained from the studies is useful in projecting potential effects of implementing the project. Following is a summary of estimated socioeconomic and environmental effects that could be expected if the 250-MW alternative were implemented in comparison to the no action, future without plan condition. Also included is a summary of input received through the public involvement program.

Socioeconomic

Socioeconomic impacts of adding 250 MW of peaking power generation to Glen Canyon would be of two basic types: (1) construction impacts and (2) potential impacts on the river rafting industry between Glen Canyon Dam and Lake Mead. Construction activity would last about 6 years so the employment, income, and population impacts would be short lived. Long-term impacts in the Page area associated with operation and maintenance of the project would be insignificant.

There would be about 3,571 man-years of employment associated with the project, or an average of about 600 man-years per year, and just over $86 million additional income, including both direct and indirect income. Based on a survey of Reclamation construction projects, it is projected that about half of the work force would come from nonlocal sources. It is estimated that over 600 workers would migrate into the region for the peak (fourth) year of construction. Average influx of employees would amount to about 350 over the 6-year construction period.

Population influx associated with the project would amount to about 1,500 people in the peak year and an average of 841 throughout the 6-year construction period. This increase amounts to about 30 percent of the total population based on the 1980 Census of 4,907 for the city. This includes population associated with the construction itself (government and contractor) and population associated with providing goods and services to the construction work force.

Since no significant increase in operation and maintenance personnel would occur with the proposal, population, employment, and income impacts would be concentrated over the 6-year construction period.

Construction impacts from a 250-MW power addition would significantly affect community services such as water, sewer, schools, police, fire, health care, and housing. The impact of the power addition, however, would be much less than that of the Navajo Powerplant built in the early 1970's when the population of Page skyrocketed from 1,439 in 1970 to over 9,000 in 1974 (over a 500 percent increase).

Recreation and tourism are important industries to the Page area, and many feel a peaking power project and its impact on river fluctuations would dampen the local economy because of reduced rafting and fishing below Glen Canyon Dam and rafting in the Grand Canyon. Very little data were available to make projections at the level of analysis of this study, but these concerns should be studied if investigations were considered later.

An appraisal estimate of the primary social effects of adding peaking power capacity to Glen Canyon Dam are summarized as follows.

1. Based on the letters received from throughout the Nation and the comments received at public meetings, any further impact on the Grand Canyon would result in additional public dissatisfaction with the manner in which man is altering the natural state of the Grand Canyon.

2. The Nation's power generation capacity would be increased by 250-MW from a renewable nonpolluting source.

3. The community of Page, Ariz., would be impacted by the influx of construction workers.

4. The tourist and recreation industries might be adversely impacted by the change in flow patterns.

Environmental

The following environmental evaluation summarizes the potential impacts from an additional 250-MW unit. The information presented is displayed in order to show the significant impacts on various elements of the environment. At the appraisal level of analysis significant differences in the degree of impacts between the 250-MW and the 125-MW alternative could not be differentiated with any degree of accuracy.

Ecological Systems

The riparian habitat was studied using infrared aerial photography to estimate the losses attributed to increased inundation as a result of higher flows in the river. A worst case estimate of the losses was developed. The estimate, 15 percent (3,066 acres), considers that maximum peak power flows would be continuous, and it assumes that all vegetation inundated for any length of time would be lost. It was assumed that all inundated vegetation was lost even though many species of riparian vegetation, especially tamarisk, are highly tolerant to extreme variations in soil moisture content; therefore, actual losses would be much less than predicted.

The aquatic habitat was evaluated by methodologies developed by the Instream Flow Group in Fort Collins, Colo., and applied to a representative reach of river within the trout fishery below the dam.

Site-specific data were collected to determine characteristics pertinent to suitability of the environment.

Overall, the analysis indicated a net increase in available juvenile rainbow trout habitat, while losses to adult rainbow and periphyton would result. An analysis of fry rainbow trout and spawning potential was not made since 1- to 2-inch fish are currently stocked by the Arizona Game and Fish Department and spawning is unsuccessful under existing conditions. Based on the information presently available, project flows would have the greatest impact to fry and fingerling fish with a possible reduction in the food base related to reduction in suitable habitat. Both of these impacts would occur as a result of the wider range of maximum and minimum flow which would inhibit the ability of smaller fish to make transitions to preferred habitat and would subject more bottom-associated life to desiccation. The significance of these impacts to the overall ecosystem cannot be predicted with the amount of data collected to date.

Endangered Species

The humpback chub, found primarily in the Little Colorado River and at the confluence area of the Little Colorado River and the Colorado River, is being studied by the Fish and Wildlife Service. Information to date indicates that the confluence area is not as crucial to the survival of the chub as was once thought. Since the only effect that flows in the Colorado River have would be in the confluence area, no significant impact was identified for the chub.

The peregrine falcon would not be impacted since its nests are located away from the river along the canyon walls and the impacts on its riparian food base would be minimal.

Recreational Resources

Information from a report prepared for the Bureau of Reclamation indicated that some loss would occur to beaches used as campsites by rafters.[1/] The report states that about 33 percent of the 38 samples of representative beaches[2/] surveyed would be unusable at flows of 40,000 cfs. These estimates do not account for the diminishing peaks and attenuating minimum flows as they travel downstream, nor was data collected for over 360 other campsites.

The report documents a qualitative survey in cooperation with Reclamation to estimate safety problems for rafting through the Grand

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1/ Dolan, Robert, Analysis of Potential Recreational Impacts Due to High Water Releases from Glen Canyon Dam on the Colorado River in the Grand Canyon.

2/ The 38 sampled beaches included most of the large camping areas of sufficient size to accommodate the large commercial rafting groups traversing the canyon. Most of the other 360 camping beaches are too small to accommodate the large groups.

Canyon. The results of the survey showed that some mooring problems could develop at particular camps because of increased fluctuations, that some rapids would be impassable by certain craft at extremely low flows, and that some of the more treacherous rapids would become less dangerous at higher flows because of the reduced exposure of rocks and boulders in the river.

Fisherman access to portions of the fishery in the first 15 miles below the dam could be reduced somewhat if the low flows were extended for longer durations. The extent of impact, however, would depend on the size of the boat and the skills of the operator.

No increased dangers to either fishermen or rafters was predicted with what limited data were available. For example, fishermen, between Lee's Ferry and the Dam, now experience some problem motoring upstream when flows are at the established minimum (4,000 cfs). This occurs only in one area a few miles up from Lee's Ferry. The restricted access presents more of a problem related to convenience since flows change during the day. The possibility exists that the period of inconvenience to fishermen could increase under a peak power plan; however, no information was collected or analyzed which would suggest that dangers would increase beyond present levels.

The limited recreational studies conducted to date would have to be expanded during the feasibility-level studies to adequately identify the significant recreation impacts resulting from the project.

Visual Quality

Visual quality would be reduced during construction and as a result of the increased erosion from the rise in river stage caused by increased releases at the dam. The effects of erosion were evident from the spill at Glen Canyon Dam in June 1980 when more than 45,000 cfs flowed down the canyon.

Archeological and Historical Resources

Indian ruins and archeological sites are situated well above the higher stages of historical flows in the Colorado River and would not be affected by flows in the river associated with peaking power expansion at the dam. Other historical resources such as the semiburied ferry in the river channel above Lee's Ferry would not be affected by changes in flow.

Public Reaction

Throughout the study, public reaction was overwhelmingly against the peaking power proposal and oriented toward a no action or nonstructural alternative. This was evidenced by the many letters from across the country and comment at public meetings as well as informal conversations with area residents and visitors. The reaction indicated an opposition to any kind of development or change in the Grand Canyon or in that portion of the Colorado River. In general, the public seemed to believe that the effects of the project would be much greater than indicated by appraisal-level data. A segment of the population believes that the current operation of Glen Canyon Dam is undesirable and is, therefore, concerned over any project which might accentuate the current flow differentials.

Conclusions

Appraisal-level studies indicate it would be economically feasible to increase the peaking power capacity at Glen Canyon Dam. The relationship between powerplant size and economic feasibility indicates the larger the size the greater its economic feasibility. Based on this relationship and physical constraints, the most desirable size powerplant from an economic point of view would be 250 MW. This alternative would have an estimated B/C ratio of 1.98:1.0, would cost $165,428,000 to construct ($790/kW), and would realize net annual benefits of $29,835,000.

Construction of this unit would have socioeconomic and environmental impacts that are as yet not completely assessed although they appear to be less than generally believed by the public. While there is support from municipalities and other power interests for developing additional peaking power capacity in the CRSP market area, there is a lack of strong support for developing additional capacity at Glen Canyon Dam.

As discussed in Chapter IV, a decrease in the projected need for peaking power in the CRSP market area led Reclamation to conduct a peaking power prioritization study to determine which potential peaking power projects in the area were most promising and should be investigated first. This study resulted in several other potential peaking power projects receiving a higher priority than the Glen Canyon studies.

Based on the above considerations, because of the general lack of public support, and public concern over potential environmental and recreational problems and because concluding this investigation at this time would help in achieving budget cuts sought by the current administration, Reclamation announced in October 1981 that the study would be concluded. The investigation of other potential peaking power projects will continue. This report summarized the results of studies made to date and will provide information for any future investigation at this site.