MASTER

FINAL REPORT ON
POTENTIAL HYDROELECTRIC POWER

**VERTICAL TURBINE — SPILLWAY COMBINE
BROADWATER DAM**

COOPERATIVE AGREEMENT NO. EW-78-F-07-1822

TO
DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

BY
MONTANA DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

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April 23, 1979

File: 737.1

Subject: Broadwater Feasibility Study

Gentlemen:

We are pleased to submit this report on the hydroelectric power potential at Broadwater Dam.

The report evaluates two alternative configurations for the potential project and also assesses the economics of four possible sources of project funding. The configurations analyzed were an apron-mounted configuration, in which the turbine-generator units are located on the downstream apron of the existing dam, and a conventional configuration, in which the units are located in a new powerhouse adjacent to the existing dam. The funding sources considered were the Department of Energy loan program, the United States Bureau of Reclamation PL-984 loan program and conventional revenue bonds, both taxable and tax-exempt.

The optimal project alternative was determined to be the apron-mounted configuration. The final choice of funding would be dependent on the power purchaser, as different restrictions apply to each of the funding sources. It was shown that, regardless of the configuration or funding source selected, the project would be feasible, with the cost of energy generation less than the value of energy for eastern Montana estimated from Federal Energy Regulatory Commission data.

The cost of the apron-mounted configuration, which would consist of four turbine-generator units for a total installed capacity of 9.76 megawatts, was estimated as \$13,250,000 with financing provided by either a PL-984 loan or tax-exempt bonds. The cost per installed kilowatt was therefore \$1,350, and the cost per kilowatt-hour was 19.6 mills. The average annual energy was estimated to be 56.44 million kilowatt-hours, the equivalent of approximately 87,000 barrels of oil per year.

It is therefore recommended that the Montana Department of Natural Resources and Conservation proceed with the project and that discussions be initiated with potential power purchasers as soon as possible.

TUDOR ENGINEERING COMPANY

Montana Department of
Natural Resources and Conservation
Page 2

April 23, 1979

Tudor Engineering Company sincerely appreciates the opportunity to prepare this study. We believe that it is important to develop all economical low-head hydroelectric sites at existing impoundments where energy is presently being wasted. The Montana Department of Natural Resources and Conservation should be commended for their action in initiating this study.

Very truly yours,

TUDOR ENGINEERING COMPANY

David C. Willer
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Principal Investigator

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FINAL REPORT

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NO. EW-78-F-07-1822

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PREPARED BY

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TUDOR

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I - INTRODUCTION

I. INTRODUCTION

A. PURPOSE

The purpose of this report is to present the results of an investigation into the feasibility of developing a hydro-electric generation facility at Broadwater Dam (also known as Toston Dam) in western Montana. The project would be known as the Broadwater Power Project.

The object of the study was to make an engineering and economic comparison between a conventional power plant, located on the left abutment of the existing dam, and a power plant on the spillway apron of the existing dam. This second configuration presented many unique problems, since flood flows will be allowed to pass through the power plant. A hydraulic model study of this alternative was therefore included in the study.

It is intended that the information presented will provide the basis for a decision either to pursue or to terminate further activities in the development of power production facilities at the site. If pursued, this report recommends the optimal alternative for project development.

B. AUTHORITY

This study was authorized by the Montana Department of Natural Resources and Conservation. The United States of America, acting through the Department of Energy (DOE), provided the major portion of the funds for the investigation.

These funds were provided under Cooperative Agreement No. EW-78-F-07-1822 between DOE and the Montana Department of Natural Resources and Conservation.

C. SCOPE OF STUDY

The primary objectives of the study were to determine the following:

1. The recommended capacity and arrangement for the two alternative project configurations: the conventional configuration and the apron-mounted configuration.
2. The expected performance characteristics of each configuration, including peak power production, annual energy generation and anticipated project life.
3. The estimated capital cost and the annual operation and maintenance costs of each configuration.
4. The potential market for the power generated, and the estimated value of the power.
5. The financial and economic feasibility of each proposed configuration, including funding alternatives and benefit-cost ratios.
6. The probable environmental and social impacts of the project.
7. The necessary licensing requirements of local, State and Federal agencies.

8. A development schedule for putting the power on-line from either configuration.

D. REPORT FORMAT

This report is presented in thirteen chapters. Each chapter presents the data and discusses the results of an individual phase of the project evaluation. The discussion for each chapter is immediately followed by the related Tables, Figures and Plates, if any. Appendix A, the hydraulic model study of the apron-mounted alternative, Appendix B, operations studies, and Appendix C, detailed cost estimates, are included after the final chapter.

E. SUBCONTRACTORS

Two subcontractors were awarded contracts for portions of this study. Hydro-Research Science of Santa Clara, California was awarded a contract to do a model study of the apron-mounted alternative. L. C. Hansen Company of Helena, Montana was retained to do surveying at the Broadwater site.

F. ACKNOWLEDGEMENTS

Tudor Engineering Company is very appreciative of the assistance and cooperation extended by Mr. Richard Bondy, Chief Engineer, Montana Department of Natural Resources and Conservation, and his staff during the preparation of this report.

II - EXISTING FACILITIES

II. EXISTING FACILITIES

A. GENERAL

Broadwater Dam is located in western Montana near the town of Toston. The dam site is situated near the headwaters of the Missouri River approximately 30 miles south, or upstream, of Canyon Ferry Reservoir. Broadwater Dam is primarily a diversion dam for an irrigation canal system which serves the Toston area. This chapter will describe the general river system of which the Missouri River and Broadwater Dam are parts, and the site characteristics, function and history of the Broadwater Project. Plate II-1 presents a map of the river system, the general location of the Broadwater site and a plan of the existing dam.

B. RIVER SYSTEM DESCRIPTION

The Missouri River originates at the confluence of the Jefferson, Madison and Gallatin Rivers at a point approximately sixteen miles to the south of the Broadwater site, near Three Forks, Montana. All three source rivers flow from headwaters on the northern and eastern slopes of the Continental Divide near the borders of Idaho and Wyoming. There is minor flow regulation on all three rivers and several of the lesser tributaries. However, the total regulatory effect is minimal. Water is diverted at and above Broadwater Dam for the irrigation of over 500,000 acres. The total drainage area above the dam is slightly less than 15,000 square miles.

C. SITE DESCRIPTION

Broadwater Dam is a concrete gravity overflow dam. Flow passes over seven ogee weir sections, each bay being 54 feet in width, for a total spillway length of approximately 375 feet. The total length of the dam is 705 feet. The dam height, from the foundation to the spillway crest, is 40 feet. Including the distance to the top of the retaining wall and pier structure, the total height is 56 feet.

The spillway crest elevation is 3,942 feet. Under the present operation, the water surface elevation of the reservoir may be raised to 3,949 feet with flashboards. The flashboards fit into supports in each of the seven spillway bays. The flashboards are normally in position during the summer months, then are removed during the winter and spring when flood conditions are more likely. The proposed hydroelectric development discussed in this report would entail replacement of the flashboard system with radial gates to allow a more flexible operation.

The irrigation diversion at Broadwater Dam is made through existing control gates located near the left abutment. An approach channel off the diversion reservoir conveys flows to the intake structure. The invert of the intake structure is located at the same elevation as the spillway crest. Control of the diversion is maintained by four 48-inch-by-84-inch slide gates. Either power plant configuration would include the replacement of the existing diversion works with a similar structure located at a higher elevation.

Recent investigations have been conducted to determine the condition of the dam and appurtenant facilities. Although certain inadequacies were noted in the distribution system downstream of the diversion works, the dam was determined to be in good repair, with no apparent deficiencies.

The photographs of the site are shown on Figures II-1 and II-2.

D. HISTORY

The construction of Broadwater Dam was completed in 1940. Funding for the project was provided by the Montana State Water Conservation Board, with assistance from the Public Works Administration. The construction contractor was the Utah Construction Company.

The Water Conservation Board maintained ownership of the dam until 1967. In that year, the Water Conservation Board was reorganized and became the Montana Water Resource Board. The Water Resource Board owned and operated the dam for the following four years. In 1971, under a general state reorganization, ownership of Broadwater Dam was transferred to the Montana Department of Natural Resources and Conservation, the current owner.

The dam operation is the responsibility of the Department in conjunction with a local water agency, the Broadwater-Missouri Water Users Association. The Association provides the on-site operational control and the Department performs overall supervisory functions.

The existing Broadwater Project is similar to many other water conservation projects within the State of Montana with regard to the manner in which the Department works in conjunction with a local water agency.

E. WATER RIGHTS

The Department has previously made application for a water right to develop power at the Broadwater site. The application, which requested a maximum diversion rate of 9,500 cubic feet per second (cfs), up to an annual maximum of 6,900,000 acre-feet, was assigned the number 16825-541-I. As of the date of this report, the application is pending.

UPSTREAM VIEW OF BROADWATER DAM
AND EXISTING CANAL FROM LEFT ABUTMENT

BROADWATER DAM FROM RIGHT ABUTMENT

DOWNSTREAM VIEW OF BROADWATER DAM
FROM LEFT ABUTMENT

EXISTING CANAL INLET STRUCTURE
ON LEFT ABUTMENT

LEGEND:
 ● USGS GAGING STATION

MISSOURI RIVER SYSTEM MAP

SCALE 0 1 2 3 4 5 6 7 8 9 10 110 MILES

EXISTING BROADWATER DAM

SCALE 0' 50' 100' 150' 200' 250' 300' FEET

LOCATION MAP

SCALE 0 1 2 3 4 MILES

STATE OF MONTANA
 BROADWATER DAM

GENERAL PLAN

III - BASIC DATA

III. BASIC DATA

A. GENERAL

Various basic data were available for the Broadwater site. A relatively long-term stream-gage record was available from a gaging station just downstream of the Broadwater Dam. Additionally, design flood parameters and criteria were available. Topographic data were available from several sources, including the original dam drawings. Additional topographic and hydrologic data were obtained as a part of this study.

B. HYDROLOGY

The United States Geologic Survey stream gage, "Missouri River at Toston", Gage No. 06054500, is on the Missouri River approximately three miles downstream of Broadwater Dam. The difference in drainage area between the gage and the dam is negligible, especially considering the large total drainage area. Therefore, the Toston record was considered to be a reasonable record of the flow over Broadwater Dam and was used in the project operation studies without modification.

The Toston stream gage record was begun in May 1941 and has been in continual operation since then. However, one of the worst series of drought years in Montana history occurred during the 1930's. This period is normally used to determine the dependable capacity of hydroelectric plants within the state. Therefore, it was necessary to extend the Toston record to cover this period.

The extension was accomplished using a computer program developed by the Hydrologic Engineering Center, U. S. Army Corps of Engineers, entitled "HEC-4, Monthly Streamflow Simulation." HEC-4 uses a normalized Pearson Type III Distribution in correlating the missing months of records with other known records in the region. Several stream-gage records, both upstream and downstream of the Toston gage, were evaluated to determine which would provide the best extension of the Toston record.

It was decided to utilize two records, both on upstream tributaries to the Missouri River. One was the "Big Hole River near Melrose", Gage No. 06025500. The Big Hole River is a tributary to the Jefferson River. The drainage area above the Melrose gage is 2,476 square miles. The other gage was the "Gallatin River at Logan", Gage No. 06052500. The drainage area above the Logan gage is 1,795 square miles. The location of each gaging station is indicated on Plate II-1.

Using data from these two gages and the HEC-4 program, the Toston record was extended back to 1929. This extension, in conjunction with existing record, gives a 50-year record over the period 1929 to 1978. The streamflow data derived for the 1930's was indicative of the known drought conditions and was found to be consistent with precipitation records for those years.

In general, the correlation coefficients for the extension were good, ranging from 0.7 to 0.9. The resulting monthly flows for the 50-year period are shown in the project operation studies in Appendix B. The average monthly flow for

the 50-year period of record is presented in Figure III-1. This figure also shows the wettest year (1976) and the driest year (1937).

Since most of the precipitation in the tributary watershed occurs as snow in the winter months, relatively low runoff occurs during the coldest months of December, January and February. The graph for the 50-year period indicates that the highest average monthly flow occurs in June when the maximum snow melt is occurring. The average minimum flow occurs in August after most of the snow pack has melted.

C. FLOOD HYDROLOGY

The annual peak-flow frequency curve (Figure III-2) for the site was developed using the existing instantaneous peak-flow records available from the U.S. Geological Survey publications. The assumption was made that these values have a Log Pearson Type III distribution and can be treated as per the recommendations of the Water Resources Council.

In assessing the capacity for safe passage of floods, the capacity of existing low-level outlets was not included. These outlets have not functioned properly since the dam was completed in 1940. It is planned to remove the existing gates and to plug the conduits with concrete grout if power development and related dam modifications are pursued.

As noted on the as-built drawings, the design flood for the original dam design was 50,000 cfs. From the flood frequency curve described above, this corresponds to a 250-year flood. With the proposed construction, passage of such a

flood is estimated to require a headwater surface elevation of 3,953.5 feet, approximately 0.5 feet higher than would be necessary to pass the same flood under the existing conditions. Use of a 250-year flood for design purposes is inadequate for a dam such as Broadwater in terms of current design practices. However, the original design did allow for five feet of freeboard before overtopping would occur at each abutment.

The maximum flood that could pass over Broadwater Dam, without overtopping the retaining wall sections at the dam abutments, was estimated to be 76,200 cfs, for which the recurrence interval is about 10,000 years. This value was calculated assuming a maximum permissible elevation of 3957.5 feet, equal to the top elevation of the nonspillway sections of the dam. This analysis recognized the constricting effect of the new piers to be constructed across the spillway. The structural additions included in the turbine bays of the apron-mounted alternative will not affect the flood-flow capacity, since they are located downstream of the control section of the ogee crest.

Criteria recommended by the United States Army Corps of Engineers were used to check the adequacy of the flood-passing capability of Broadwater Dam. The Corps, for sites similar to Broadwater where dam failure would not endanger human life, recommends that the dam be capable of passing one-half of the probable maximum flood.¹ Neither danger to human life nor property damage would be likely results of the failure of Broadwater Dam.

1 U.S. Department of the Army, Corps of Engineers, 1977, National Program of Inspection of Dams Report.v.1, Appdx. D, Recommended Guidelines for Safety Inspection of Dams.

The probable maximum flood at Canyon Ferry Dam, a short distance downstream of Broadwater Dam, was determined by the United States Bureau of Reclamation to be 150,000 cfs. Based on the drainage areas of the two sites, the probable maximum flood at Broadwater was estimated to be 143,000 cfs.

One-half of the probable maximum flood would be about 72,000 cfs which is less than the actual capacity of 76,200 cfs. The flood-passage capacity of the dam is therefore considered adequate and in accordance with current design practices.

D. TAILWATER-RATING CURVE

A tailwater-rating curve was developed for use in the assessment of the potential project power production, for use in the hydraulic analysis of the downstream flow conditions, and in establishing boundary conditions for the hydraulic model testing.

A tailwater curve, or stage-discharge curve, is a plot of water surface elevation versus flow. The stage-discharge data for the Missouri River nearest to the Broadwater site was the rating curve at the previously mentioned Toston gage, located approximately three miles downstream. To develop and tabulate the curve directly below Broadwater Dam, it was necessary to compute the river flow profile between the gage and the dam for various discharges. The profiles were calculated by the standard step method using the U.S. Army Corps of Engineers' computer program "HEC-2, Water Surface Profile". Surveyed river cross sections taken at approximately one-half-mile intervals were used as input.

Calibrating the resulting computer model of the river-flow profile was accomplished by using water surface elevations measured at the cross-section locations for the day of the survey. The discharge values ranged from 4,000 to 5,590 cfs for the survey period, November 6 to December 6, 1978, which encompasses the average discharge of 4,470 cfs. The tailwater-rating curve thus developed is presented in Figure III-3.

E. MAPPING

The only detailed site topographic maps available at the beginning of this investigation were the original construction drawings dated 1938. To supplement this information, the surveyor prepared a topographic map of the reservoir, dam, and proposed power plant site. It should be noted that a discrepancy of approximately seventeen feet in the 1938 survey was uncovered. This report reflects the corrected elevations, which are seventeen feet above the original construction elevations.

AVERAGE MONTHLY FLOWS

PEAK FLOW FREQUENCY CURVE

FIGURE
III-2

TAILWATER RATING CURVE

IV - DESCRIPTION OF AVAILABLE TURBINES
AND GENERATORS

IV. DESCRIPTION OF AVAILABLE TURBINES AND GENERATORS

A. GENERAL

Hydroelectric power plants transform the energy of falling water into electrical energy. In general, a hydroelectric power plant consists of a dam or canal for producing the head (and often storage of water); an intake and penstock or flume for conveying the water to the hydraulic turbine; the turbine which is coupled to a generator; and the accessory electrical equipment required to deliver the power to a transmission system.

This chapter describes the commercially available generation equipment that could be used for the Broadwater Power Project.

B. DESCRIPTION OF AVAILABLE TURBINES

Conventional turbine equipment may be classified either as impulse or reaction. The only exception to this classification system is the Ossberger turbine, which is discussed later in this chapter.

An impulse turbine is one having one or more free jets discharging into an aerated space and impinging on the buckets of the runner. For the same plant capacity, the jet size must increase as the head on the turbine decreases, and for low head applications the cost of an impulse turbine is not competitive with the cost of a reaction turbine. Impulse

turbines generally become competitive with reaction turbines only at heads above 1000 feet. The effective head at Broadwater is such that impulse turbines have been eliminated as a practical consideration.

A reaction turbine is one in which water is passed under pressure over the fixed or adjustable angular vanes of a runner, imparting rotation and torque to the turbine shaft. A reaction turbine consists of a water case, a mechanism for controlling the quantity of water and distributing it equally over the runner intake, the runner itself and a draft tube. There are two principal types of reaction turbines: Francis turbines and propeller turbines.

A Francis turbine is one having a runner with a large number of fixed blades attached to a crown (top) and a band (bottom). The dimensions of the runner are designed to suit the head conditions of the application. Designs are commercially available to suit head conditions ranging from 15 to 1500 feet. In general, a Francis turbine is not economically competitive with a propeller turbine below a head of about 60 feet. The head range at Broadwater is such that Francis turbines have also been eliminated as a possible selection.

A propeller turbine is one having a runner resembling a propeller with a small number of blades, usually four, five, or six to which water is supplied in an axial direction. The blades are attached to the hub of the runner. Runners are available with either fixed or adjustable pitch blades. Fixed-blade propellers have the blades set at an angle determined by the average flow conditions. The blade angles of adjustable pitch propeller may be adjusted according to vary-

ing flow conditions. The suitable head range of propeller turbines is from 15 to 110 feet. This type of turbine is therefore suitable for the Broadwater site.

Propeller turbines may be used in a vertical, slant or horizontal orientation. The vertically mounted configuration is known simply as a conventional propeller turbine. The horizontal and slant mounted units have been given trade names which describe the mechanical design such as Tube, Bulb and Straflo. These various types have certain differences in performance, equipment cost and civil construction cost.

The conventional vertical propeller turbine is the most widely used of the types considered by this study. An adjustable-blade unit can achieve higher efficiencies than would be possible for a fixed-blade unit when operating above or below design head or when operating below full unit capacity. At the design conditions, the fixed-blade unit operates with better efficiency. The vertical propeller turbine may have an open flume or a penstock and spiral scrollcase for delivery of the water. In the open-flume construction, the wicket gate mechanisms are located within the water passageways and are water lubricated. This can be the most economical configuration in terms of capital cost but the maintenance requirements are high. When a penstock is utilized rather than the open flume, a concrete or steel scrollcase under pressure is used to direct the water flow to the turbine blades. Both the open-flume and scrollcase configurations are shown on Figure IV-1.

A "Tube" turbine consists of a propeller-type runner mounted in a horizontal configuration with a circular water

passage. Downstream of the runner, the turbine shaft passes through the wall of the draft tube at an elbow and is connected to a gearbox and thence to the generator. The costs of civil work for tube turbines tend to be greater than for vertical shaft installations because of the separate areas for the turbine and generator. A tube turbine configuration is shown on Figure IV-1.

For a "Bulb" turbine configuration, the water passage and turbine runner are similar to those of a tube turbine; however, the generator is situated within the turbine passageway. The generator is integrally housed in an immersed upstream cone and is driven directly by a shaft from the turbine runner. The operating characteristics and efficiencies of the bulb turbine are similar to those of a vertical propeller turbine. Powerhouse size requirements of the bulb turbine allow a smaller plan area but a greater structural height than for the tube turbine. Maintenance access to the bulb turbine is less convenient than for either the vertical or tube turbines. Down time for major repair would probably be greater. A bulb turbine configuration is shown on Figure IV-1.

The "Straflo" type of turbine is the development of Sulzer Bros. Ltd. of Switzerland. The turbine characteristics are similar to the the bulb turbine. The mechanical arrangement differs in that the rotor of the generator is attached to the rim of the runner. The rim of the runner has a seal which uses filtered water at a higher pressure than the effective head on the unit. The generator stator is located in air outside of the flow passageway. The design has been successfully operated in Europe and would appear to offer a cost benefit for certain size units. To date, no Straflo turbines

have been installed in the United States.

The Ossberger turbine, previously mentioned as being the one kind of turbine that is neither impulse nor reaction, is available for heads from 15 to 550 feet. The runner design is classified as cross-flow and derives energy from both impulse and reaction turbine principles. Water is conveyed through a rectangular cross-section and guide vane system and then across the horizontal runner blades. This flow pattern has the advantage of passing refuse such as grass, leaves, melting snow and ice which may enter the blades of the runner with the water. Water flow rates from 16 percent to 100 percent of the design flow may be utilized with high efficiency. The power plant cost at lower heads is generally higher than for propeller turbines. Although Ossberger turbines would be appropriate for the Broadwater site, they were not considered because of the higher cost. An Ossberger configuration is shown on Figure IV-1.

C. DESCRIPTION OF AVAILABLE GENERATORS

Generators can either be synchronous or induction type. Induction generators are often considered more practical for smaller turbine-generator installations because they cost less and require less maintenance. They require no excitation and need only a squirrel-cage rotor which uses no wound coils or brushes. Furthermore, since they do not run at exact synchronous speed, complex equipment is not needed to bring them on line. They must be connected to a system which has synchronous generators to establish frequency and voltage. The generators produce energy with a high degree of efficiency.

Synchronous generators are usually three-phase star or Y-connected machines with one end of each winding connected together in common, the other ends being used as line terminals. The generator, or alternator, delivers its induced alternating current directly to the external circuit and is used where transmission is to be sent over long lines. The alternating current can be transformed to the desired transmission voltage.

For the purpose of this study, the generators assumed are the more costly synchronous type because it is likely that most potential power purchasers would require a synchronous-type generator. The use of an induction generator, if it meets the approval of all parties, should be reconsidered during final design.

VERTICAL FRANCIS

RIGHT ANGLE TUBE

HORIZONTAL FRANCIS

BULB

VERTICAL PROPELLER

RIM

OPEN FLUME FRANCIS OR PROPELLER

HORIZONTAL PELTON

TUBE

CROSSFLOW (OSSBERGER)

V - APRON-MOUNTED TURBINE ALTERNATIVE

V. APRON-MOUNTED TURBINE ALTERNATIVE

A. GENERAL

A preliminary layout was developed for the Broadwater Power Plant, utilizing an apron-mounted configuration. It would consist of a power plant with a number of vertical-shaft turbines mounted in an open-flume configuration on the downstream face and apron of the existing spillway structure. The installation would be designed so that spillway flows could pass through the structure as necessary without significantly reducing the existing spillway capacity. A hydraulic model test of the configuration was performed to facilitate and confirm the design. Information regarding the determination of the proposed project layout, the selection of the turbine-generator equipment, and the model study results is presented in this chapter.

B. DESCRIPTION OF APRON-MOUNTED TURBINE ALTERNATIVE

As discussed in Chapter II and shown on Plate II-1, the existing spillway consists of seven bays, each approximately fifty-four feet wide. Piers separate the sections of the ogee-crest spillway.

With the proposed apron-mounted configuration, two existing spillway bays near the left abutment would be split with a middle pier into two bays, each approximately twenty-four feet wide. Within each of the resulting smaller bays, a turbine-generator unit would be mounted, with the turbine shaft located approximately thirty-six feet downstream of the spillway crest. In addition, the existing piers would be modified to provide support for the generator floor. The turbine case and draft tube would be encased in a concrete

spillway extension. The existing spillway would be partially removed to provide a good bonding surface between the existing concrete and the new concrete. The generators and other appurtenant plant facilities would be located in a superstructure mounted on the modified existing and new piers above the downstream spillway. An inspection gallery would be included immediately downstream of the turbine and a drainage and grouting gallery would be placed at the interface of the existing dam and the new structure.

The existing flashboard system, used to increase the water surface elevation in the reservoir during the summer months would be removed. Additional piers identical to those proposed for the turbine bays would be constructed. Radial gates, approximately 24-feet wide by 12-feet high, would be installed in all bays. A new service bridge with a movable gantry crane would be added for maintenance access to the gates. The bridge would be composed of precast T-beams, several of which could be removed when additional access is necessary.

Since the turbine-generator units will be occupying spillway bays it would be necessary, for the turbine bays to be designed to pass flood flows directly through them. Splitter piers, in addition to the piers already discussed, would be constructed in the middle of each power bay with a fixed wheel gate spanning between the major piers and the splitter piers. The rear wall of the power bays would thus be removable. During periods of high flow the turbines would be stopped, and the fixed wheel gates raised to allow unhindered passage of the flood flows through the turbine bays.

Trashracks would be included upstream of the existing dam crest. They would be removed by the upstream gantry crane when the turbine bays were converted, during periods of flooding, to spillway bays.

A downstream, outside gantry crane would be included to facilitate the fixed wheel gate removal and to insert stop-logs when necessary.

The substation for the power plant would be located on the left abutment, near the existing picnic area.

A new canal inlet structure would replace the existing structure on the left bank. The structure would be equipped with radial gates and would operate automatically to insure a uniform discharge.

The existing low-level outlets through the dam would be plugged with grout and the gates removed. These outlets have never functioned as planned and one gate is currently frozen in a half-open position.

The preliminary layout of the apron-mounted alternate is shown on Plates V-1 and V-2.

C. DESIGN CONSIDERATIONS AND ASSUMPTIONS

Several assumptions were made for the layout and analysis of the apron-mounted alternative. In general, the assumptions used are the same as the assumptions used in analyzing the conventional configuration.

One of the primary considerations concerned the operational control of the power facilities. It was assumed that the headwater elevation would be held constant at 3952.6 feet and that operation of Broadwater facilities, including both power plant control and radial gate control, would be regulated to attain this objective. This will be covered in detail in Flow Control and Operating Modes.

Another prime consideration in the analysis of the Broadwater Power Project was the question of manning the power plant. At most power projects of similar size, it is usual to provide the capability for some remote operation from a centralized communications center. Equipment for complete remote monitoring of flow, water surface elevations, unit status and generation output and a remote unit stop capability was included in the project layout and estimates. No remote start capability was included. However, because of the distance of the Broadwater site from a population center, it was decided that occasional on-site operation would be desirable for safety reasons. It was assumed that the plant would be manned eight hours per day, five days per week. Staff facilities, including working space and comfort facilities, were included. Also, it was assumed that the facility would be continually attended during periods of probable flooding to operate the radial gates and convert the turbine bays to spillway bays as required.

D. SELECTION OF TURBINE SIZE

The selection of a vertical shaft propeller turbine for the apron-mounted alternative was dictated by the physical constraints of the site; the low head required a propeller

turbine and the placement of the unit on the downstream face of the spillway made a vertical shaft unit clearly the most suitable type.

The area of the inlet flume and the height of the water surface above the turbine entrance limited the size of the vertical turbine which could be installed and operated without vortices occurring in the entrance. The model tests (see Appendix A) established that vortices occurred with a discharge of 1800 cfs through the turbine. A turbine with a maximum discharge of 1600 cfs was selected to provide a suitable margin of safety. The resulting turbine output at 22 feet of head is 2.44 MW. Using these parameters, recommendations for turbine runner size were sought from turbine manufacturers. A standardized tube turbine runner with a runner diameter of 2750 mm (9 feet) was found to meet these requirement and estimated prices for this configuration were then requested and received.

The turbine finally selected has an adjustable blade propeller runner with fixed guide vanes. The loss in power output from the fixed vanes, compared to that which could have been achieved by the use of movable wicket gates, is more than compensated for by the lesser cost of the fixed vanes.

With the turbine type and size determined, it still remained necessary to determine the economic number of units. Installations of two, three, four and six turbines were evaluated.

The optimization analysis was based on the net present value, the difference between the present worth costs and the present worth benefits over an assumed 50 year project life.

The installation that produced that greatest present-worth benefit was assumed to be the optimum installation. This type of analysis is equivalent to an incremental benefit-cost analysis. The methodology used is explained in detail in Chapter XI, which covers the overall project economics. In that chapter, an energy value of 34.0 mills per kilowatt-hour is derived for the apron-mounted alternative.

The optimization was very dependent on inflation. One feature of the economics of hydroelectric generation that is different from that of most other conventional sources of energy is the high ratio of capital cost to actual operating costs. There are no fuel costs, and little operating and maintenance expenses, so the annual cost is virtually constant over the life of the project. Thus, as inflation and the attendant escalation in the value of energy occurs, the increases in the value of the power are greater than the increases in the annual cost. The ultimate effect of this relationship is that, as the assumed inflation rate is increased, the optimum plant capacity also increases. Additional power from incremental plant capacity, in an inflationary economy, increases in value to assist in the justification of the additional capacity. Thus, the optimum number of units for the Broadwater site is dependent upon the assumed inflation rate over the project life.

Cost estimates and average annual energy estimates were prepared for each combination of unit sizes considered. The methods of cost and benefit estimating are described more fully in later chapters.

Based upon the estimates, discounted cash flow analyses were performed for various assumed rates of inflation, ranging from no inflation to eight percent inflation. It was

shown that under no conditions was two turbine installation optimal. For inflation rates under two percent, the three turbine installation was optimal. At two percent, the four unit option became optimal and, above seven percent inflation, the six unit installation became optimal.

Based on these considerations, it was decided that a reasonably conservative approach would be to assume an inflation rate of less than seven percent over the project life. The four turbine installation would therefore be the recommended configuration and used for further studies by this report. The total plant capacity would be 9.76 MW. If the inflation rate is such in the ensuing years that it proves economical to add more units, this can be easily accomplished.

E. FLOW CONTROL AND OPERATING MODES

In periods of flood, as the turbine bays must also function as spillway bays, the flow control of the apron-mounted alternative would be more complex than is typical for a hydroelectric project. There would be four distinct modes of operation; the pure generation mode, the combined operation mode, the controlled flood mode and the uncontrolled flood mode. A detailed enumeration of the various water surface elevations, related flows, and generator conditions is shown in Table V-1. These modes are described as follows:

1. Pure Generation Mode

In the pure generation mode, the entire release past the dam would be through the turbines. The range of flows would

be from 515 cfs (the lower limit of one turbine) to 5,920 cfs. The turbine flow would be regulated so as to maintain a constant upstream water surface elevation of 3952.6 feet.

2. Combined Operation Mode

In the combined operation mode, the required outflow would be greater than could be passed through the turbines. Therefore, the radial gates in as many spillway bays as necessary will be opened to pass the additional flow. The range of flows would be between 5,920 cfs and 32,408 cfs. The turbines would remain in operation, and the head water surface elevation would still be held constant at 3952.6 feet, the same as for the pure operation mode.

3. Controlled Flood Mode

In the controlled flood mode, the required outflow would be larger than could be passed by the turbines and all of the spillway bays fully open. Therefore, as many turbine bays as required to hold the normal upstream water surface at elevation 3952.6 feet would be converted to spillway bays by raising the fixed wheel gates that would form the downstream wall of the powerhouse structure. The range of flow would be between 32,408 cfs and 43,782 cfs. Turbine operation would not be possible in those bays converted to spillway flow, due to the turbulent conditions within the bay.

The following sequence of events would be involved in converting a power bay to a spillway:

1. The turbine would be stopped.
2. The radial gate would be lowered.

3. The trashrack would be removed.
4. The fixed wheel gates comprising the rear of the power bay would be removed.
5. A section of the removed fixed wheel gate would be placed in the downstream stop log slot to prevent further flows from passing through the draft tube.
6. The radial gate would be raised and flows would then pass unhindered through the plant.

The above steps may at first seem somewhat complex, but it is assumed that the entire procedure could be accomplished in one hour or less.

It should be noted that the necessary conversion of one or more power bays to spillway bays will only occur very infrequently. The hydrology analyses show that, in conjunction with the regular spillway bays functioning only one power bay will be necessary to pass a 20-year flood, two bays for a 33-year flood, three bays for 50-year flood and all four bays for greater floods.

4. Uncontrolled Flood Mode

In the uncontrolled flood mode, all of the turbine bays would be converted to spillway flow and no turbine operation would be possible. No further control on the upstream water surface elevation would be possible. As previously discussed in Chapter III, a flow of 76,200 cfs with a recurrence interval of 10,000 years could be passed before overtopping of the existing abutments would occur.

F. DISCUSSION OF MODEL STUDIES

The results of the model study indicated that the proposed design for changing a power bay to a spillway is feasible. No major problems were discovered. The study determined that the upstream pier within the power bay should be streamlined and that a vortex breaker should be added to smooth out the water surface at higher discharges. The location of the back power bay wall (fixed wheel gate) was studied and the optimal location was determined.

It was found, under the uncontrolled flood mode condition that the tailwater was sufficiently high to drown out the hydraulic jump of the water passing through the power bay, and the resulting turbulence was confined to the bay. It had been of some concern that the jump would occur downstream and that dissipation and erosion problems would have resulted. The model study proved, however, that this would not be a problem.

The detailed results of the model study are contained in the model study report, Appendix A.

OPERATION MODE SUMMARY
TABLE V-1

Case #	Mode Description	1 Turbine	Discharge		Frequency (years)	Elevation (ft)		Head (ft)	
			1 Spillway ^{1/} Bay	(cfs) Total		Headwtr Surface	Tailwtr Surface	Turbine	Spillway
I	<u>Pure generation mode</u>								
1	Shutdown	460							
a.	Oper. 1 var. pitch turbine	510-1580	closed	515-1580		3952.6	3925.0-3927.1	27.6-25.5	closed
b.	" 2 " " "	510-1560		1020-3120		3952.6	3926.2-3928.8	26.4-23.8	
c.	" 3 " " "	510-1520		1530-4560		3952.6	3927.0-3930.0	25.6-22.6	
d.	" 4 " " "	510-1480		2040-5920		3952.6	3927.6-3931.0	25.0-21.6	
II	<u>Combined operation mode</u>								
2a.	4 turbines + 1 spillway bay	1430	2630	8350	1	3952.6	3932.4	20.2	11.0
b.	" " " 2 " "	1370	2860	11200	1	3952.6	3933.8	18.8	11.0
c.	" " " 3 " "	1310	2940	14000	1	3952.6	3935.2	17.4	11.0
d.	" " " 4 " "	1250	2970	16900	2	3952.6	3936.4	16.2	11.0
e.	" " " 5 " "	1190	3000	19700	2	3952.6	3937.5	15.1	11.0
f.	" " " 6 " "	1140	3010	22600	3	3952.6	3938.6	14.0	11.0
g.	" " " 7 " "	1090	3020	25500	5	3952.6	3939.6	13.0	11.0
h.	" " " 8 " "	1050	3030	28400	8	3952.6	3940.4	12.2	11.0
i.	" " " 9 " "	1010	3040	31400	14	3952.6	3941.2	11.4	11.0
j.	0 " "10 " "	-	3045	30400	12	3952.6	3941.0	11.6	11.0
k.	1 " "10 " "	1010	"	31400	14	3952.6	3941.3	11.3	11.0
l.	2 " "10 " "	990	"	32400	17	3952.67	3941.6	11.0	11.0
III	<u>Controlled flood mode</u>								
3a.	10 spillway bays + 1 power bay		3050	33500	20	3952.6	3941.8	shutdown	11.0
b.	" " " 2 " "		3050	36600	33	3952.6	3942.7	shutdown	11.0
c.	" " " 3 " "		3055	39700	53	3952.6	3943.5	shutdown	11.0
d.	" " " 4 " "		3055	42800	91	3952.6	3944.3	shutdown	11.0
IV	<u>Uncontrolled flood mode</u>								
	Surcharge to HWSE = 3953.6	-	3530	49500	250	3953.6	3945.9	-	12.0
	Surcharge to HWSE = 3957.6	-	5670	79400	10,000	3957.6	3952.0	-	16.0

^{1/} The variation in spillway discharge per spillway bay is caused by the discharge coefficient which increases as the total effective spillway width increases. Ref: "Hydraulic Design Criteria - USCE".

SECTION A
SCALE: $\frac{1}{8}'' = 1'-0''$

TYPICAL POWERHOUSE LAYOUT - 4 REQ'D
SCALE: $\frac{1}{8}'' = 1'-0''$

SECTION B
SCALE: $\frac{1}{8}'' = 1'-0''$

TYPICAL BRIDGE PLAN
SCALE: $\frac{1}{8}'' = 1'-0''$

VI - CONVENTIONAL ALTERNATIVE

VI. CONVENTIONAL ALTERNATIVE

A. GENERAL

A preliminary layout was developed for the conventional configuration as an alternative to the apron-mounted configuration. The conventional facility would consist of a powerhouse structure located outside of the river channel near the left abutment of the existing dam. Excavation would be necessary to provide an approach channel to the powerhouse and a tailrace. The dam would be modified with radial gates, the same as proposed for the apron-mounted configuration, to allow a higher water surface elevation within the reservoir. The existing headworks on the diversion canal would be removed and replaced by a new radial gate control structure located immediately adjacent to the new powerhouse. Information regarding the determination of the project layout and the selection of the turbine-generator equipment is presented in this chapter.

B. DESCRIPTION OF CONVENTIONAL ALTERNATIVE

Two configurations were evaluated for the conventional installation. One concept involved increasing the cross-sectional area and flow capacity of the existing diversion canal approach channel and converting it into a power plant forebay. The powerhouse would then have been located downstream of the left dam abutment and would have conveyed water from the forebay back to the river channel. The flow paths through the powerhouse would have been at right angles to the river channel. After evaluation, this concept was modified

to the proposed configuration in which the powerhouse is constructed as an extension to the left end of the dam. The flow paths through the powerhouse would be aligned parallel to the river channel.

As in the apron-mounted configuration, the conventional configuration would include radial gates mounted on the spillway crest to increase the water surface elevation. Each of the existing, fifty-four foot wide spillway bays would be divided by intermediate piers into two bays, approximately twenty-four feet wide. Each of the resulting fourteen smaller bays would have a twelve-foot high radial gate.

The proposed conventional configuration would entail more site preparation than would be required for the apron-mounted configuration. An approach forebay would be excavated upstream of the powerhouse, through the area presently traversed by the approach channel to the diversion canal headworks. The existing channel would be obliterated and releases to the diversion canal would be made from the forebay. The existing diversion headworks would be removed and a new headworks built, at a higher elevation, to accommodate the higher reservoir water surface elevation caused by the radial gate installation. The new headworks would consist of a radial gate installation, similar to that proposed for the spillway crest. Downstream of the powerhouse an excavated tailrace would convey the power plant flows back to the river channel.

Several other necessary features would be included as integral parts of the conventional alternative. As in the apron-mounted alternative, the existing low-level outlets through the dam would be plugged and grouted. Also, trash-

racks would be installed at the inlet to the powerhouse. The area of the trashracks would be considerably larger than the area of the turbine inlets, to minimize head loss. A power plant crane would be located within the powerhouse structure for plant maintenance. The plant substation would be located on the left abutment of the dam.

As with the apron-mounted configuration, several operational modes, depending on the total river flow, are possible for the conventional layout. These modes are discussed later in this chapter.

Plates VI-1 and VI-2 illustrate the proposed conventional layout.

C. DESIGN CONSIDERATIONS AND ASSUMPTIONS

The assumptions made in the layout and analysis of the conventional configuration are the same as those made for the apron-mounted configuration. Those assumptions were, first, that the criteria by which the generation facilities were to be operated would be the maintenance of a constant water surface in the reservoir and, second, that the facility would be equipped for both manned and unmanned operation. Also, it was assumed that the facility would be manned during periods of probable floods.

D. SELECTION OF TURBINE SIZE

In Chapter V, it was shown that a total installed capacity of 10 megawatts (MW) was optimum for the Broadwater site. This capacity was assumed, without further analysis, for the

conventional configuration. However, because the conventional installation allows more flexibility in the turbine-generator orientation, various types and unit capacities of propeller turbines are physically suitable for the conventional configuration and were evaluated.

The turbine configurations assessed included the following: one ten-megawatt Kaplan turbine, two five-megawatt Kaplan turbines, one ten-megawatt bulb turbine, two five-megawatt bulb turbines, four 2.5 megawatt tube turbines, five two-megawatt open flume configuration vertical shaft propeller turbines and six two-megawatt open flume configuration vertical shaft propeller turbines. The last two alternates included the same type of turbine, a two-megawatt unit manufactured by Barber Engineering of Canada. The unit is simple and inexpensive, but is prone to maintenance problems and considerable down-time. Therefore, the manufacturer recommended that, six two-megawatt units be installed in order to get ten megawatts of effective capacity. Thus, each unit could be inoperable up to one-sixth of the time without decreasing the total plant capacity below ten megawatts. The five unit installation, using the Barber turbines, was included in the analysis for comparative purposes, but was not considered a viable alternative because of the maintenance problems.

Preliminary cost estimates were prepared for each of the possible alternatives. The estimates included not only the turbine-generator costs, but also the civil, switchyard and general station equipment costs. It should be noted that these estimates were prepared on a very preliminary level. As a result, the detailed cost estimate for the selected

alternative, as presented in Chapter IX, is larger than the estimate presented here. However, the estimates given here are sufficiently representative of the costs involved, so that a reasonable selection may be made.

Estimates were also prepared of the average annual project generation, based on the methodology described in Chapter VIII.

Using the estimated project costs and estimated project energy, a discounted cash flow analysis was prepared to evaluate the net benefits that would accrue to the Department over the life of the project. The results of this analysis are shown in Table VI-1. As can be seen, the five open flume turbine installation yields the greatest net benefit. However, for the maintenance reasons discussed above, this alternative is not recommended. Therefore, the four 2.5 megawatt tube turbine installation was selected and will be the configuration discussed in the remainder of this report.

Plates VI-1 and VI-2 show the recommended configuration for the conventional installation. Included are the switchyard and other facilities necessary for plant operation.

Project costs for the conventional configuration and an economic analysis are presented in later chapters.

E. FLOW CONTROL AND OPERATING MODES

The conventional configuration, because it entails a powerhouse separate from the existing dam and spillway structure, would require fewer operating modes than the apron-

mounted configuration. Only three modes would be necessary; the generation mode, the combined mode and the uncontrolled spill mode.

The generation mode would be equivalent to the generation mode for the apron-mounted configuration. All of the releases past the dam would be made through the turbines. The water surface elevation would be held constant.

In the combined mode, water would be conveyed past the dam both through the turbines and over the spillway. The radial gates on the spillway would be adjusted enough to maintain the water surface within the reservoir at a constant elevation. At some point in the upper end of the range of flows possible under the combined mode operation, the tailwater will reach a downstream level such that turbine operation must be curtailed. After that point, all releases will have to be made over the spillway.

In the uncontrolled spill mode, all of the spillway radial gates are fully open and the turbines are not operating.

Table VI-1

Comparison of Alternative Turbine Configurations
For Conventional Installation

<u>Turbine</u>	<u>Total Project Cost</u>	<u>Average Annual Energy (MkWh)</u>	<u>Net Benefit</u>
One Ten-mega- watt Kaplan turbine	8,653,000	51.86	5,133,780
Two five-mega- watt Kaplan turbines	9,631,000	58.00	8,080,536
One ten-mega- watt bulb turbine	8,619,000	52.32	5,276,995
Two five-mega- watt bulb turbines	9,732,000	58.48	8,182,287
Four 2.5 mega- watt tube turbines	8,304,000	55.02	8,793,120
Five two-mega- watt open flume turbines	8,094,000	57.41	9,297,851
Six two-mega- watt open flume turbines	9,297,000	59.80	8,102,825

HALF POWERHOUSE PLAN
 SCALE: $\frac{1}{8}" = 1'-0"$

SECTION A
 SCALE: $\frac{1}{8}" = 1'-0"$

BRIDGE SECTION
 SCALE: $\frac{1}{8}" = 1'-0"$

KEY PLAN
 NOT TO SCALE

VII - PROJECT POWER PRODUCTION

VII. PROJECT POWER PRODUCTION

A. GENERAL

In order to determine the economic feasibility of the Broadwater Power Project, and to compare the two alternative configurations, operation studies were performed to determine the potential energy generation. The studies were developed on a computer, using the site and hydrologic data presented in Chapter III.

The power and energy generated by falling water at a hydroelectric facility are functions of the annual flow pattern, the volume of flow, the head through which the water falls and the characteristics of the turbine-generator. Once this data is determined, operation studies are performed by assuming that the power plant existed over the period of the available flow record period. The power and energy production that would have been generated is computed. Analyzing the study results then yields the average annual energy, the firm power and the project capacity factors. This information in turn is then utilized in assessing the project economics and making comparisons between various alternatives.

This chapter presents the results and analyses of the power and energy operation studies.

B. DEFINITIONS USED

The following definitions will be used in the ensuing discussions of the generation of power and energy and the

determination of the value of energy from the Broadwater Power Project.

Power - Power is a rate of work or, for generation facilities, the rate at which energy is generated. The usual units of power, when discussing electrical generation, are kilowatts (kW) and megawatts (MW). (One megawatt is equal to one thousand kilowatts.) In common usage, as followed by this report, the term "power" is used to represent both energy and power.

Energy - Energy is the ability to do work. Energy may be measured in either foot-pounds or kilowatt-hours (kWh). Electrical energy is usually given in kilowatt-hours. For generation facilities, the annual output is often given in million kilowatt-hours (MkWh).

Capacity Factor - The capacity factor is the ratio, expressed in percent, of the actual annual generation of a power facility to the generation that would have occurred had the facility operated at full capacity for the entire year. For example, if a 10,000 kW power plant operated at full capacity throughout the entire year, it would generate 87,600,000 kWhs. If the plant actually generates 21,900,000 kWh during a given year, the capacity factor for the year would be 25 percent.

C. STUDY METHODOLOGY

The operation studies for the project were accomplished using a computer program developed specifically for a run-of-the-river operation such as Broadwater. The required

inputs to the program include the average monthly flows, a turbine-generator efficiency curve and a tailwater curve. The monthly flow data used the 50-year historical and extended record described in Chapter III. The tailwater curve used was also presented in Chapter III and is shown on Figure III-3. The turbine-generator performance curve used in the operation studies for the apron-mounted alternative is shown on Figure VII-1. The curve for the conventional alternative is similar.

The program used is capable of evaluating multiple turbine installations. Under a given flow condition, the various possible combinations of turbines are evaluated to determine which combination gives the optimum output. For example, if the total flow is 3600 cfs, the program determines whether to use three turbines at 1200 cfs each or four turbines at 900 cfs each.

From the flow and tailwater data, the effective head for a given month is calculated. From the head and flow data the number of turbine-generator units on-line and the resulting monthly power and energy generation are determined. Any flow in excess of the combined turbine capacities is considered spill.

Results of operation studies performed for the Broadwater Power Plant using the above methodology are summarized below.

D. STUDY RESULTS

As discussed in Chapter V, the optimal installation for the apron-mounted configuration was determined to be four

2.44 MW turbine-generator units with a total capacity of 9.76 MW. A 50-year monthly operation study for this installation was performed and is included with the report as Appendix B-1. The resulting annual energy production is shown on Figure VII-2. As shown, the average annual energy production is 56.44 MkWh and the range of annual energy production is between 40.46 MkWh in 1937 and 69.48 MkWh in 1976. The 40.46 MkWh represents the amount of firm energy generated for the apron-mounted configuration.

For the apron-mounted configuration, the 50-year average monthly power production is shown on Figure VII-3 and the energy production on Figure VII-4. These figures also include the monthly power and energy values for 1937 to illustrate the amount of firm power and energy available.

The 50-year monthly operation study for the conventional configuration, four 2.5 megawatt tube turbines mounted in a powerhouse to be constructed adjacent to the existing dam, is included as Appendix B-2. The average annual energy was determined to be 55.09 MkWh, approximately two percent less than that for the apron-mounted installation. The energy generation for this alternative differs from the apron-mounted configuration because of differences in the turbine efficiency curve used; the headwater, tailwater and monthly flow data are the same.

As the included operation study results show, the range of annual energy production is between 39.00 MkWh in 1937 and 69.87 MkWh in 1976. These high and low years are the same as the apron-mounted configuration and the energy generation values differ only slightly.

The 50-year annual energy production, and the monthly power and energy production values for the conventional configuration have not been shown graphically, because they would differ only very slightly from Figure VII-2, VII-3 and VII-4 for the apron-mounted configuration.

VARIABLE PITCH PROPELLER WITHOUT WICKET GATES
VERTICAL, TUBE, BULB OR RIM

$$kW_R = H_R Q_R E_R E_G / 11.81, (kW)$$

where:

kW_R = Rated capacity at H_R

H_R = Selected Design Head, (ft.)

Q_R = Turbine Discharge at H_D & kW_R , (cfs)

E_R = Turbine efficiency at H_D & kW_R , (%)

E_G = Generator efficiency, (%)

50 YEAR ANNUAL ENERGY PRODUCTION
APRON-MOUNTED CONFIGURATION

FIGURE
VII-2

MONTHLY POWER PRODUCTION
APRON-MOUNTED CONFIGURATION

FIGURE
VII-3

MONTHLY ENERGY PRODUCTION
APRON-MOUNTED CONFIGURATION

FIGURE
VII-4

VIII - PROJECT POWER VALUE AND MARKETING

VIII. PROJECT POWER VALUE AND MARKETING

A. GENERAL

The value of power and energy from a hydroelectric project is usually determined by comparison with the cost of power and energy from the least cost alternative. The alternative considered is typically a fossil-fuel facility, which is capable of satisfying the same portion of the load-duration curve as would be satisfied by the hydroelectric project.

Using this economic rationale, it is evident that events of the past decade have greatly increased the value of hydroelectric power. The cost of oil-fired generation has increased sharply as a result of the price rise in both foreign and domestic oil. The cost of coal-fired generation has increased almost as rapidly because of the increased demand for coal as an alternative to oil and because of stricter environmental controls on the burning and mining of coal.

It is likely that the value of power from alternative sources will continue to rise sharply in the future. As a national energy policy evolves, dictating a reduced dependence on foreign energy sources, and as political turmoil in the Middle East increases, the cost of imported oil and the cost of both coal-fired and oil-fired generation will climb quickly. The value of hydroelectric power will climb at a similar rate.

Hydroelectric generation has certain characteristics that make it different from other contemporary energy resources. For one, hydroelectric generation relies upon a renewable energy source, one that is not susceptible to depletion.

Second, the generation of hydroelectric energy is virtually pollution-free, in contrast to other energy sources. Lastly, because hydroelectric generation is dependent on the supply of falling water, hydroelectric facilities are prone to outages during drought conditions. All of these characteristic features are considered in determining the value of hydroelectric energy.

This chapter presents, in order, the present and future regional energy resources for Montana, the methodology used to establish the unit value of the project power and energy and the marketing potential of the project power.

B. PRESENT AND FUTURE REGIONAL ENERGY RESOURCES

The State of Montana's electrical needs are satisfied by generating facilities owned by the federal government and by investor-owned utilities, principally Montana Power Company and Montana-Dakota Utilities. The major power suppliers and distributors are as follows:

1. Montana Power Company

Montana Power Company and Puget Sound Power and Light Company are jointly constructing a 660,000 kW mine-mouth coal-fired plant at Colstrip, Montana. The companies will have equal ownership and output from the two 330,000 kW units, and, together with Washington Water Power Company, Portland General Electric Company and Pacific Power and Light Company, propose to construct two additional 700,000 kW units at the Colstrip site.

In 1976, Montana Power Company distributed and sold approximately 65 percent of the electrical sales to ultimate consumers. Montana Power Company supplies power to the majority of the communities in the western two-thirds of Montana. The total installed capacity owned by the Montana Power Company in 1975 was 769,000 kW, which was provided by 13 hydroelectric plants and two thermal generation plants. An additional capacity of 376,000 kW was supplied by firm power purchases, exchange agreements and wheeling payments in power to meet the system demand, making the total 1975 system capacity 1,145,000 kW. The maximum system demand in that year was 911,000 kW. Total system sales for that year totaled 5,472 M kWh. In 1976, the total sales were 6,742 M kWh, an increase of 23.2 percent.

The Company also is participating in the proposed Pleasant Valley-Mountain Sheep Project, a 2,700,000 kW hydroelectric development on the Middle Snake River. This project is currently tied up in litigation and lacks Congressional approvals.

2. Bonneville Power Administration

The Bonneville Power Administration (BPA) is the marketing agent for all Federally produced power in the Northwestern United States. In 1976, the energy generated for BPA totaled 91,414 M kWh. The energy was primarily from hydroelectric plants operated by the Bureau of Reclamation and the Corps of Engineers, both within Montana and in Northwestern states, and by the Washington Power Supply System, the Hanford Nuclear Plant, the Centralia, Washington Thermal (coal-fired) Plant and the Trojan Nuclear Plant. This generation is more than 13 times the total sales of Montana Power Company in 1976. In addition, through the extensive BPA transmission line network

and by wheeling arrangements pursuant to the Pacific Northwest Coordination Agreements, BPA power can reach nearly every community in the Northwest. In 1976, BPA sold power in Montana to six electrical cooperatives, one Indian Affairs irrigation district, Montana Power Company and two private industries.

Energy sold by BPA in Montana during 1976 totaled about 4,539 MkwH or about 5 percent of their total generation.

3. United States Bureau of Reclamation

The Western Area Power Administration (WAPA) with regional office in Billings, Montana is responsible for marketing power in eastern Montana. WAPA acts in a manner similar to BPA and serves several generation and transmission cooperatives who, in turn, serve many rural electric cooperatives.

4. Vigilante Electric Cooperative, Inc.

The Vigilante Electric Cooperative serves about 4000 customers in the southwestern area of Montana, including the area surrounding Broadwater Dam. Their load is approximately 65 MkwH and all of their power is presently obtained from Bonneville Power Administration. Their load is approximately the output from the proposed Broadwater Project. Since their power needs may not occur when generation is available, an arrangement for banking the energy would need to be made to fully utilize the power potential.

C. ENERGY SUPPLY IN MONTANA

The Pacific Northwest Utilities Conference Committee (PNUCC) has described in general the power supply position of

Bonneville Power Administration in Western Montana. It stated that the regional energy supply from the public's viewpoint has changed dramatically and that western Montana will no longer enjoy an abundance of low-cost hydroelectric power. New thermal plants are being added to increase supply but the cost of building such plants is increasing at a rapid rate. The region's consumers, who are having to pay increasing prices for electricity, should realize that hydroelectric resources are limited.

Until recently, BPA has been meeting the full requirements of all the public utilities in Montana. For the first time in history, BPA has informed such utilities that its resources will not be sufficient to meet their growth needs after 1983. BPA, by statute, cannot purchase or create more power generation; it can only reallocate the resources it has been authorized to market from Federal projects.

In general, low-cost Federal hydroelectric power is no longer available to private utilities from BPA, and the use of new, expensive fossil-fueled power plants results in a growing disparity in the cost of power between publicly owned and privately owned utilities.

The difference in bulk power cost is reflected in significantly different rates to consumers, often between neighboring communities. This has led to proposals that existing BPA power be allocated to new public entities that would be created. Since BPA has no new resources, it could mean dividing the Federal generation into smaller shares. The result would be more uncertainty for communities now receiving BPA power, but no new power.

BPA has notified the aluminum, chemical, nickel and other basic industries which it serves directly that it cannot renew their power contracts when they expire in the mid-1980's. Currently, these industries face the possibility of having to close down or leave the region if they cannot obtain a future supply of power at a price they can afford. Loss of these basic industries to the Northwestern States would mean a substantial loss of jobs and production (including one-third of the country's aluminum production and all of its nickel production). The industries use a type of power that can be interrupted at a time of shortage so other consumer loads can be served. Without these industries, utilities and their consumers would have to pay more to maintain stand-by or spinning reserve.

D. UNIT VALUE OF PROJECT POWER AND ENERGY

The value of capacity and energy from a hydroelectric project is normally based on the value of generation from alternate sources such as oil-fired, combined cycle, gas turbine, coal-fired or nuclear plants. These different types of plants operate at different capacity factors and the particular type of plant on which to base the comparisons depends on the capacity factor of the hydroelectric project.

A gas turbine plant is a peaking facility, operating only at the highest use hours each day. The resulting capacity factors range from 0 to about 25 percent.

A combined cycle plant is an intermediate load facility, utilizing the combination of an oil-fired combustion turbine linked with a conventional turbine plant, where the excess

heat from the turbine is used to produce steam. Combined cycle plants operate with capacity factors of between 25 percent and 45 percent.

A nuclear, coal-fired, or lignite-fired generating plants are base load facilities, operating a high percentage of the daily and yearly generating hours. The capacity factors of these plants range from 45 percent to 100 percent.

Early in 1978, the United States Army Corps of Engineers requested the Federal Energy Regulatory Commission (FERC) to develop generalized power values for various regions of the United States to be used in the analysis of the relative economic merits of projects for the National Hydropower Study.

Preliminary values were developed based on January 1978 prices and transmitted to the Corps of Engineers on June 23, 1978. The study divided the continental United States (Alaska and Hawaii excluded) into twenty-three regions. The power values developed in the study for Eastern Montana, the region containing Broadwater Dam, are included as Table VIII-1.

The values developed for Table VIII-1 were based on a range of hydroelectric capacity factors from zero to 100 percent, in increments of ten percent. In each capacity factor level, the individual component power values for Capacity Value and Energy Value are shown in addition to an equivalent total annual value expressed in \$/kW yr and in mills/kWh.

From Chapter VII, the average capacity factor is 66.0 percent for the apron-mounted alternative and 62.9 percent for the conventional alternative. For the purpose of obtaining a benefit value, a 65-percent capacity factor was assumed for both alternatives. In Table VIII-1, for a 65-percent capacity factor, interpolating between 60 and 70 percent, for a conventional coal-fired base load steam plant, the capacity value is \$135.50 per kW per year and the energy value is 9.95 mills per kWh. These may be combined into a single value of 34 mills per kWh. Other alternatives such as nuclear and lignite-fired generation were not considered appropriate for Montana.

From the determination that the alternative cost of energy from a 65-percent capacity factor coal-fired system is 34 mills per kWh, this same value was used in Chapter XI for assessing the project economics. It should be noted that this computation assumes that the capacity from the hydroelectric plant is equal to capacity from a coal-fired plant. As indicated previously, the mechanical rehabilitation of a hydroelectric plant is much superior but the availability due to hydraulic conditions is less. The two factors balance each other.

E. PROJECT POWER MARKETING

As indicated previously, the "economic value" of hydroelectric power can be taken to be the least cost of the alternative source of power, i.e., a coal-fired plant. This value is used in the benefit cost studies. However, the selling price, or "financial value," of the power is also important. The financial value is the price at which the developer of the power source would sell the power to a power

purchaser. The financial value must be greater than the development cost, or the project is economically unfeasible. Similarly, the selling price must be less than the economic value, or the purchaser would have no incentive to buy the power. Thus, if the power is to be sold to a power purchaser, the financial value must be less than the economic value.

The financial value can be determined by negotiations or bidding. Both procedures have been used in the Western states. The form of financing and interest rate are often a prime consideration in the selection process for the power purchaser.

During the course of this study, a preliminary meeting was held with the Montana Power Company. The company stated that they had a need for additional power supplies and indicated a desire to investigate the matter further after the project power and economic studies were completed.

In addition, the Vigilante Electric Cooperative has filed a preliminary FERC application for power development at Broadwater Dam. However, the site is owned by the State of Montana and the State clearly indicates a desire and intent to develop the site. Being the site owner, the State, under the FERC rules, would have the rights for power development. However, it is felt that the Vigilante Electric Co-operative, having a demonstrated need for additional power supplies, would be a potential customer.

TABLE VIII-1

CHICAGO REGIONAL OFFICE
Mid-Continent Area Reliability Coordination Agreement (MARCA)

Hydro Capacity Factor %	Capacity Value (\$/kW-yr)	Energy Value mills/kWh)	Equivalent Total Power Value ^{1/} (\$/kW-yr)	(mills/kWh)
<u>Combustion Turbine Alternative</u>				
0	36.90	-	36.90	-
10	31.50	40.3	66.80	76.3
20	31.50	37.2	96.80	55.2
<u>Combined Cycle Alternatives</u>				
30	63.50	24.1	126.90	48.3
40	63.50	22.6	142.70	40.7
<u>Nuclear Alternatives</u>				
50	168.90	3.9	185.90	42.5
60	168.90	4.5	192.50	36.6
70	168.90	4.9	199.10	32.5
80	168.90	5.2	205.60	29.3
90	168.90	5.5	212.20	26.9
100	168.90	5.7	218.80	25.0
<u>Coal-Fired Alternative</u>				
50	135.50	10.1	179.90	41.1
60	135.50	10.0	188.00	35.8
70	135.50	9.9	196.10	32.0
80	135.50	9.8	204.20	29.1
90	135.50	9.7	212.30	26.9
100	135.50	9.7	220.40	25.2
<u>Lignite-Fired Alternative</u>				
50	143.40	8.8	181.70	41.5
60	143.40	8.8	189.50	36.1
70	143.40	8.8	197.20	32.2
80	143.40	8.8	205.00	29.3
90	143.40	8.8	212.70	27.0
100	143.40	8.8	220.50	25.2

^{1/} Example: Component power values of \$31.50/kW-yr and 40.3 mills/kWh at 10 percent hydro capacity factor are equivalent to a total annual value of either \$66.80/kW-yr or 76.3 mills/kWh (but not both).

TABLE VIII-1
CONTINUED

TYPE OF ALTERNATIVE:	Lignite-fired
NUMBER AND SIZE OF UNITS:	2-650 MW units
ALTERNATIVE INVESTMENT COST:	\$737/kW
ALTERNATIVE HEAT RATE:	11,500 Btu/kWh
ALTERNATIVE FUEL COST:	56¢/10 ⁶ Btu
TYPE OF ALTERNATIVE:	Coal-fired
NUMBER AND SIZE OF UNITS:	2-650 MW units
ALTERNATIVE INVESTMENT COST:	\$693/kW
ALTERNATIVE HEAT RATE:	9,000 Btu/kWh
ALTERNATIVE FUEL COST:	85¢/10 ⁶ Btu
TYPE OF ALTERNATIVE:	Nuclear
NUMBER AND SIZE OF UNITS:	2-1000 MW units
ALTERNATIVE INVESTMENT COST:	\$845/kW
ALTERNATIVE HEAT RATE:	-
ALTERNATIVE FUEL COST:	\$75/kW and 4.75 mills/kWh
TYPE OF ALTERNATIVE:	Combined cycle, oil-fire
NUMBER AND SIZE OF UNITS:	1-400 MW unit
ALTERNATIVE INVESTMENT COST:	\$325/kW
ALTERNATIVE HEAT RATE:	10,000 Btu/kWh
ALTERNATIVE FUEL COST:	265¢/10 ⁶ Btu
TYPE OF ALTERNATIVE:	Combustion turbine, oil-fired
NUMBER AND SIZE OF UNITS:	2-135 MW units
ALTERNATIVE INVESTMENT COST:	\$160/kW
ALTERNATIVE HEAT RATE:	15,000 Btu/kWh
ALTERNATIVE FUEL COST:	265¢/10 ⁶ Btu
TYPE OF FINANCING ASSUMED:	Private (100 percent cost of money)
SUGGESTED MIX OF BASE LOAD ALTERNATIVES:	60% lignite-fired steam 25% coal-fired steam 15% nuclear

IX - PROJECT COSTS

IX. PROJECT COSTS

A. GENERAL

The project costs consist of the initial capital costs and the continuing annual costs. This chapter presents the estimated project costs and the assumptions on which these costs are based. It should be noted that all costs are based on March 1979 prices.

B. CAPITAL COSTS

The initial capital costs consist of direct construction costs, including contingencies, and the indirect costs which consist of engineering costs, administrative and legal costs, and interest during construction.

The construction costs for the apron-mounted and conventional configurations are presented in Tables IX-1A and IX-1B, respectively. The detailed cost estimates from which the summaries were derived are presented in Appendices C-1 and C-2. The cost estimates for the electrical-mechanical equipment are based on direct quotes provided upon request by various manufacturers. The remaining costs were estimated on the basis of recent bid prices for similar construction work. A 15 percent contingency for the civil work and a ten percent contingency for the electrical-mechanical work is provided.

The engineering costs are presented in Table IX-2. The engineering activities would consist of an environmental impact report, the Federal Regulatory Commission (FERC) application, surveys, borings and miscellaneous investigations, various permits, preparations of contract plans and

specifications, and construction management. The estimated costs for these items was based on the following criteria:

Environmental Impact Report: An EIR will be required as Exhibit W for the FERC license application and will also be necessary for a PL-984 Loan application if that particular method of project financing is pursued. The indicated cost of \$30,000 is based on past experience of similar studies.

FERC Application: Included in this extensive document will be detailed preliminary designs, operation studies and a financial plan. The indicated cost of \$40,000 is based on experience on similar projects.

Preliminary Design, Surveys, Borings, and Miscellaneous Structural Investigations: Prior to beginning the detailed design of the power plant, it will be necessary to establish firmly the project parameters. These parameters can be established by means of topographic surveys, soil borings and tests, structural investigations, and a preliminary design of the powerplant and appurtenant features. The cost of these efforts is based on experience and estimated to be \$110,000.

Contract Plans and Specifications: The indicated cost of \$600,000 is based on the American Society of Civil Engineers' cost curve and recent experience in the design of hydroelectric facilities.

Construction Management: The activity will consist of on-site construction inspection and coordination activities and home office support. The indicated cost of \$550,000 would support a full-time Resident Engineer and a full-time inspector (consultant or Montana State personnel) and the necessary engineering office activities.

Miscellaneous Permits: The indicated cost of \$30,000 would cover the PL-984 loan application and any other miscellaneous state or federal permits required.

The administrative costs are also presented in Table IX-2. The administration cost of \$100,000 represents the estimated State of Montana costs to oversee the overall project and also any legal costs that may be incurred. The loan fee of \$180,000 represents approximately 1.8 percent of the initial construction cost and would consist of the necessary financial and bond consultant fees if revenue bonds are used to finance the project or review and administration charges if a PL-984 loan is used.

Table IX-3 shows a summation of the project costs, excluding interest during construction. The interest during construction is dependent upon the method of financing and will be discussed in the next chapter. As shown, the estimated cost for the apron-mounted and configuration is \$1,638,000 less than the conventional configuration.

C. ANNUAL COSTS

The annual costs consist of the debt service to retire the bonds or loans used to finance the capital costs described above, and the annual expenses necessary for operation

and maintenance. The debt service is a function of the project financing utilized and a discussion of the annual debt service will be covered in Chapter X in which the various financing options are discussed. The expected operation and maintenance costs are discussed below.

Annual operation and maintenance expenses include administration, insurance, operation and maintenance personnel, allowance for equipment replacement, license costs, fees and other miscellaneous expenses. The following criteria were used as a guide in the determination of estimated operating expenditures.

Insurance: Coverage should be provided for fire and storm damage, vandalism, property damage and public liability. In the present analysis, an average rate of 0.2 percent of construction cost, which is representative of current practice, was used to determine insurance costs. The amount, estimated \$20,000 annually, has been included. However the Department's present policy may be extended to include the power plant at a lower cost.

Operation and Maintenance Costs: Included in this item are funds to cover the costs for employees, services, office, expenditures, repair shop equipment and parts incurred in project operation and maintenance, including periodical replacement of minor components and equipment that have an estimated useful life significantly shorter than the forty-year amortization period for the project capital costs. As discussed earlier, it is anticipated that the plant will be attended for forty-hours per week, thus accounting for one man-year of labor annually. Additionally, periodic maintenance

activities and an annual overhaul are anticipated to account for another man-year. Assuming a cost of \$30,000 per man-year, which includes transportation, miscellaneous expenses and fringe benefits, the total annual labor cost would be \$60,000. Interim replacement of minor components was assumed to amount to 0.3 percent of the construction cost annually, or \$30,000.

General Expenses: Administrative and other miscellaneous general costs required during the project operation for supervision, administration, and license fees in connection with power production, transmission and distribution, and other overhead costs are estimated at 0.2 percent of the cost of the power facilities, or \$20,000.

The total annual operation and maintenance expense is estimated to be \$130,000 annually as shown in Table IX-4.

TABLE IX-1A
CONSTRUCTION COST SUMMARY ^{1/}
APRON-MOUNTED CONFIGURATION

<u>Acct. No.</u> ^{2/}	<u>Cost Item</u>	<u>Amount</u>
330	Land and Land Rights	\$ 50,000
331	Structures and Improvements	1,950,000
332	Reservoirs, Dams and Waterways	1,965,000
333	Waterwheels, Turbines and Generators	3,854,000
334	Accessory Electrical Equipment	952,000
335	Miscellaneous Power Plant Equipment	128,000
355	Transmission Line	<u>200,000</u>
	Subtotal	\$9,099,000
	Contingencies	<u>1,108,000</u>
	Total Construction Cost	\$10,207,000

^{1/} See appendix C-1 for detailed construction estimate

^{2/} FERC cost account number

TABLE IX-1B
CONSTRUCTION COST SUMMARY ^{1/}
CONVENTIONAL CONFIGURATION

<u>Acct. No.</u> ^{2/}	<u>Cost Item</u>	<u>Amount</u>
330	Land and Land Rights	\$ 50,000
331	Structures and Improvements	1,900,000
332	Reservoir, Dams and Waterways	2,200,000
333	Waterwheels, Turbines and Generators	5,150,000
334	Accessory Electrical Equipment	952,000
335	Miscellaneous Power Plant Equipment	128,000
355	Transmission Line	<u>200,000</u>
	Subtotal	\$10,580,000
	Contingencies	<u>1,265,000</u>
	Total Construction Cost	\$11,845,000

^{1/} See appendix C-2 for detailed construction estimate

^{2/} FERC cost account number

TABLE IX - 2
ENGINEERING AND ADMINISTRATIVE COSTS

ENGINEERING COSTS

Environmental Impact Report	\$ 30,000
FERC Application	40,000
Preliminary Design, Surveys, Borings and Misc. Structural Investigations	110,000
Contract Plans and Specifications	600,000
Construction Management	550,000
Miscellaneous Permits	<u>30,000</u>
Total Engineering Costs	\$ 1,360,000

ADMINISTRATIVE COSTS

Administration & Legal Fees	\$ 100,000
Financial Fees	<u>180,000</u>
Total Administrative Costs	\$ 280,000

TABLE IX - 3
INITIAL COST SUMMARY

	<u>Apron-Mounted Alternative</u>	<u>Conventional Alternative</u>
Construction Cost	\$10,207,000	\$11,845,000
Engineering Cost	1,360,000	1,360,000
Administrative Cost	<u>280,000</u>	<u>280,000</u>
Total	\$11,847,000	\$13,485,000

TABLE IX - 4
ANNUAL OPERATION AND MAINTENANCE COSTS

Insurance	\$ 20,000
O&M Manpower	60,000
Interim Replacement	30,000
General Expenses	<u>20,000</u>
Total Annual O&M Cost	\$130,000

X - FINANCIAL ALTERNATIVES
AND ENERGY COSTS

X. FINANCIAL ALTERNATIVES AND ENERGY COSTS

A. GENERAL

The cost of producing energy is directly related to the method of financing employed. The method of financing determines the interest rate and the repayment period and therefore directly influences the annual expenses and the energy cost. This chapter presents the financial alternatives available to the State of Montana for the Broadwater Power Project and presents the cost per kWh and the cost per installed kW.

B. FINANCIAL ALTERNATIVES

There are four principal sources of funding open to the State to finance the project. The first two are government loans through either the Department of Energy (DOE) or the United States Bureau of Reclamation (USBR). The third potential source is the direct sale of general obligation or revenue bonds which would be subject to taxation. The fourth source is the sale of tax-exempt bonds.

The DOE loans are made possible by recently enacted legislation entitled "Public Utility Regulation Policies Act of 1978". This act authorizes the Secretary of Energy to make loans to any municipality, electric cooperative, industrial development agency, nonprofit organization, or other person for up to 75 percent of the cost of a small hydro-electric project. The loan would be for up to 30 years and the interest rate would be the prevailing federal discount

rate. This rate is currently 6-7/8 percent. The act further authorizes the appropriation of \$100,000,000 per year for each of three years to fund these loans. The loans would be repaid by the power sale revenues derived from the projects.

This act became effective in November 1978. However, the recent budget submitted to Congress by the President contained no funds for this act and it does not appear likely that Congress will fund this program for the forthcoming fiscal year 1979-1980, which commences on October 1, 1979. If funds were to be authorized for the following fiscal year (1980-1981), the earliest possible time that funds would be available under this program would be October 1980.

The second source of funding would be a USBR loan under the Small Reclamations Act of 1956, also known as Public Law 984 (PL-984). This act provides funding for eligible multiple purpose water resource projects. The loans are long-term and the repayment period can extend to 40 years. Like the DOE loans, the interest rate would be the prevailing federal discount rate, currently 6-7/8 percent. Repayment would be from the power sales revenues from the project.

This particular source of funding has not previously been utilized to fund hydroelectric projects, but the original act plainly authorized such a use as long as the project was multi-purpose with some irrigation benefits. The USBR has defined such a project as eligible, as long as a minimum of 5 percent of the total cost was for irrigation. This project will qualify since it will include rehabilitation work on Broadwater Dam, better water control facilities and a new canal inlet works for the existing canal.

The USBR regional office in Billings, Montana, has indicated a belief that the Broadwater Project may be eligible and that the Bureau would be cooperative in a request for a PL-984 loan.

The third source of funding would be the sale of taxable revenue bonds. This is the "conventional" source of funding which has been most commonly used on previous similar projects. Federal tax laws currently provide that, if the power from the project is purchased, as has been assumed, by an investor-owned utility, up to \$1,000,000 of bonds could be sold that are exempt from federal income tax. Under this condition it is currently estimated that such bonds could be sold at an interest rate of seven percent. Bonds for the amount in excess of \$1,000,000 would be subject to federal income tax and would most likely carry an interest rate of ten percent. The term of both the tax-exempt and the taxable bonds would be 40 years. To be sold as revenue bonds the power purchaser must pledge to retire the bonds. This pledge would be provided for in the power purchase agreement which would be negotiated with a power purchaser prior to the bond sale.

The fourth possible source of funding would be the sale of tax-exempt revenue bonds. In order to sell these bonds the power purchaser would have to be a public utility district. These bonds would have an interest rate of approximately 7 percent.

It should be noted that, with governmental funding, money would be granted as required throughout the development

and construction of the project. With bonds, however, the funds would be acquired in a lump sum, reinvested, and paid out as required.

Using these sources of funding, there are four primary financial options for the project. These are:

1. Obtain a loan from DOE for the first 75 percent of the project cost at an interest rate of 6-7/8 percent and a term of 30 years. Sell revenue bonds for the remaining 25 percent of the project cost. The first \$1,000,000 of these bonds would have a 7 percent interest rate and the remainder would have a 10 percent interest rate. The term of all the bonds would be 40 years. This funding method will be called the "DOE Loan Option" in the ensuing discussions. This funding scheme would be the most attractive if the purchaser of the power is an investor-owned utility.
2. Obtain a PL-984 loan from the USBR for the entire project cost at an interest rate of 6-7/8 percent and a term of 40 years. This funding method will be called the "PL-984 Loan Option" in the ensuing discussions. Power developed under this form of financing must first be offered to preferential customers under the applicable terms of the reclamation law.
3. Sell tax-exempt revenue bonds in the amount of \$1,000,000 at a non-taxable interest rate of 7 percent. Sell bonds sufficient to cover the remaining project cost at a taxable rate of 10 percent. The term of both bond issues would be for 40

years. This funding method will be called the "Conventional Funding Option" in the ensuing discussion. This form of financing would be applicable when power is sold to an investor-owned utility or a non-exempt power utility such as the Federal Government.

4. Sell tax-exempt revenue bonds to fund the entire project. The bonds would have an interest rate of approximately 7 percent and a term of 40 years. For the purpose of evaluation, this option is equal to the PL-984 option.

The repayment period of the options discussed above does not start at the time of the acquisition of funds, but, rather, at the beginning of plant operation. Interest is charged on the borrowed money during the period prior to the start of repayment. This interest amount, known as Interest During Construction, is dependent on the financing scheme. Tables X-1A through X-1C show the estimated amounts of Interest During Construction for each funding source and installation alternative.

C. ENERGY PRODUCTION COST

With the project costs, power production and financing options established, the project Energy Production Cost (EPC) and the cost per installed kW can now be determined. For each financial option, the EPC is calculated for both the apron-mounted and the conventional alternative.

Table X-1A presents the EPC for the Broadwater Power Project using the DOE loan option. As previously discussed, this option may not be available.

Table X-1B presents the EPC for the Broadwater Power Project using the PL-984 Loan Option which is effectively equal to issuing tax-exempt revenue bonds. For the apron-mounted alternative the annual expense of \$1,109,000 is a combination of the loan payment and the annual operation and maintenance cost. Under this financial option, the Energy Production Cost would be 19.6 mills per kWh.

Table X-1C presents the EPC for the Broadwater Power Project using the Conventional Funding Option. As shown, the annual expenses are a combination of two bond payments and the annual operation and maintenance cost. Under this option, the EPC would be 26.9 mills per kwh.

Table X-2 is a summary of the energy production costs for all possible combinations of options. As can be seen, the lowest EPC is 19.6 mills per kWh for the apron-mounted configuration, with either a PL-984 Loan or tax-exempt revenue bonds.

D. COST PER INSTALLED KILOWATT

The cost per installed kilowatt is dependent on the financing method and is shown in Tables X-1A through X-1C.

TABLE X-1A
ENERGY PRODUCTION COST
DOE LOAN OPTION

	<u>Apron-Mounted</u>	<u>Conventional</u>
<u>CAPITAL COST</u>		
Initial Cost	\$ 11,847,000	\$ 13,485,800
Interest During Construction	\$ <u>1,560,000</u>	\$ <u>1,770,000</u>
Total Capital Cost	\$ 13,407,000	\$ 15,255,000
<u>COST PER KILOWATT</u>	\$ 1,374	\$ 1,526

ANNUAL EXPENSES

Repayment:

75% @ 6-7/8%, 30 yrs.	800,000	910,500
\$1,000,000 @ 7%, 40 yrs.	75,000	75,000
Remainder @ 10%, 40 yrs.	240,500	287,500
Operation and Maintenance	<u>130,000</u>	<u>130,000</u>
Total Annual Expenses	\$ 1,245,500	\$ 1,403,000

ENERGY PRODUCTION COST (EPC)

a) Apron-Mounted Alternative

$$\begin{aligned} \text{Average Annual Energy} &= 56,440,000 \text{ kWh} \\ \text{EPC} &= \frac{1,245,500 \times 1000}{56,440,000} = \underline{\underline{22.1 \text{ mills/kWh}}} \end{aligned}$$

b) Conventional Alternative

$$\begin{aligned} \text{Average Annual Energy} &= 55,090,000 \text{ kWh} \\ \text{EPC} &= \frac{1,403,000 \times 1000}{55,090,000} = \underline{\underline{25.5 \text{ mills/kWh}}} \end{aligned}$$

TABLE X-1B
ENERGY PRODUCTION COST
WITH PL-984 LOAN OPTION
OR TAX-EXEMPT BONDS

	<u>Apron-Mounted</u>	<u>Conventional</u>
<u>CAPITAL COST</u>		
Intitial Cost	\$ 11,847,000	\$ 13,485,000
Interest During Construction	\$ <u>1,400,000</u>	\$ <u>1,600,000</u>
Total Capital Cost	\$ 13,247,000	\$ 15,085,000
<u>COST PER KILOWATT</u>	\$ 1,357	\$ 1,509
<u>ANNUAL EXPENSES</u>		
Repayment: 6-7/8%, 40 years	\$ 979,000	\$ 1,115,000
Operation and Maintenance:	\$ <u>130,000</u>	\$ <u>130,000</u>
Total Annual Expenses	\$ 1,109,000	\$ 1,245,000

ENERGY PRODUCTION COST (EPC)

a) Apron-Mounted Alternative

Average Annual Energy = 56,440,000 kwh

$$\text{EPC} = \frac{1,109,000 \times 1,000}{56,440,000 \text{ kwh}} = \underline{\underline{19.6 \text{ mills/kwh}}}$$

b) Conventional Alternative

Average Annual Energy = 55,090,000 kwh

$$\text{EPC} = \frac{1,245,000 \times 1,000}{55,090,000} = \underline{\underline{22.6 \text{ mills/kwh}}}$$

TABLE X-1C
ENERGY PRODUCTION COST
W/CONVENTIONAL LOAN OPTION

	<u>Apron Mounted</u>	<u>Conventional</u>
<u>CAPITAL COST</u>		
Initial Cost	\$ 11,847,000	\$ 13,485,000
Interest During Construction	<u>2,000,000</u>	<u>2,300,000</u>
Total Capital Cost	\$ 13,847,000	\$ 15,785,000
<u>COST PER KILOWATT</u>	\$ 1,419	\$ 1,579

ANNUAL EXPENSES:

Repayment:

1,000,000 @ 7%, 40 yrs.	75,000	75,000
Remainder @ 10%, 40 yrs.	1,313,500	1,512,000
Operation and Maintenance	<u>130,000</u>	<u>130,000</u>
Total Annual Expenses	\$ 1,518,500	\$ 1,717,000

ENERGY PRODUCTION COST (EPC)

a) Apron-Mounted Alternative

$$\begin{aligned} \text{Average Annual Energy} &= 56,440,000 \text{ kWh} \\ \text{EPC} &= \frac{\$1,518,500 \times 1,000}{56,440,000} = \underline{\underline{26.9 \text{ mills/kWh}}} \end{aligned}$$

b) Conventional Alternative

$$\begin{aligned} \text{Average Annual Energy} &= 55,090,000 \text{ kWh} \\ \text{EPC} &= \frac{\$1,717,000 \times 1,000}{55,090,000} = \underline{\underline{31.2 \text{ mills/kWh}}} \end{aligned}$$

TABLE X-2
ENERGY PRODUCTION COST
SUMMARY

	<u>Apron Mounted</u>	<u>Conventional</u>
DOE Loan Option	22.1 mills/kWh	25.5 mills/kWh
PL-984 Loan Option or Tax-Exempt Bonds	19.6 mills/kWh	22.6 mills/kWh
Conventional Loan Option	26.9 mills/kWh	31.2 mills/kWh

XI - ECONOMIC EVALUATION

XI. ECONOMIC EVALUATION

A. GENERAL

An economic evaluation is basically a comparison of the benefits and costs over the life of the project. The method used to compare the apron-mounted and conventional configurations will be net benefit, that is, the project with the largest net benefit is considered the optimal solution. The method used in this report to demonstrate economic feasibility for each alternative will be the benefit-cost (B/C) ratio. Private utilities generally use the rate of return on investment but public agencies utilize the B/C ratio.

B. PROJECT LIFE

The economic life will be taken as 50 years, the estimated length of time the project will be in service producing power and accruing benefits.

Hydroelectric generating equipment often has a service life well beyond 50 years when the equipment is properly maintained. Typical maintenance procedure consists of yearly repair of the runner, shaft seal and inspection of moving parts, refurbishing of bearings every 5 to 10 years and stator rewinding every 15 to 20 years.

C. COST AND BENEFIT STREAMS

As previously discussed, the project costs depend on the method of financing employed. Tables XI-1A and XI-1B present the annual costs and benefits over the 50 year project life

for the apron-mounted and conventional alternative configurations, respectively, for the DOE Loan, PL-984 Loan or Tax-Exempt Bonds, and Conventional Loan methods of financing. The cost streams show the annual repayment, as derived in Tables X-1A, X-1B and X-1C, ending after 30 or 40 years when complete repayment has been made, but with the annual O&M costs continuing over the entire 50 year project life.

Tables XI-1A and XI-1B also show the benefit streams for each alternative. The annual benefits depend on the average annual energy generated and the applicable unit value of energy. The benefit stream for the apron-mounted alternative is based on a unit energy value of 34.0 mills/kWh and average annual energy of 56.44 MkWh (Appendix B-1). The benefit stream for the conventional alternative is based on a unit energy value of 34.0 mills/kWh and average annual energy of 55.09 MkWh (Appendix B-2).

It should be noted that, in this evaluation, it was assumed that the value of power and the project costs will increase at the same rates.

D. PRESENT WORTH COSTS AND BENEFIT

The present worth of both the annual cost and benefit streams over the 50 year project life depends on the discount rate employed. This rate is generally taken as the cost of money to the borrowing agency, in this case the State of Montana. Since interest rates are currently in a considerable state of flux, the present worth for the benefits and costs has been computed using discount rates of 6 percent and 8 percent.

The results are shown in Table XI-2A for the apron-mounted alternative and Table XI-2B for the conventional alternative.

E. BENEFIT COST RATIOS

The Benefit Cost Ratio (B/C ratio) is derived by dividing the present worth of the project benefit stream by the present worth of the project cost stream. As long as the resulting B/C is greater than 1.0, the project can be deemed feasible since the project benefits exceed the project costs.

The B/C ratios, using discount rates of 6 percent and 8 percent for each of the proposed three financial options, are presented in Table XI-2A for the apron-mounted alternative and in Table XI-2B for the conventional alternative.

For the apron-mounted alternative, the B/C ratios range from 1.63 to 1.70 for the DOE Loan Option, 1.77 to 1.80 for the PL-984 or Tax-Exempt Bonds Option and 1.29 to 1.32 for the "Conventional Loan Option." These values indicate that the apron-mounted alternative is therefore economically feasible using any loan option proposed.

For the conventional alternative, the B/C ratios range from 1.42 to 1.47 for the DOE Loan Option, 1.54 to 1.57 for the PL-984 Loan or Tax-Exempt Bonds Option and 1.12 to 1.14 for the Conventional Loan Option. These values also indicate that the conventional alternative is economically feasible using any loan option considered.

Tables XI-2A and XI-2B show that the calculated B/C ratios are not highly dependent on the discount rate used, but are quite sensitive to the method of financing chosen. From a purely financial viewpoint and based on the B/C ratios cited above for both alternatives, the PL-984 Loan and Tax-Exempt Revenue Bonds or the DOE Loan appear to be roughly equal and more desirable than a conventional loan. However, a PL-984 loan may involve substantial time delays, and, as mentioned earlier, funds for the DOE loan may not be available.

It should be noted that inflation has not been taken into account in the above analysis and the results are therefore very conservative. The only component of the annual costs that can escalate is the O&M component, since the debt service expense (bond or loan repayment costs) will remain fixed. However, the annual project benefits will almost certainly increase since the project power sales agreement will provide for the selling price of the project power to be tied to a fuel cost index, which should certainly increase in the foreseeable future.

To illustrate the effect of a very mild inflation rate of 3 percent, a B/C computation for the conventional alternative was made using the Conventional Loan Option and a discount rate of 8 percent. As shown in Table XI-2B, the B/C ratio for this case if inflation is not considered is 1.12, the lowest B/C ratio obtained for all options studied. If it is assumed that the annual bond repayment costs of \$1,717,000 remain fixed, the annual O&M costs of \$130,000 and the benefits of \$1,873,000 increase at 3 percent per year, the B/C ratio changes from a very marginal figure of 1.12 to a very

reasonable value of 1.60. A similar analysis of the other noninflated B/C ratios would show similar results.

F. COMPARISON OF APRON-MOUNTED
AND CONVENTIONAL CONFIGURATIONS

As previously mentioned, the method used to compare the two alternative configurations is the Net Present Value, which is defined as the difference between the present worth benefits and present worth costs. This approach is a practical method of comparison between two alternatives when no limits exist on the amount of capital available for the project. This case generally prevails for a hydroelectric project where sufficient capital may be obtained through loans or revenue bonds to construct the project and all costs can be repaid through revenues resulting from the sale of power. In this analysis, whichever project alternative results in the highest net present value will be the best economic choice since it will result in the highest net return to the State of Montana.

The Net Present Values are presented in Table XI-2A for the apron-mounted alternative and in Table XI-2B for the conventional alternative.

A comparison of the Net Present Value figures from these tables for any particular loan option and any particular discount rate demonstrates that the Net Present Value for the apron-mounted alternative is considerably greater than the Net Present Value for the conventional alternative. For instance, using the PL-984 at a discount rate of 8 percent, the Net Present Value is \$10,210,000 for the apron mounted

alternative and \$8,025,000 for the conventional alternative, a difference of \$2,185,000 in favor of the apron-mounted alternative. Using the Conventional Loan Option at a 6 percent discount rate yields a Net Present Value difference of \$3,711,000 between the alternatives, again in favor of the apron-mounted configuration.

Therefore, the apron-mounted alternative is a more desirable economic investment than the conventional alternative.

G. COMPARISON OF FINANCING OPTIONS

From a purely financial viewpoint and based on the discussions above of B/C ratios and Net Present Values, it is apparent that the PL-984 loan, tax-exempt bonds and the DOE loan are nearly equivalent in their desirability. The conventional loan method would be less desirable, but still feasible. It must be pointed out that a PL-984 loan may involve substantial time delays and that funds may not be readily available for the DOE loan. Therefore, funding by means of bonds, either tax-exempt or taxable, should be considered the more practical methods of financing.

TABLE XI - 1A
COST AND BENEFIT STREAMS
APRON-MOUNTED ALTERNATIVE

<u>YEAR</u>	<u>COST STREAM^{1/}</u>			<u>BENEFIT STREAM^{2/}</u>
	DOE Loan	PL-984	Con- ventional	
1	\$1,245,500	\$1,109,000	\$1,518,500	\$1,919,000
	↓	↓	↓	↓
30	1,245,500			
31	445,500			
	↓	↓	↓	↓
40	445,500	1,109,000	1,518,500	
41	130,000	130,000	130,000	
	↓	↓	↓	↓
50	130,000	130,000	130,000	1,919,000

^{1/} From Tables X-1A, X-1B, and X-1C

^{2/} Based on Unit Energy Value of 34.0 mills/kWh and
Average Annual Energy of 56.44 MkwH

TABLE XI - 1B
COST AND BENEFIT STREAMS
CONVENTIONAL ALTERNATIVE

YEAR	COST STREAM ^{1/}			BENEFIT STREAM ^{2/}
	DOE Loan	PL-984	Con- ventional	
1	\$1,403,000	\$1,245,000	\$1,717,000	\$1,873,000
	↓	↓	↓	↓
30	1,403,000			
31	492,500			
	↓	↓	↓	↓
40	492,500	1,245,000	1,717,000	
41	130,000	130,000	130,000	
	↓	↓	↓	↓
50	130,000	130,000	130,000	1,873,000

^{1/} From Tables X-1A, X-1B, and X-1C

^{2/} Based on Unit Energy Value of 34.0 mills/kWh and
Average Annual Energy of 55.09 M kWh

TABLE XI - 2A
COST AND BENEFIT SUMMARY
APRON MOUNTED ALTERNATIVE

	<u>Discount Rate</u>	
	6%	8%
<u>DOE Loan Option</u>		
Present Worth Benefits	\$30,247,000	\$23,475,000
Present Worth Costs	<u>17,808,000</u>	<u>14,359,000</u>
Net Present Value	\$12,439,000	\$ 9,116,000
Benefit Cost Ratio	1.70	1.63
<u>PL-984 Loan Option</u>		
Present Worth Benefits	\$30,247,000	\$23,475,000
Present Worth Costs	<u>16,779,000</u>	<u>13,265,000</u>
Net Present Value	\$13,468,000	\$10,210,000
Benefit Cost Ratio	1.80	1.77
<u>Conventional Loan Option</u>		
Present Worth Benefits	\$30,247,000	\$23,475,000
Present Worth Costs	<u>22,941,000</u>	<u>18,148,000</u>
Net Present Value	\$ 7,306,000	\$ 5,327,000
Benefit Cost Ratio	1.32	1.29

TABLE XI - 2B
COST AND BENEFIT SUMMARY
CONVENTIONAL ALTERNATIVE

	<u>Discount Rate</u>	
	6%	8%
<u>DOE Loan Option</u>		
Present Worth Benefits	\$29,522,000	\$22,912,000
Present Worth Costs	<u>20,036,000</u>	<u>16,164,000</u>
Net Present Value	\$ 9,486,000	\$ 6,748,000
Benefit Cost Ratio	1.47	1.42
<u>PL-984 Loan Option</u>		
Present Worth Benefits	\$29,522,000	\$22,912,000
Present Worth Costs	<u>18,825,000</u>	<u>14,887,000</u>
Net Present Value	\$10,697,000	\$ 8,025,000
Benefit Cost Ratio	1.57	1.54
<u>Conventional Loan Option</u>		
Present Worth Benefits	\$29,522,000	\$22,912,000
Present Worth Costs	<u>25,927,000</u>	<u>20,515,000</u>
Net Present Value	\$ 3,595,000	\$ 2,397,000
Benefit Cost Ratio	1.14	1.12

XII - ENVIRONMENTAL, SAFETY AND
SOCIO-INSTITUTIONAL ASPECTS

XII. ENVIRONMENTAL, SAFETY AND SOCIO-INSTITUTIONAL ASPECTS

A. GENERAL

This chapter presents an initial assessment of the environmental safety and socio-institutional aspects of the project. Described below, these impacts are expected to be minor.

B. ENVIRONMENTAL IMPACT

Broadwater Dam is located on the main stem of the Missouri River above the point where it becomes a broad river valley. At the dam site, the valley is narrow, with abrupt rocky hills on both sides.

The vegetation in the vicinity of the dam is primarily perennial grasses with only a few trees located along the banks of the river. The land is not arable and is not currently utilized for any commercial activity.

The species of fauna present at the Broadwater site include several families of rodents common to grasslands and rocky areas, such as rabbits, gophers, ground squirrels and field mice, various birds, including some game species, and various larger mammals. Aquatic life includes several species of fish with major populations of both brown and rainbow trout.

Use of the Broadwater site by local residents is limited. The reservoir behind Broadwater Dam is not a recrea-

tional reservoir. The use of the site is largely limited to fishing. A small picnic area just downstream of the left abutment is also used occasionally.

The construction and operation of a hydroelectric power plant at the Broadwater site is not expected to have any significant effect on the local environment. Since no modification of the existing flow patterns is anticipated, operation of the plant will not have any effect on the downstream environment.

No pollutants would be released into the downstream reaches by this project. The only probable effect of the facility on water quality is turbidity from construction-related activities. Care would be taken to minimize this effect and the released silt is likely to be insignificant in comparison to the silt load already carried by the river.

The impact on the regional air quality from the project should be limited to dust from the construction activities, some construction vehicle emissions and minor amounts of ozone released during operation of the plant. However, as the operation of the Broadwater Power Plant would reduce the demands for power from other power-producing facilities, such as coal-fired power plants, the net effect on air quality for the state of Montana should be beneficial.

Noise attributable to construction of the plant may cause a reduction in bird and mammal activity in the immediate vicinity. However, as the noise levels would be low when the plant is in normal operation, any effects are expected to be temporary.

The power plant, for either configuration, would require a concrete structure approximately 40 feet wide by 100 feet long by 40 feet high. However, because the building will be an adjunct to the existing dam, the addition of the building would cause little additional visual impact.

The transmission line away from the site would have some visual impact. The line, which would follow the existing road alignment down the left bank, would likely consist of single-pole structures spaced about 100 yards center to center.

The existing picnic area on the left abutment would be removed as a part of either project configuration. The switchyard is projected to occupy this area. However, a new picnic area would be constructed at a site further downstream.

C. SAFETY ASPECTS

No major safety hazards are expected as a result of power plant operations. The plant will be fully enclosed, so there will be no electric shock hazard to casual site visitors. No moving parts of the plant will be exposed. No changes will be made in the releases through Broadwater Dam, so there would be no changes in the safety of fishermen and other site visitors.

D. SOCIO-INSTITUTIONAL IMPACT

Construction and operation of a power plant at the Broadwater site should have a slightly beneficial impact on the regional and national economy. The power cost will be less than that of most other options for future power that

suppliers within Montana are considering. The Broadwater Power Plant thus will help hold down the cost of power for all consumers. As the construction work on the plant will be done by a private contractor, the impact on the local job market will also be beneficial. A successful power plant at Broadwater is likely to spark greater interest in construction of hydroelectric plants at similar sites throughout the region. Future construction projects of this type will directly benefit the local construction economy, and indirectly benefit the regional economy by helping to hold down power rates.

XIII - CONCLUSIONS AND RECOMMENDATIONS

XIII. CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL

This chapter presents both the specific and general study conclusions. Recommendations are made for further action to implement the project and a proposed project development plan is presented.

B. CONCLUSIONS

From the data, analyses and discussions developed in the preceding chapters, the following specific conclusions can be reached:

1. It is both technically and economically feasible to develop hydroelectric power at Broadwater Dam.
2. Both the apron-mounted and conventional configurations are feasible, but the apron-mounted alternative is clearly the more economically attractive development.
3. The USBR PL-984 loan, the DOE loan, and the issuance of tax-exempt bonds are equally desirable methods of funding from a financial viewpoint. However, a PL-984 loan may result in substantial time delays and funds may not be readily available for the DOE loan.

On a broader scale, it can be concluded that the study has demonstrated the technical and economic feasibility of the overall concept of constructing a power plant directly over an

existing ogee crest dam with little or no resulting impediment to the passage of flood flows. It is thought that this concept may have wide applicability to many other existing ogee crest dams throughout the United States and other countries.

C. RECOMMENDATIONS

It is recommended that development of hydroelectric power at Broadwater Dam should proceed as early as possible on the apron-mounted configuration. To facilitate this general recommendation, the following initial activities should be undertaken:

1. All sources of funding should be explored and more deeply evaluated. At this time, it is recommended that the issuance of bonds be pursued with the most diligence as bonds are a more practical method of funding. The bonds would be either taxable or tax exempt, depending on the power purchaser.
2. Negotiations should be initiated in the near future with the potential power purchasers; Montana Power Company and the Vigilante Electric Cooperative.
3. An application for a license to develop hydroelectric power at Broadwater Dam should be made to the Federal Energy Regulatory Commission. The DOE has indicated that a program to provide low interest loans for FERC license applications and other preliminary project developments will be activated in late summer or early fall of 1979.

To illustrate these recommendations and to indicate the necessary complete action to bring power on line at Broadwater, a Project Development Schedule is included as Figure XIII-1. This schedule assumes initiation of further activities in October, 1979. The timetable shown for the PL-984 loan application and approval has been informally discussed with USBR personnel from the Billings office.

FIGURE
XIII-1
PROJECT DEVELOPMENT PLAN

APPENDIX A - MODEL STUDY

POTENTIAL HYDROELECTRIC POWER DEVELOPMENT INVESTIGATIONS FOR VERTICAL TURBINE-SPILLWAY COMBINE, BROADWATER DAM

HYDRAULIC MODEL STUDIES
for
TUDOR ENGINEERING CO.

by
Dr. A.B. Rudavsky
and
Wei-Yih Chow
February 1979

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PREFACE

Model investigations to hydraulically assess and experimentally develop the vertical turbine-spillway combine structure at Broadwater Dam were requested by the Tudor Engineering Company of San Francisco, to be performed by Hydro Research Science (HRS), Santa Clara, California.

The extent of the model study, its execution, and associated administrative procedures were discussed in terms of a two-dimensional system which would model one spillway bay of the Broadwater Dam and the vertical turbine-spillway combine structure, using a scale of 1:24, model to prototype. The testing program included two sets of tests, the first set of tests used a wide range of headwater-tailwater relationships to assess the broad spectrum of flow conditions used to bracket the operational scope of the proposed structure. This test series provided useful preliminary data for engineering planning and synthesis of the parameters which were investigated. The second set of tests incorporated the surveyed and verified tailwater rating curve and some changes in the basic geometric layout based on the preliminary testing program. This included a larger draft tube opening and recommended HRS modifications.

The project was divided into three stages: Stage 1 - construction of the model, Stage 2 - hydraulic testing of the model and experimental development of modifications, and Stage 3 - report writing. The first stage was completed in December 1978, the second phase was concluded in February, 1979, and the third phase was finished in March, 1979.

During the course of the model construction and model investigations, the model was visited by Messrs. Dave Willer, Gordon Little, Lemma Wendim-Agegnehu and Don Guild from Tudor Engineering Company; Mr. Rick Bondy from Montana Dept. of Natural Resources and Conservation; Dr. M. J. McLatchy, U.S. Department of Energy; Robert Pate, EG&G Idaho, Inc.; and G. R. Skopecek, Jr., Trident Engineering Company.

These gentlemen visited the model to discuss the testing program, to develop revisions and plans, and to correlate tests results with the engineering work currently performed by Tudor Engineering Company.

The layout, construction, modifications, and subsequent model investigations were conducted by personnel of Hydro Research Science, Santa Clara, California, under direct supervision of Dr. A. B. Rudavsky, with special assistance by Wei-Yih Chow.

SUMMARY

Model investigations for the hydraulic assessment and the experimental modifications of the Vertical Turbine-Spillway Combine Structure at Broadwater Dam were performed for the Tudor Engineering Company, by Hydro Research Science (HRS), Santa Clara, California. The model investigations were conducted to verify the hydraulic performances of the proposed design, to observe the complex flow conditions, and to develop the necessary modifications to alleviate any undesirable flow conditions revealed by the model study.

The model complex consisted of three main parts: The model of the structures, auxiliary appurtenances, and instrumentation.

The test program was divided into three main phases: Phase I, Base Test Studies; Phase II, Developmental Studies; Phase III, Verification Test Studies. In Phase I, tests of the proposed design under four different operational modes were investigated to evaluate the performances of the structure. Modifications were introduced in Phase II to correct the undesirable flow conditions. These recommended modifications were subjected to a rigorous examination in Phase III by again going through all operational modes and flow conditions. Satisfactory flow conditions were observed in the structure.

The testing program is summarized for quick reference in Table 1. All tests were conducted at the Hydro Research Science laboratory in Santa Clara, California.

PART I: INTRODUCTION

General

1. This report describes the construction, test sequences and test results of the hydraulic model studies of the Broadwater Dam Vertical Turbine-Spillway Combine Structure for Tudor Engineering Company. The model investigations were performed to verify the hydraulic performance of the proposed turbine-spillway design, to develop any necessary modification of the design, and to alleviate any unacceptable flow conditions revealed by the model study.
2. This report consists of four major parts:
 - I: Introduction
 - II: The Model
 - III: Description of Tests and Results
 - IV: Illustrative Material
3. General information about the Broadwater Dam Vertical Turbine-Spillway Combine Structure was contained in the following:
 - a. Drawings furnished by Department of Natural Resources, state of Montana;
 - b. A sequence of sketches and drawings prepared by Tudor Engineering Company; and
 - c. Communication regarding the design data and general information of the structure.

Project Description

4. The general layout of Broadwater Dam is shown in Plate 1. It is located on the Missouri River about seven miles southwest of the town of Toston in Broadwater County in the state of Montana on the Missouri River. The spillway section is an ogee concrete structure rising 24 ft from its base to its crest (El. 3941.6 ft). The normal operating head water surface elevation will be constant at 3952.6 ft with a maximum of 3957.0 ft during a 10,000 year flood. The tailwater elevation varied from El. 3927.1 ft to 3953.0 ft and was established using a rating curve supplied by Tudor Engineering Company.

System Description

5. The proposed modification to the dam structure consists of the addition of four to six power bays. Each bay would have a vertical shaft, low head turbine and generator unit, a movable gate to facilitate spillway operation, and a draft tube to allow the water to exit the power bay after passing the turbine vanes. Each power bay is 24 ft wide with a 3 ft thick wall separating each bay. The layout of one power bay includes two piers 3 ft thick located along the centerline of the power bay, one pier immediately upstream of the draft tube entrance, and the second pier immediately downstream of the draft tube entrance. Two gates located 15 ft downstream of the centerline of the turbine shaft were used to confine water during power generation. The gates were 10.5 ft wide, spanning the channel on either side of the pier downstream of the draft tube entrance. The draft tube entrance diameter was 10.78 ft at elevation 3929.4 ft and narrowed to a diameter of 9.2 ft in a vertical distance of 4.66 ft. The draft tube below the turbine vanes exits through a transition section from a single vertical circular shape to a double rectangular shape with a horizontal orientation before exiting the structure. Inside the horizontal section there was a gate used to block flow through the tube during operation as a spillway.

Need for Model Investigation

6. Although the design of the addition of the Vertical Turbine-Spillway Combine Structure to Broadwater Dam is in accordance with standard hydraulic practices, the withdrawal patterns through the draft tube and the projected hydraulic conditions in the area downstream of the structure are not susceptible to theoretical analysis. A number of uncertainties inherent in solely analytical determinations must be confirmed by model studies if reliable predictions of the suitability of individual designs for the various elements are to be made with confidence. The main elements of concern were: (a) the flow conditions and withdrawal patterns around the turbine entrance when generating power; (b) flow conditions through the power bay when operating as a regular spillway bay; and (c) flow conditions in the area downstream of the structure during flood conditions.

PART II: THE MODEL

Model Setup

7. The sectional model of the Vertical Turbine-Spillway Combine addition to Broadwater Dam was constructed to an undistorted linear scale ratio, model to prototype, of 1:24. The model was built to be flexible enough to make the components readily exchangeable if the need arose for major revisions to the model structure. The model consisted of four main parts:

- a. The experimental basin
- b. The model proper of the structure
- c. The auxiliary appurtenances
- d. Instrumentation

Overall views of the model with auxiliary equipment and instrumentation during construction and after completion are shown in photographs 1, 2, and 3.

Model Description

8. The experimental basin encompassed an area of approximately 4 ft by 24 ft (photograph 1). The model basin was contained within a parallel-wall enclosure, with the inner enclosed area simulating a significant portion of the reservoir around the modeled section of the dam. The elevation in the model basin could be set at predetermined desired levels.
9. The model proper of the structure only simulated one power bay. Since the power bay structure is symmetrical about the centerline, the model was constructed in basically a mirror image. The model consisted of the significant approach area to the structure (the experimental basin), the dam crest, the draft tube entrance, the diffuser for the draft tube, and the proposed piers and gates within the power bay.
10. All key components were made of acrylic plastic to enable the experimenter to observe the flow pattern throughout the system. Only the nonessential parts in which transparency was not important were made of wood. The actual model components were augmented by

auxiliary equipment: a sump to store water, centrifugal pumps to circulate the water through the model, and a system of discharge valves and butterfly valves to regulate the flow to simulate the inflow conditions.

11. The major metering devices used in the model to measure elevations and velocities included manually operated point gages, current velocity meters, dye meters, and orifice meters associated with manometers to help determine the discharges. These instruments and their uses are briefly described in subsequent paragraphs.
12. Higher velocities were measured by a pygmy-type current meter. Subsurface current patterns were determined by means of dye introduced into the model at the desired depths. The dye meters employed in observing the flow pattern consisted of probes which could be immersed in the model to any desired depth and through which the dye was directed from the source of the probe.

Model Laws

13. The similitude relations between the model and the prototype for this type of model are based on the Froude Law. The resulting mathematical relationships between the basic hydraulic quantities of the model and the prototype are summarized in the following table:

<u>Dimension</u>	<u>Ratio of Model to Prototype</u>	<u>Scale Relationships</u>
Length	$L_r = \frac{L_m}{L_p}$	1:24
Area	$A_r = (L_r)^2$	1:576
Time	$T_r = (L_r)^{1/2}$	1:4.90
Velocity	$V_r = (L_r)^{1/2}$	1:4.90
Discharge	$Q_r = (L_r)^{5/2}$	1:2821.8
Roughness	$n_r = (L_r)^{1/6}$	1:1.7

The above scale relationships will be used to transfer quantitatively the discharge, depth of flow, and the velocity of flow from the model to the prototype.

14. In the report, (p) indicates prototype values, (m) applies to model values, and subscript (r) signifies the ratio of model to prototype. Unless otherwise designated or self-evident, the quantities given in this report refer to the prototype. Model data has been transferred to prototype equivalences by the scale relationships listed above.

Interpretation of Model Results

15. Similarity between the model and the prototype was obtained in accordance with the Froude Law, which assumes gravity as the dominant force. Since complete dynamic similitude and accurate reproduction of some properties of the prototype materials are not possible, some limitations must be imposed on the model results.
16. Measurements of discharge, water elevations, and velocities in the model can be transferred quantitatively to prototype equivalences without any reservations.
17. Since it is not feasible to reproduce the prototype roughness of steel or concrete surfaces in a plywood or acrylic plastic surfaced model of this scale, a slight decrease in conveyance efficiency of the model can result. A slight variation from the theoretical model roughness will have almost no effect on the performance of the flow in the model power intake structure or in the turbine throat and draft tube.
18. This two-dimensional model simulated only part of the whole system, therefore, it is of limited value for prediction and experimental analysis of the hydraulic interaction between adjacent regular spillway bay or power bay, especially for the flood mode conditions. These points will be discussed later in the report.

19. Data on scour are to be considered as qualitatively indicative since it has not yet been found practicable to reproduce quantitatively, in a model, the resistance to erosion of a prototype which has cohesive or rock bed material. Purely granular materials were used in the model and the erosion tests gave only comparative, rather than absolute, results.
20. Air entrainment cannot be modeled by the Froude Laws alone. Air entrainment is a function of the flow velocity, depth and distance traveled. At present, there is no acceptable method to correlate air entrainment between the model and prototype.
21. The segments of the draft tube and the motion of turbine were not simulated although vanes were included. Therefore, neither the prototype turbine nor a model scale relationship for the turbine was established. Instead, the properly scaled flow quantities were discharged through the draft tube to simulate the prototype discharges. Therefore, the model should be considered as representative only within the confines of the draft tube section. Obviously, well-distributed flow patterns observed in the modeled approach segments to the draft tube should assure flawless turbine performance so far as inflow conditions are concerned.

PART III: TESTS AND RESULTS

Scope of the Experimental Program

22. The general purpose of the model study was to determine the soundness of the hydraulic aspects of the proposed design and, if necessary, modify the design to improve any undesirable flow conditions revealed by the model tests. Tests were conducted to analyze hydraulic conditions in the following areas of concern: (a) discharge-head rating curve of the spillway; (b) the area above the draft tube entrance during the generation and combined operation modes; (c) the area immediately downstream of the model structure during the generation, combined operation and flood modes; and (d) flow through the structure during the flood mode. Close liaison was maintained with the client to ensure that the model investigations were practical in terms of design and construction and representative of site and operating conditions.
23. The experimental program was divided into four different modes according to the operation:
 - a. Pure generation mode:

This condition exists when the river flow, after irrigation diversion, is less than 5920 cfs. Depending on the magnitude of the available flow, one to four units would be generating power while all the spillway bays remained closed.
 - b. Combined operation mode:

When the range of flow at the site is between 5930 and 31400 cfs, all four units would be generating power and depending on the flow magnitude, one to nine spillway bays may be opened to bypass excess flow.
 - c. Controlled flood mode:

When the flow is between 32500 and 42800 cfs, generating power is terminated and the power bays are successively converted to spillways as needed.

d. Uncontrolled flood mode (surcharge mode):

In the event of rare floods (100 to 10,000-year floods) the surcharge space, from top of the embankment dam (El. 3957.6 ft) to the normal operating level (el. 3952.6 ft), will be utilized to facilitate their safe passage. Of course, all the gates will be fully open.

Table 4 shows the experimental program.

24. Base test studies were conducted first to assess the flow patterns in the power bay and downstream of the structure for the pure generation mode and the combined operation mode conditions. The preliminary investigations of the flood mode conditions were also conducted. The second phase, developmental studies, consisted of determinations of the most effective shape of the spillway section in front of the draft tube, the location of tailgate, and the head-discharge rating curve of the spillway. The third phase of the study was verification tests. In this phase, the recommended modifications were optimized and verified through model tests.
25. The parameter specifications for the selected conditions to be tested were not available in their final form until late January, 1979. Therefore, two series of experimental tests were conducted to cover all possible conditions which could occur in the prototype. The first series of experimental programs (based on preliminary estimated parameters) is shown in Table 3 and the second one (based on best acquired information) is shown in Table 4.
26. In the second series of tests, the revised draft tube and the updated hydrological data were used. Due to time limitations of the project, and small variation in discharges, not all 22 cases were tested, but a sufficient number of selected case tests were performed to have enough data to make a reliable judgment.

Test Procedures

27. The test program consisted of two main operating configurations. The first configuration included the pure generation and combined operation modes with the tailgate closed and the flow going through the draft tube. The second configuration simulated the controlled

and uncontrolled flood modes with the tailgate open and the structure operating as a spillway. For the pure generation and combined operation modes, the test procedure was to reproduce the desired discharge through the draft tube and establish the desired headwater and tailwater elevations. Once the flow conditions were established, the following conditions were carefully monitored: The flow patterns in the power bay and downstream of the model structure were observed and recorded; any tendencies for vortices to form or any scour tendencies along the bottom downstream of the structure were also investigated. For the controlled and uncontrolled flood modes, the desired discharge and headwater elevations were set. Then the corresponding tailwater elevations were set using adjustable weirs. The flow patterns, water surface profiles, and general assessment of flow behavior upstream, over the structure and downstream of the structure were observed and analyzed and their suitability for the proposed "turbine spillway design" judged.

Data Presentation

28. The presentation of test data in this report does not follow the chronology of the experimental program. Instead, each of the experimental phases of the study is considered in turn. All tests conducted under the revised testing program are described with the appropriate phase.

Phase I: Base Test Studies

29. Base tests were conducted to establish a base for comparison and to indicate the extent and direction of the model study. In this particular study, there were two sets of base data tests. The first set of tests used a wide range of headwater-tailwater relationships to assess the broad spectrum of flow conditions used to bracket the operational scope of the proposed structure. This test series provided useful preliminary data for engineering planning and synthesis of the parameters which were investigated (Table 3). The second set of tests incorporated the surveyed and verified tailwater rating curve and some changes in the basic geometric layout based on the preliminary testing program (Table 4). This included a larger draft tube opening and the HRS modifications that had been developed to that point.

30. The first set of base test studies were divided into three modes of operation: 1) pure generation; 2) combined operation; and 3) flood mode. The first two operating modes required the tailgate to be closed and the discharge to flow through the structure via the draft tube. When operating the model in the flood mode the tailgate was removed and the draft tube gate was closed.
31. Base test model observations for the generation and combined operation modes were directed at the area above the turbine entrance and the area downstream of the structure. Model observations using three representative discharges and corresponding headwater and tailwater elevations for the first set of base studies, with the model operating in the generation mode, indicated that the area above the throat of the turbine exhibited some undesirable flow characteristics including eddies and dimples on the surface. Observation of the flow pattern in this area revealed two large eddies, one on either side of the channel. The eddy depressions moved away from the downstream side of the pier upstream of the turbine entrance (Plate 5). The blunt nose of the pier appeared to contribute to the formation of these eddies. The flow pattern over the ogee section and above the turbine intake, displayed eddy patterns and nonuniform approach conditions. However, the pattern could be easily changed through modeling strategic modifications of the approach geometry. The observations of the downstream flow conditions showed typical outflow pattern from a diffuser structure under submerged conditions (Plates 6, 7, 8 and 9). The flow conditions were judged satisfactory and for final design, velocity measurements should be taken to assess the need, or degree of protection downstream of the structure.
32. Observations of the model during the base tests in the flood mode ranged from very low to very high tailwater conditions with the lower tailwater conditions definitely outside the range of Broadwater Dam tailwater conditions. This was done to properly assess the gamut of flow conditions and to judge the sensitivity of these conditions to the changes in tailwater. Discussion of the first base tests of the model in the flood mode has a broad base and will be included in a generalized assessment at the end of the report.

33. The tailwater rating curve which was obtained using the surveyed data of the prototype placed all flow conditions for Broadwater Dam into a submerged jump condition. This condition will be discussed in subsequent paragraph.
34. For the controlled flood mode, the model was observed with a constant discharge of 3100 cfs and a headwater elevation of 3952.6 ft with two tailwater elevations of 3941.8 ft and 3944.3 ft. Under these conditions, the hydraulic jump was contained within the structure with a high velocity jet downstream of the jump that remained about 10 ft below the surface. When tailwater was set at 3941.8 ft, the maximum jet velocity was 10.65 ft/sec 30 ft downstream of the structure. When the tailwater was raised to El. 3944.3 ft, the maximum jet velocity was 11.14 ft/sec 10 ft downstream of the structure (Plates No. 10 and 11).
35. Velocity measurements and the scour pattern in the erodible material were used to assess the energy dissipation problem downstream of the spillway structure. The overall assessment indicates that for final design the geologic structure in the downstream riverbed, the existing energy dissipators, and flow conditions under different recurrence intervals must be evaluated and the need or the design of an energy dissipator decided upon (Photograph 5). Also, at that stage of the design, the three dimensional aspects of the downstream flow conditions should be considered.
36. During the two-test series of base studies, the first series bracketed the broad range of problems that could be encountered for hydraulic conditions for Broadwater Dam modifications; the second series addressed itself to preliminary design considerations within the projected operating range of Broadwater's modifications. Findings of the first series lead to scoping of the total program and to some changes for the second test series. It also provided the needed input into the overall assessment which is given at the end of the report.

37. The second test series identified the problematic areas for the defined range of the Broadwater Dam and gave guidance for improvements to be experimentally explored. The problematic areas of concern were:

1) the establishment of a discharge rating curve; 2) the shaping of the downstream dam face; 3) the shape of the piers; 4) the location of the tailgate; and 5) assessment of energy dissipation problems.

Phase II: Developmental Studies

38. The developmental test series was based on indications developed and conclusions reached during the first series of base tests of the proposed design. The plan concentrated on the interrelated flow conditions over the ogee section and into the turbine during the generation mode.

39. The data needed and modifications of practical value for generation mode can be grouped into the following broad classifications: a) establishment of discharge rating curve over the existing ogee section; b) modifications to the power bay to improve approach conditions to the turbine; and c) assessment and optimization of the shapes and location of the auxiliary structures inside the power bay and the tailgate.

40. Tests were conducted through using the flood mode configuration range of flows to establish the discharge rating curve for the existing ogee section. The model test results were in close agreement with computational results after checking the existing ogee section profile to presently accepted standardized designs. The head-discharge relationship obtained from the model studies is shown in Table 2.

41. Model studies were conducted to establish the most efficient transition connecting the downstream face of the ogee section with the floor of the power bay. The best fit curve was experimentally determined and is shown in Plate 3 and Photograph 4.

42. Tests to compare the efficiency of a streamlined pier nose and a semicircular nose were conducted on the pier immediately upstream of the turbine entrance. The separation of flow, and the formation of eddies and dimples around the downstream edge of the semicircular nose pier was eliminated. However, occasional eddies moved off the downstream edge of the pier. When operating the model as a spillway, the "streamlined" pier shape changed the flow patterns around the pier by eliminating the riding-up effect on the pier. It also directed the inflow patterns into the turbine shaft under the controlled flood mode (Plate 5 and Photograph 6).
43. A series of tests was conducted to optimize the location of the tailgate by moving the tailgate further upstream from its original location, 15 ft downstream of the centerline of the turbine shaft. During the investigation, the tailgate was moved to a position 7.5 ft downstream of the centerline of the pier. The model was observed in the generation mode. The flow patterns indicated that the eddies that form on either side of the structure became more intense. It appears as though the original position of the gates was satisfactory.
44. Once a streamlined approach and inflow conditions into the turbine were obtained, the structure was tested beyond the intended withdrawal rate to assess the limits when vortexing would be initiated. Such a technique was used due to the unstable characteristics of the vortex phenomena and to assess the degree of conservatism in the design. The experiments were conducted using a range of discharges from 1108 cfs to 1600 cfs.
45. As the model studies proceeded with the first series of tests, Tudor Engineering Company was conducting prototype tailwater investigations. Their prototype survey produced a revised tailwater rating curve and a new draft tube opening dimension. From this revised data, HRS began a new series of tests using a revised draft tube throat opening of 9.2 ft (original dimension was 8.0 ft) and a revised tailwater rating curve. The revised testing program is shown in Table 4.

46. In the preliminary studies, tests were conducted to establish an energy dissipation system to be used during controlled flood mode operation that would improve flow conditions and possibly eliminate any tendency to scour the channel bed. The tests were limited to overflow weirs located in the area between the downstream pier and the wall of the structure. The results indicated that a weir of 4 ft to 6 ft high may improve the flow conditions. The second series of tests, because of high tailwater conditions, no apparent improvement in flow conditions resulted with these weirs. The results of these tests are shown on Plate 12.
47. Model observation using the revised testing program indicated that the flows above 1250 cfs, required the addition of some sort of vortex spoiler. A single guide beam was placed on each side of the upstream pier with the leading edge kept at El. 3952.6 ft and inclined at various angles. An angle of 45° was found to be the optimum for eliminating the vortex formations (Photograph 7). A series of tests were conducted on the configurations in the generation and combined operation modes. Observation indicated that the beams directed the flow into the draft tube effectively and the small roller was of sufficient magnitude to prevent the formation of the eddy pattern in the area above the draft tube entrance (Plate 6, 7, 8 and Photographs 7-11). With the vortex spoiler in place, a maximum discharge of 1800 cfs can be discharged through the turbine without vortices forming. However, due to the limitation of modeling, certain safety factors should be imposed on the results.

Phase III: Verification Tests

48. Having evolved the final recommended design in the previous test phase, and on the basis of construction and economic considerations, the recommended design was modeled and subjected to a series of tests including three different modes of operation. The details of the recommended design are shown on Plate 4.
49. Since the flow characteristics had been defined in the previous phase of study, the main objective of this test series was to verify the effectiveness of the recommended modifications to the proposed design. The test results showed that the recommended modifications were hydraulically effective and the hydraulic performances for different modes of operation were satisfactory.

50. During the conditions of flood mode operation, one point of concern was the clearance between the water surface profile and the lowest point of the anti-vortex guide beams. As tailwater was progressively raised, and the corresponding discharge increased, the hydraulic jump moved up into the power bay (Photographs 12, 13, and 14) and the distance between the beams and the water surface decreased until the minimum distance was reached for the 10,000-year flood conditions. Under these conditions the minimum clearance was 3.4 ft. Plates 10 and 11 shows the water surface profile and the beam.

Discussion of Results

51. In general, the proposed design of the structure was satisfactory, only minor modifications need to be done where the pure turbine generation and combined operation modes are concerned.
52. The flow patterns in the power bay during the pure generation mode and combined operation modes are satisfactory for the recommended design (Photographs 7-11).
53. The bottom of the anti-vortex beams is at elevation 3951.2 ft. It is suggested that the turbine be operated only when the water surface is above 3950.0 ft to keep the generation unit safe.
54. The streamlined pier reduced the tendency of formation of eddies and vortices.
55. The tailgate position is important to the withdrawal pattern through the draft tube. There is a definite withdrawal area above the entrance of the draft tube which has been defined by this model study (Photograph 7).
56. The section of the spillway shape in front of the draft tube is important to the flow approaching the draft tube (Photograph 4).
57. The following factors are important to the hydraulic performances of the structure:
- a. The hydrological data regarding flood discharge and tailwater information, and hydraulic condition of the approach to the dam are basic design information for the structure. The model tests were conducted based on this information. Therefore, sufficient and updated data will help properly design the structure;

- b. The choice of the size and type of turbine is important to the hydraulic structural design; and
 - c. One important factor affecting the hydraulic performance of the structure is the head difference between upstream water surface and tailwater elevations, because the discharge through the draft tube is partly a function of the head difference.
58. Since this model only simulated one power bay, it only reflected two-dimensional characteristics of the phenomena. Some limitations must be imposed on the model test results, also the results regarding the three-dimensional aspects have to be interpreted carefully.
59. One important three-dimensional hydraulic phenomena in this model was the hydraulic condition immediately downstream of the structure.
- a. Conditions of pure generation and combined operation mode:

The flow through the draft tube discharged downstream of the structure into a dead water area. Because of the dynamic behavior of the jet, it oscillated and could have a tendency to cause scour on the river bottom. (The amount of scour which will occur in the prototype will depend on the insitu bed materials.)
 - b. Conditions of flood mode:

During the flood condition, the power bay will serve as regular spillway bay. Flow discharges over the spillway and a hydraulic jump will occur in the power bay and due to instability of the flow, the flow may cause scour at the toe of the dam (Photograph 5). The flow patterns for different conditions are shown in Plates 10 and 11.

Conclusions

60. The results of the model tests indicate that the conceptual design for changing the spillway into a power bay operating unit for Broadwater Dam is favorable and feasible from a hydraulic point of view and easily executed with minimal changes to the system. The preliminary studies coupled with suggested modifications, indicate satisfactory flow conditions under all modes of operation.

61. The scope of the experimental study involved the assessment and hydraulic solution to two key flow conditions: a) flow over the crest, withdrawal of water through the turbine, subsequent discharge downstream during power operation mode, and b) flow over the modified spillway section under flood mode. Both flow conditions, after the introduction of modifications, were found satisfactory and did not pose any insurmountable hydraulic problems in the final design.
62. Flow conditions under the generating mode displayed uniform overflow over the ogee section and streamlined approach motion to the turbine throat. No vortexing or adverse eddying pattern was present. These excellent approach conditions had been created by streamlining the auxiliary structures in the power bay, optimizing the location of the tailgate and providing a crossbeam which acted as a guide vane and assured prevention of vortexing at a considerable margin of safety. The flow plume outflow pattern beyond the draft tube displayed typical effluent emergence under high tailwater conditions.
63. Flow conditions under the flood mode displayed a typical submerged hydraulic jump under high tailwater conditions at an abrupt drop. Such flow conditions were characterized by two large rollers above and below the drop. The velocity distribution under such characteristics in the downstream region displayed higher velocities at the surface than on the bottom.
64. It is recommended that when the feasibility stage of this project progresses to the design stage, the following aspects be experimentally investigated and optimized for final design: a) under operation mode the velocity in the draft tube exit area be evaluated to assess the erosional potential of geologic formation and bottom quality of the riverbed; b) optimize the location of the guide beam and its configuration from structural construction and maintenance point of view; c) under flood mode, study further and analyze the submerged hydraulic jump behavior with respect to possible adverse pressure fluctuations, energy dissipation measures and stabilization of the phenomena; and d) special shaping or protective cover arrangement for turbine intake should be investigated and seriously

discussed with the turbine manufacturer. It is standard HRS practice that in any dynamic condition pressure fluctuations are measured in the model. This technique is expedient and very valuable to the designer and structural engineer.

65. Also, for both operational and flood modes the three-dimensional aspects of the merging flows should be investigated during design stage. For these studies a two-dimensional setup as used in present studies can be utilized but a two or three bay configurations should be modeled. Such an arrangement does not involve great effort on the part of the laboratory.

General Observations Applicable to Other Locations

66. In consideration of the large amount of experience of Tudor Engineering Company in the modification of small dams into hydroelectric developments, and the hydraulic expertise in dam design and energy dissipation of Hydro Research Science, a general assessment and hydraulic background is provided here for the conceptual technique of transforming spillway bays into power bays. The discussion is drawn upon from the expertise and the wide range of generalized studies done under this contract.
67. There are two key flow conditions that the designer must deal with:
 - a) the operational mode where the flow is guided over the ogee section into the confined space above the turbine, to assure vortex-free uniform approach conditions to the turbine and good performance of the turbomachinery, and
 - b) the flood mode where the flow is effectively conveyed over the spillway and provided with an effective energy dissipation system.
68. The solution to flow conditions under operation modes is dependent upon geometric conditions within the structure, and at the present time, must be solved through physical modeling. A generalized study could be undertaken to standardize such a confinement. However, experienced experimenters must be employed. The preliminary generalized investigations indicate that there is great sensitivity to vortex formation due to geometric changes, opening changes or discharge and elevation changes. It appears that under certain circumstances, such as the final conditions of this study, that

some vortex inhibiting device similar to one suggested in this report may have to be employed. The suggested vortex suppresser has been used effectively by HRS and has been verified in prototype installations.

69. The solution to flow conditions under flood mode conditions presents more difficult problems since the flood flows over that type of structure display a number of different flow patterns under different tailwater conditions which differ in character. Therefore, several different solutions must be applied dependent upon the tailwater conditions. The most difficult condition to handle is at minimum tailwater which is subject to great erosional potential downstream of the structure.

TABLES AND ILLUSTRATIVE
MATERIALS

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 1 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE I: BASE TEST (original testing program)				
Base test	Spillway gate closed, no material in section to be modified.	Q = 436 T.W. 3924.3 Q = 1180 cfs T.W. 3925.4 H.W. El. 3952.6 in both cases	Flow patterns indicate that a simple curve, tangent to the end of the existing ogee section and to the floor at the edge of the draft tube pipe would be sufficient for good flow conditions.	
	Tailgate closed, ogee section filled, no other modifications.	Q = 1000 cfs H.W. 3952.6 T.W. 3937.6 Q = 1103 cfs H.W. 3952.6 T.W. 3931.0 Q = 1180 cfs H.W. 3952.6 T.W. 3925.4	Flow patterns show eddies are present on either side of the center pier but no vortices were observed to enter the draft tube. Eddies caused by separation are present around the trailing edge of the center pier. Some dead area was observed upstream of the tailgate. Modified section of ogee appears to perform quite well.	T.S. 31 Pl 5
	Tailgate open	Q = 3360 cfs H.W. 3953.0 T.W. 3937.6 Q = 3360 cfs H.W. 3953.0 T.W. 3931.0	High velocities through structure (super critical flow). Jet continues into tailwater causing scour to riverbed. Velocities taken in the jet (max.) at a distance of 30 ft from the end of the structure were 12 fps for T.W. 3920 and 16.8 fps for T.W. 3913.	T.S. 32

SYMBOLS

Q = Discharge cfs
HW = Headwater
T.W. = Tailwater

T.S. = Text section
Pl = Plate No.
Ph = Photograph No.

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 2 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE II: DRAFT TUBE ENTRANCE CONDITIONS				
Gate placement	Tailgate moved to 7.0 ft from centerline of turbine shaft.	Q = 1000 cfs T.W. 3937.6 Q = 1103 cfs T.W. 3930.6 Q = 1180 cfs T.W. 3914.6	By moving the gate upstream from its original position the flow patterns indicate that the eddies on either side of the pier become stronger with intermittent depressions showing up on the surface.	T.S. 43
Streamlined pier	Tailgate 15.0 ft downstream of centerline of turbine shaft, existing pier modified.	Q = 1103 cfs T.W. 3930.6	Flow conditions around pier shows some improvement over blunt nosed pier, weaker eddy near trailing edge, more symmetric flow pattern on surface.	
	Tailgate 15.0 ft downstream from centerline of turbine shaft. New pier installed.	Q = 1103 cfs T.W. 3931.0 H.W. 3952.6	Flow conditions appear to be improved over the previous streamlined pier, flow is nearly symmetric, very small eddies coming off trailing edge. There is still a roller near the bottom over the modified ogee section.	T.S. 42 Pl 5
Additional discharge through draft tube	Tailgate 15.0 downstream from centerline of turbine shaft, streamlined pier.	Q = 1600 cfs T.W. 3930.6 H.W. 3952.6	Flow patterns should intermittent vortices in three separate areas, from trailing edge of pier and in areas on either side of the draft tube opening.	T.S. 44
		Q = 1500 cfs T.W. 3930.6 H.W. 3952.6	The areas that had vortices with 1600 cfs discharge now have only intermittent dimples with a Q = 1500 cfs.	

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 3 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE I: REVISED BASE TEST (pure generation mode)				
	Streamlined pier. Tests, with new data were picked up at the same stage of development as were left with development of the pier. Tailgate closed.	Q = 1580 cfs H.W. 3952.6 (case A) T.W. 3927.1	Strong vortex tendencies, depressions in area above draft tube entrance.	T.S. 47 Pl 6 Ph 6
		Q = 1896 cfs H.W. 3952.6 (case A) T.W. 3927.1. (case A + 20% Q)	Deep depressions with occasional vortex reaching draft tube entrance.	T.S. 47
		Q = 1480 cfs H.W. 3952.6 (case D) T.W. 3931.0	Depressions, strong tendencies, very intermittent vortex was observed reaching to draft tube entrance.	T.S. 47
PHASE I: REVISED BASE TEST (combined operation mode)				
	Streamlined pier, tailgate closed.	Q = 1430 cfs H.W. 3952.6 T.W. 3932.4	Depressions present in area on either side of draft tube entrance. Roller above draft tube exit from end of structure. No scour was observed.	Pl 7 T.S. 47
		Q = 1250 cfs H.W. 3052.6 (case H) T.W. 3936.4	Eddies with intermittent depressions present on either side of draft tube entrance. Roller above draft tube exit. No scour.	T.S. 47 Ph 9
		Q = 1050 cfs H.W. 3952.6 (case L) T.W. 3940.4	Eddies with small intermittent depressions present on either side of draft tube entrance. Roller above draft tube exit. No scour observed.	T.S. 47 Pl 8

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 4 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE I: Revised Base Test (combined operation mode)				
	Streamlined pier, tailgate closed.	Q = 990 cfs H.W. 2952.6 T.W. 3941.6	Slow eddies, on either side of draft tube entrance, no depressions were observed. Roller above draft tube exit. No scour downstream.	T.S. 47 Pl 9
PHASE I: REVISED BASE TEST (controlled flood mode)				
	Streamlined pier, tailgate open.	Q = 3100 cfs H.W. 3952.6 (case Q) T.W. 3941.8	Super critical flow as water goes over the crest. Hydraulic jump is contained within the structure, approximately 6 ft to 7 ft downstream of centerline of turbine shaft. Velocities downstream of structure indicate the highest velocities stay near the surface about d = 10 ft (10.65 ft/sec) with velocities near the bottom between 2 and 4 ft/sec.	T.S. 34 Pl 10 Ph 12
		Q = 3100 cfs H.W. 3952.6 (case T) T.W. 3944.3	Super critical flow downstream of the crest. Hydraulic jump contained within the structure approximately 4 ft upstream of the centerline of turbine structure. Downstream velocity profile shows a high velocity jet about d = 10 ft (11.14 ft/sec). Jet appears to be pretty well diffused by the time it is 50 ft downstream of end of the structure. Velocities near bottom are about 2 to 3 ft/sec.	Pl 10 Ph 13 T.S. 34

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 5 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE I: REVISED BASE TEST (uncontrolled flood mode)				
	Streamlined pier, tailgate open.	Q = 3650 cfs H.W. 3953.6 T.W. 3945.9	Super critical flow downstream of the crest. Hydraulic jump located near leading edge of streamlined pier. Same base velocity distribution as previous test with highest velocities of $d = 10$ ft (11.67 ft/sec).	Pl 11 Ph
		Q = 5360 cfs H.W. 3957.6 T.W. 3952.0	Super critical flow downstream of the crest. Hydraulic jump located upstream of pier. Velocity profile shows highest velocity of $d = 10$ ft to $d = 20$ ft (17.5 ft/sec) with velocities near the bottom are from 2.51 to 2.72 ft/sec.	Pl 11
PHASE II: DEVELOPMENTAL TEST (flood mode)				
	4 ft weir on flood of structure, 15 ft downstream of centerline of turbine shaft.	Q = 3100 cfs H.W. 3952 T.W. 3941.8	Hydraulic jump is moved upstream to a position 12 ft upstream of centerline of turbine shaft. A second smaller jump is located 20 ft downstream of the end of the structure. Scour pit noted 25 to 30 ft downstream of end of structure about 2 to 3 ft deep.	T.S. 46 Pl 12
	6 ft weir on floor of structure, 15 ft downstream of centerline of turbine shaft.	Q = 3100 cfs H.W. 3952.6 T.W. 3941.8	Hydraulic jump is moved upstream to a position 16 ft upstream of centerline of turbine shaft. Second hydraulic jump located 20 ft downstream of end of structure. Scour pit noted in same position as previous test.	

TABLE 1: SUMMARY OF EXPERIMENTAL PROGRAM AND RESULTS (page 6 of 6)

Test Series	Geometric Conditions	Hydraulic Conditions	Summary of Experimental Findings	References
PHASE III: VERIFICATION TEST (generation mode)				
	Final design, guide beam installed.	Q = 1580 cfs T.W. 3927.1 H.W. 3952.6	The beam creates a back roller on the surface which eliminates the eddy flow pattern, and the depressions, The effect of the beam seems to be limited to very near the surface with the lower levels remaining the same as without the beam.	T.S. 52, 53, 54 Pl 6 Ph 7
		Q = 1430 cfs T.W. 3932.4 H.W. 3952.6	Same effect as previous experiment but small eddies show up downstream of beam with intermittent small depressions.	Pl 7 T.S. 52, 53, 54
		Q = 990 cfs H.W. 3952.6 T.W. 3941.6	Slow eddies on either side of pier just downstream of the guide beams.	Pl 9 Ph 8 T.S. 52, 53, 54
PHASE III: VERIFICATION TEST (flood mode)				
	Streamlined pier, tail-gate open. Guide beams installed.	Q = 5360 cfs H.W. 3957.6 T.W. 3952.0	Profile shows 3.4 ft of clearance below guide beams.	Pl 11 T.S. 50

TABLE 2: Spillway H-Q Curve

TABLE 3: ORIGINAL TEST CASES

Case #	Description	Discharge			Elevation		Head	
		1 Turbine	1 Spillway Bay	Total	Headwater Surface	Tailwater Surface	Turbine	Spillway
I 1	Pure generation mode Oper. 1 variable pitch turbine	436	0	436	3952.6	3924.3	28.3	-
2 a.	Oper. 1 fixed blade turbine	1180	0	1,180	↓	3925.4	27.2	-
b.	" 2 " " "	1162		2,324		3926.7	25.9	-
c.	" 3 " " "	1148		3,444		3927.6	25.0	-
d.	" 4 " " "	1137		4,548		3928.4	24.2	-
e.	" 5 " " "	1129		5,645		3929.0	23.6	-
f.	" 6 " " "	1115		6,690		3930.1	22.5	-
II 3 a.	Combined operation mode 6 turbines + 1 spillway bay	1103	3360	9,980	↓	3931.0	21.6	11.0
b.	" + 2 " "	1084	↓	13,224		3932.2	20.4	↓
c.	" + 3 " "	1072		16,512		3933.2	19.4	
d.	" + 4 " "	1062		19,818		3934.1	18.5	
e.	" + 5 " "	1049		23,094		3935.0	17.6	
f.	" + 6 " "	1034		26,364		3935.9	16.7	
g.	" + 7 " "	1017		29,622		3936.8	15.8	
h.	" + 8 " "	1000		32,880		3937.6	15.0	
III	Flood mode 5 turbines & 8 spillway bays + 1 power bay							
a.	Initial condition	984	3107	32,880	3952.0	3937.6	14.4	10.4
b.	Maximum discharge capacity	"	3360	35,180	3952.6	3938.2	"	11.0

TABLE 4: REVISED CASES

Case #	Description	Discharge (cfs)				Elevation (ft)		Head (ft)	
		1 Turbine	1 Spillway Bay	Total	Frequency (years)	Headwater Surface	Tailwater Surface	Turbine	Spillway
I	Pure generation mode								
1	Shutdown	<460							
a.	Oper. 1 var. pitch turbine	515-1580	closed	515-1580	never	3952.6	3925.0-3927.1	27.6-25.5	closed
b.	" 2 " " "	510-1560	↓	1020-3120	occurred	↓	3926.2-3928.8	26.4-23.8	↓
c.	" 3 " " "	510-1520		1530-4560			3927.0-3930.0	25.6-22.6	
d.	" 4 " " "	510-1480	↓	2040-5920		↓	3927.6-3931.0	25.0-21.6	↓
II	Combined operation mode								
2a.	4 turbines + 1 spillway bay	1430	2630	8350	1	3952.6	3932.4	20.2	11.0
b.	" " " 2 " "	1370	2860	11200		↓	3933.8	18.8	↓
c.	" " " 3 " "	1310	2936	14048			3935.2	17.4	
d.	" " " 4 " "	1250	2974	16897			3936.4	16.2	
e.	" " " 5 " "	1190	2997	19745			3937.5	15.1	
f.	" " " 6 " "	1140	3012	22634			3938.6	14.0	
g.	" " " 7 " "	1090	3023	25522			3939.6	13.0	
h.	" " " 8 " "	1050	3031	28451			3940.4	12.2	
i.	" " " 9 " "	1010	3038	31380	14		3941.2	11.4	
j.	0 " " 10 " "	-	3043	30428	12		3941.0	11.6	
k.	1 " " " " "	1010	"	31438	14		3941.3	11.3	
l.	2 " " 10 " "	990	"	32408	17	↓	3941.6	11.0	↓
III	Controlled flood mode								
3a.	10 spillway bays + 1 power bay		3047	33516	20	↓	3941.8	shutdown	↓
b.	" " " 2 " "		3050	36605	33		3942.7	↓	
c.	" " " 3 " "		3053	39694	53		3943.5		
d.	" " " 4 " "		3056	42782	91	↓	3944.3	↓	↓
IV	Uncontrolled flood mode								
	10 spillway bays + all	-	3534	49478	250	3953.6	3945.9	-	12.0
	power bays	-	5670	79380	10,000	3957.6	3952.0	-	16.0

EXTENT OF MODEL

PLATE 1

PROJECT LOCATION AND EXTENT OF MODEL

MODEL LAYOUT
PLAN VIEW

ARTIST'S CONCEPT
NOT TO SCALE

**GUIDE BEAM
DETAIL**

(NOT TO SCALE)

PROFILE VIEW

PLAN VIEW

H.W. EL. 3952.6
T.W. EL. 3927.1
TURBINE Q = 1580 CFS

H.W. EL. 3952.6
T.W. EL. 3927.1
TURBINE Q = 1580 CFS

H.W. EL. 3952.6
T.W. EL. 3932.4
TURBINE Q = 1430 CFS

H.W. EL. 3952.6
T.W. EL. 3932.4
TURBINE Q = 1430 CFS

FLOW PATTERNS FOR
GUIDE BEAM TESTS
Q = 1430 CFS

H.W. EL. 3952.6
T.W. EL. 3940.4
TURBINE Q = 1050 CFS

H.W. EL. 3952.6
T.W. EL. 3940.4
TURBINE Q = 1050 CFS

FLOW PATTERNS FOR
GUIDE BEAM TESTS
 $Q = 990$ CFS

FLOW PATTERNS FOR ENERGY DISSIPATOR TESTS

Photograph 1

Construction of the two-dimensional flume which housed the Broadwater Dam model.

Photograph 2

Acrylic plastic model of the ogee section and turbine draft tube in the overflow spillway of the Broadwater Dam.

Photograph 3

View of the model showing draft tube exits and pier placement.

Photograph 4

Side view of model structure showing modified section from the ogee section to the entrance of draft tube.

Photograph 5

Scour pit immediately downstream of the draft tube exit created during flood mode, $Q = 3060$ cfs, low T.W. 3930.6 ft.

Photograph 6

Generation mode condition, $Q = 1480$ cfs, T.W. 3931.0 ft. No beams in place, but note depression in water surface downstream of pier.

Photograph 7

Generation mode condition,
 $Q = 1580$ cfs, T.W. 3927.1
ft. Guide beams in place
with satisfactory hydraulic
performance.

Photograph 8

Generation mode condition,
 $Q = 990$ cfs, T.W. 3941.6
ft. Guide beam in place with
satisfactory flow conditions.

Photograph 9

Generation mode condition,
 $Q = 1250$ cfs. T.W. 3936.4 ft.
Guide beams not in place and
satisfactory flow condition.

Photograph 10

Generation Mode Condition,
 $Q = 1250$ cfs. T.W. 3936.4 ft.
with guide beams in place and
satisfactory flow conditions.

Photograph 11

Generation mode, $Q = 1250$
cfs T.W. 3936.4 ft. with guide
beams and dye injection from
behind the beam.

Photograph 12

Controlled flood mode condition,
 $Q = 3060$ cfs, T.W. 3941.8 ft.
Top view of the flow condition
in the power bay. Strong hy-
draulic jump occurred in the
bay. The clearance between
water surface and guide beams
is approximately 22.0 ft.

Photograph 13

Controlled flood mode condition,
 $Q = 3060$ cfs T.W. 3944.3 ft.
Hydraulic jump in the power bay,
which is semi-submerged. Compare
the flow condition to that of
photograph 12. The clearance
between water surface and guide
beams is approximately 14.0 ft.

Photograph 14

Uncontrolled flood mode condition,
 $Q = 3650$ cfs, T.W. 3945.9 ft.
Flow condition in the power bay.

APPENDIX B - OPERATION STUDIES

BROADWATER HYDROELECTRIC PROJECT
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

RUN # : SP-1

FEBRUARY 1, 1979

APRON-MOUNTED ALTERNATIVE

* MONTHLY POWER OPERATION STUDY *

UNIT #	RATED CAPACITY (KW)	DESIGN CAPACITY (KW)	DESIGN FLOW (CFS)	DESIGN HEAD (FT)
1	2444	2444	1491	22
2	2444	2444	1491	22
3	2444	2444	1491	22
4	2444	2444	1491	22

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (KWH)
1929	OCT	262000	4261	22.9	123	7.22	5.37
	NOV	308000	5176	22.2	1234	8.45	6.08
	DEC	229000	3724	23.3	123	6.32	4.70
	JAN	217000	3529	23.5	123	5.98	4.45
	FEB	180000	3241	23.7	123	5.48	3.68
	MAR	218000	3545	23.5	123	6.01	4.47
	APR	231000	3882	23.2	123	6.59	4.74
	MAY	213000	3464	23.5	123	5.87	4.37
	JUN	528000S	5327	19.9	1234	8.16	5.87
	JUL	285000	4635	22.6	1234	7.59	5.65
1930	AUG	136000	2212	24.7	12	3.87	2.88
	SEP	147000	2470	24.4	12	4.36	3.14
						TOTAL	55.40
	OCT	271000	4407	22.8	123	7.45	5.55
	NOV	281000	4722	22.6	1234	7.73	5.57
	DEC	211000	3432	23.6	123	5.81	4.32
	JAN	184000	2992	23.9	123	5.00	3.74
	FEB	188000	3385	23.6	123	5.77	3.85
	MAR	230000	3741	23.3	123	6.35	4.72
	APR	417000S	5327	20.9	1234	8.39	6.04
	MAY	469000S	5327	20.6	1234	8.31	6.19
	JUN	343000S	5327	21.8	1234	8.59	6.18
	JUL	121000	1968	25.0	12	3.40	2.53
	AUG	103000	1675	25.4	12	2.83	2.10
	SEP	113000	1899	25.1	12	3.26	2.35
						TOTAL	53.15

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1931	OCT	315000	5123	22.3	1234	8.36	6.22
	NOV	287000	4823	22.5	1234	7.89	5.68
	DEC	200000	3253	23.7	123	5.58	4.89
	JAN	189000	3074	23.9	123	5.13	3.85
	FEB	141000	2539	24.4	12	4.49	3.02
	MAR	234000	3806	23.3	123	6.46	4.80
	APR	255000	4285	22.9	123	7.26	5.23
	MAY	151000	2456	24.5	12	4.33	3.22
	JUN	350000S	5327	21.7	1234	8.57	6.17
	JUL	77000	1252	26.1	1	2.31	1.72
	AUG	36000	585	27.4	1	0.92	0.69
	SEP	79000	1328	26.0	1	2.46	1.77
						TOTAL	46.47
1932	OCT	186000	3025	23.9	123	5.09	3.79
	NOV	217000	3647	23.4	123	6.19	4.45
	DEC	176000	2862	24.0	12	5.08	3.78
	JAN	180000	2927	24.0	12	5.19	3.86
	FEB	150000	2701	24.2	12	4.79	3.22
	MAR	225000	3659	23.4	123	6.21	4.62
	APR	232000	3899	23.2	123	6.62	4.76
	MAY	389000S	5327	21.4	1234	8.50	6.32
	JUN	736000S	5327	18.2	1234	7.16	5.15
	JUL	214000	3480	23.5	123	5.98	4.39
	AUG	100000	1626	25.5	12	2.73	2.03
	SEP	150000	2521	24.4	12	4.45	3.21
						TOTAL	49.58
1933	OCT	240000	3903	23.2	123	6.62	4.93
	NOV	253000	4252	22.9	123	7.21	5.19
	DEC	176000	2862	24.0	12	5.08	3.78
	JAN	182000	2960	24.0	12	5.25	3.91
	FEB	155000	2791	24.1	12	4.95	3.33
	MAR	228000	3708	23.3	123	6.29	4.68
	APR	266000	4470	22.8	123	7.56	5.44
	MAY	317000	5155	22.2	1234	8.41	6.26
	JUN	763000S	5327	18.0	1234	7.03	5.06
	JUL	148000	2407	24.5	12	4.24	3.15
	AUG	92000	1496	25.7	12	2.47	1.84
	SEP	132000	2218	24.7	12	3.88	2.79
						TOTAL	50.36
1934	OCT	240000	3903	23.2	123	6.62	4.93
	NOV	237000	3983	23.1	123	6.75	4.87
	DEC	189000	3074	23.9	123	5.13	3.85
	JAN	200000	3253	23.7	123	5.58	4.89
	FEB	216000	3889	23.2	123	6.60	4.45
	MAR	176000	2862	24.0	12	5.08	3.78
	APR	222000	3731	23.3	123	6.33	4.56
	MAY	233000	3789	23.3	123	6.43	4.78
	JUN	143000	2403	24.5	12	4.23	3.05
	JUL	128000	2082	24.8	12	3.61	2.69
	AUG	49000	797	27.0	1	1.37	1.02
	SEP	77000	1294	26.0	1	2.40	1.72
						TOTAL	43.77

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1935	OCT	180000	2927	24.0	12	5.19	3.86
	NOV	191000	3210	23.7	123	5.42	3.90
	DEC	172000	2797	24.1	12	4.96	3.69
	JAN	222000	3610	23.4	123	6.12	4.56
	FEB	172000	3097	23.8	123	5.22	3.51
	MAR	190000	3090	23.8	123	5.20	3.87
	APR	276000	4638	22.6	1234	7.59	5.47
	MAY	200000	3383	23.6	123	5.73	4.26
	JUN	421000	5327	20.9	1234	8.38	6.04
	JUL	93000	1512	25.7	12	2.50	1.86
	AUG	84000	1366	25.9	1	2.54	1.89
	SEP	106000	1781	25.3	12	3.04	2.19
						TOTAL	45.10
1936	OCT	183000	2976	23.9	12	5.28	3.93
	NOV	213000	3580	23.4	123	6.07	4.37
	DEC	170000	2765	24.1	12	4.90	3.65
	JAN	138000	2244	24.7	12	3.93	2.92
	FEB	152000	2737	24.2	12	4.85	3.26
	MAR	259000	4212	23.0	123	7.14	5.31
	APR	413000	5327	21.0	1234	8.40	6.05
	MAY	677000	5327	18.8	1234	7.54	5.61
	JUN	326000	5327	22.0	1234	8.64	6.22
	JUL	85000	1382	25.9	1	2.57	1.91
	AUG	105000	1708	25.4	12	2.89	2.15
	SEP	109000	1832	25.2	12	3.13	2.26
						TOTAL	47.64
1937	OCT	170000	2765	24.1	12	4.90	3.65
	NOV	179000	3008	23.9	123	5.06	3.64
	DEC	174000	2830	24.1	12	5.02	3.74
	JAN	138000	2244	24.7	12	3.93	2.92
	FEB	151000	2719	24.2	12	4.82	3.24
	MAR	204000	3318	23.7	123	5.61	4.18
	APR	220000	3697	23.4	123	6.27	4.52
	MAY	186000	3025	23.9	123	5.09	3.79
	JUN	223000	3748	23.3	123	6.36	4.58
	JUL	91000	1480	25.7	12	2.44	1.81
	AUG	87000	1415	25.8	1	2.64	1.96
	SEP	117000	1966	25.0	12	3.39	2.44
						TOTAL	40.46
1938	OCT	189000	3074	23.9	123	5.18	3.85
	NOV	185000	3109	23.8	123	5.24	3.77
	DEC	166000	2700	24.2	12	4.79	3.56
	JAN	199000	3236	23.7	123	5.47	4.07
	FEB	156000	2809	24.1	12	4.98	3.65
	MAR	206000	3350	23.6	123	5.67	4.22
	APR	319000	5361	22.1	1234	8.73	6.29
	MAY	403000	5327	21.2	1234	8.46	6.19
	JUN	644000	5327	18.9	1234	7.59	5.47
	JUL	335000	5448	22.0	1234	8.86	6.59
	AUG	133000	2163	24.7	12	3.77	2.81
	SEP	133000	2235	24.7	12	3.91	2.82
						TOTAL	53.08

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1939	OCT	278000	4521	22.7	1234	7.40	5.51
	NOV	246000	4134	23.0	123	7.01	5.05
	DEC	216000	3513	23.5	123	5.95	4.43
	JAN	214000	3480	23.5	123	5.90	4.39
	FEB	149000	2683	24.2	12	4.75	3.20
	MAR	208000	3383	23.6	123	5.73	4.26
	APR	357000S	5327	21.6	1234	8.55	6.16
	MAY	652000S	5327	19.0	1234	7.66	5.70
	JUN	460000S	5327	20.5	1234	8.30	5.98
	JUL	196000	3188	23.8	123	5.38	4.00
	AUG	120000	1952	25.0	12	3.36	2.50
	SEP	117000	1966	25.0	12	3.39	2.44
						TOTAL	53.61
1940	OCT	221000	3594	23.4	123	6.10	4.54
	NOV	258000	4336	22.9	123	7.34	5.29
	DEC	195000	3171	23.8	123	5.35	3.98
	JAN	193000	3139	23.8	123	5.29	3.94
	FEB	192000	3457	23.5	123	5.86	3.94
	MAR	255000	4147	23.0	123	7.03	5.23
	APR	306000	5142	22.2	1234	8.39	6.04
	MAY	392000S	5327	21.3	1234	8.49	6.31
	JUN	380000S	5327	21.3	1234	8.48	6.11
	JUL	116000	1887	25.1	12	3.24	2.41
	AUG	97000	1578	25.6	12	2.63	1.96
	SEP	136000	2286	24.6	12	4.01	2.89
						TOTAL	52.63
1941	OCT	208000	3383	23.6	123	5.73	4.26
	NOV	225000	3781	23.3	123	6.42	4.62
	DEC	188000	3057	23.9	123	5.15	3.83
	JAN	195000	3171	23.8	123	5.35	3.98
	FEB	180000	3241	23.7	123	5.48	3.68
	MAR	211000	3432	23.6	123	5.81	4.32
	APR	273000	4588	22.7	1234	7.51	5.41
	MAY	259000	4212	23.0	123	7.14	5.31
	JUN	384000S	5327	21.3	1234	8.47	6.10
	JUL	136000	2212	24.7	12	3.87	2.88
	AUG	141000	2293	24.6	12	4.02	2.99
	SEP	208000	3496	23.5	123	5.92	4.27
						TOTAL	51.65
1942	OCT	270000	4391	22.8	123	7.43	5.53
	NOV	255000	4285	22.9	123	7.26	5.23
	DEC	246000	4001	23.1	123	6.79	5.05
	JAN	183000	2976	23.9	12	5.28	3.93
	FEB	186000	3349	23.6	123	5.67	3.81
	MAR	246000	4001	23.1	123	6.79	5.05
	APR	519000S	5327	20.0	1234	8.17	5.99
	MAY	622000S	5327	19.3	1234	7.79	5.80
	JUN	943000S	5327	16.7	1234	6.46	4.65
	JUL	286000	4651	22.6	1234	7.62	5.67
	AUG	112000	1821	25.2	12	3.11	2.32
	SEP	159000	2672	24.2	12	4.73	3.41
						TOTAL	56.31

YEAR	MONTH	OUTFLOW (AF) (CFS)		AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1943	OCT	200000	3253	23.7	123	5.50	4.09
	NOV	242000	4067	23.1	123	6.90	4.97
	DEC	234000	3806	23.3	123	6.46	4.80
	JAN	191000	3106	23.3	123	5.23	3.89
	FEB	259000	4663	22.6	1234	7.64	5.13
	MAR	325000	5286	22.1	1234	8.62	6.41
	APR	515000S	5327	20.0	1234	8.18	5.89
	MAY	577000S	5327	19.6	1234	8.03	5.97
	JUN	1151000S	5116	15.4	1234	5.73	4.12
	JUL	479000S	5327	20.5	1234	8.29	6.17
	AUG	212000	3448	23.6	123	5.84	4.35
	SEP	185000	3109	23.8	123	5.24	3.77
						TOTAL	59.58
1944	OCT	224000	3643	23.4	123	6.18	4.60
	NOV	244000	4100	23.0	123	6.95	5.01
	DEC	233000	3789	23.3	123	6.43	4.78
	JAN	225000	3659	23.4	123	6.21	4.62
	FEB	201000	3619	23.4	123	6.14	4.13
	MAR	216000	3513	23.5	123	5.95	4.43
	APR	220000	3697	23.4	123	6.27	4.52
	MAY	279000	4537	22.7	1234	7.43	5.53
	JUN	823000S	5327	17.5	1234	6.76	4.87
	JUL	427000S	5327	21.0	1234	8.40	6.25
	AUG	180000	2927	24.0	12	5.19	3.86
	SEP	196000	3294	23.7	123	5.57	4.01
						TOTAL	56.60
1945	OCT	207000	3366	23.6	123	5.70	4.24
	NOV	219000	3680	23.4	123	6.24	4.50
	DEC	198000	3220	23.7	123	5.44	4.05
	JAN	237000	3854	23.2	123	6.54	4.87
	FEB	207000	3727	23.3	123	6.32	4.25
	MAR	201000	3269	23.7	123	5.53	4.11
	APR	193000	3243	23.7	123	5.40	3.95
	MAY	320000	5204	22.2	1234	8.49	6.32
	JUN	571000S	5327	19.5	1234	7.96	5.73
	JUL	268000	4359	22.8	123	7.38	5.49
	AUG	153000	2488	24.4	12	4.39	3.27
	SEP	174000	2924	24.0	12	5.19	3.73
						TOTAL	54.50
1946	OCT	213000	3464	23.5	123	5.87	4.37
	NOV	220000	3697	23.4	123	6.27	4.52
	DEC	207000	3366	23.6	123	5.70	4.24
	JAN	218000	3545	23.5	123	6.01	4.47
	FEB	208000	3745	23.3	123	6.36	4.27
	MAR	259000	4212	23.0	123	7.14	5.31
	APR	357000S	5327	21.6	1234	8.55	6.16
	MAY	467000S	5327	20.6	1234	8.32	6.19
	JUN	435000S	5327	20.8	1234	8.35	6.02
	JUL	234000	3806	23.3	123	6.46	4.80
	AUG	151000	2456	24.5	12	4.33	3.22
	SEP	215000	3613	23.4	123	6.13	4.41
						TOTAL	57.98

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1947	OCT	260000	4228	22.9	123	7.17	5.33
	NOV	267000	4487	22.7	1234	7.35	5.29
	DEC	277000	4505	22.7	1234	7.38	5.49
	JAN	225000	3659	23.4	123	6.21	4.62
	FEB	206000	3709	23.3	123	6.29	4.23
	MAR	316000	5139	22.3	1234	8.39	6.24
	APR	450000S	5327	20.6	1234	8.32	5.99
	MAY	797000S	5327	17.9	1234	6.99	5.20
	JUN	882000S	5327	17.1	1234	6.60	4.75
	JUL	351000S	5327	21.8	1234	8.60	6.40
	AUG	183000	2976	23.9	12	5.28	3.93
	SEP	235000	3949	23.2	123	6.70	4.83
						TOTAL	62.30
1948	OCT	300000	4879	22.4	1234	7.98	5.94
	NOV	280000	4705	22.6	1234	7.70	5.55
	DEC	280000	4554	22.7	1234	7.46	5.55
	JAN	245000	3984	23.1	123	6.76	5.03
	FEB	220000	3961	23.1	123	6.72	4.52
	MAR	277000	4505	22.7	1234	7.38	5.49
	APR	499000S	5327	20.2	1234	8.22	5.92
	MAY	895000S	5327	17.2	1234	6.64	4.94
	JUN	1213000S	5116	15.0	1234	5.57	4.01
	JUL	398000S	5327	21.3	1234	8.47	6.30
	AUG	219000	3562	23.5	123	6.04	4.49
	SEP	208000	3496	23.5	123	5.92	4.27
						TOTAL	62.00
1949	OCT	261000	4245	22.9	123	7.19	5.35
	NOV	261000	4386	22.8	123	7.42	5.35
	DEC	236000	3838	23.2	123	6.51	4.85
	JAN	197000	3204	23.7	123	5.41	4.02
	FEB	192000	3457	23.5	123	5.86	3.94
	MAR	271000	4407	22.8	123	7.46	5.55
	APR	490000S	5327	20.3	1234	8.24	5.93
	MAY	626000S	5327	19.2	1234	7.77	5.78
	JUN	521000S	5327	20.0	1234	8.17	5.88
	JUL	182000	2960	24.0	12	5.25	3.91
	AUG	130000	2114	24.8	12	3.68	2.74
	SEP	198000	3327	23.6	123	5.63	4.05
						TOTAL	57.35
1950	OCT	233000	3789	23.3	123	6.43	4.78
	NOV	236000	3966	23.1	123	6.73	4.84
	DEC	207000	3366	23.6	123	5.70	4.24
	JAN	184000	2992	23.9	123	5.03	3.74
	FEB	203000	3655	23.4	123	6.20	4.17
	MAR	241000	3919	23.2	123	6.65	4.95
	APR	294000	4941	22.4	1234	8.08	5.82
	MAY	331000	5383	22.1	1234	8.76	6.52
	JUN	708000S	5327	18.4	1234	7.29	5.25
	JUL	372000S	5327	21.6	1234	8.54	6.36
	AUG	203000	3301	23.7	123	5.58	4.15
	SEP	237000	3983	23.1	123	6.76	4.87
						TOTAL	59.68

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1951	OCT	289000	4700	22.6	1234	7.76	5.73
	NOV	275000	4621	22.6	1234	7.57	5.45
	DEC	267000	4342	22.9	123	7.35	5.47
	JAN	207000	3366	23.6	123	5.70	4.24
	FEB	215000	3871	23.2	123	6.57	4.42
	MAR	250000	4066	23.1	123	6.90	5.13
	APR	334000S	5327	21.9	1234	8.62	6.20
	MAY	677000S	5327	18.8	1234	7.54	5.61
	JUN	550000S	5327	19.7	1234	8.08	5.82
	JUL	234000	3806	23.3	123	6.46	4.80
	AUG	201000	3269	23.7	123	5.53	4.11
	SEP	221000	3714	23.3	123	6.30	4.54
						TOTAL	61.52
1952	OCT	255000	4147	23.0	123	7.03	5.23
	NOV	251000	4218	22.9	123	7.15	5.15
	DEC	201000	3269	23.7	123	5.53	4.11
	JAN	193000	3139	23.8	123	5.29	3.94
	FEB	226000	4069	23.1	123	6.90	4.64
	MAR	259000	4212	23.0	123	7.14	5.31
	APR	499000S	5327	20.2	1234	8.22	5.92
	MAY	904000S	5327	17.1	1234	6.62	4.92
	JUN	713000S	5327	18.4	1234	7.26	5.23
	JUL	317000	5155	22.2	1234	8.41	6.26
	AUG	176000	2862	24.0	12	5.08	3.78
	SEP	215000	3613	23.4	123	6.13	4.41
						TOTAL	58.90
1953	OCT	226000	3675	23.4	123	6.23	4.64
	NOV	247000	4151	23.0	123	7.04	5.07
	DEC	254000	4131	23.0	123	7.01	5.21
	JAN	250000	4066	23.1	123	6.90	5.13
	FEB	198000	3565	23.5	123	6.04	4.06
	MAR	213000	3464	23.5	123	5.87	4.37
	APR	225000	3781	23.3	123	6.42	4.62
	MAY	283000	4602	22.7	1234	7.54	5.61
	JUN	907000S	5327	16.9	1234	6.54	4.71
	JUL	291000	4733	22.6	1234	7.75	5.76
	AUG	143000	2326	24.6	12	4.08	3.04
	SEP	178000	2991	23.9	123	5.03	3.62
						TOTAL	55.83
1954	OCT	254000	4131	23.0	123	7.01	5.21
	NOV	269000	4521	22.7	1234	7.40	5.33
	DEC	221000	3594	23.4	123	6.10	4.54
	JAN	182000	2960	24.0	12	5.25	3.91
	FEB	211000	3799	23.3	123	6.45	4.33
	MAR	202000	3285	23.7	123	5.56	4.13
	APR	227000	3815	23.3	123	6.47	4.66
	MAY	310000	5042	22.3	1234	8.24	6.13
	JUN	365000S	5327	21.5	1234	8.53	6.14
	JUL	252000	4098	23.0	123	6.95	5.17
	AUG	139000	2261	24.6	12	3.96	2.95
	SEP	153000	2571	24.3	12	4.55	3.27
						TOTAL	55.77

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1955	OCT	224000	3643	23.4	123	6.18	4.60
	NOV	241000	4050	23.1	123	6.87	4.95
	DEC	173000	2814	24.1	12	4.99	3.71
	JAN	167000	2716	24.2	12	4.82	3.58
	FEB	147000	2647	24.3	12	4.69	3.15
	MAR	174000	2830	24.1	12	5.02	3.74
	APR	214000	3596	23.4	123	6.10	4.39
	MAY	348000S	5327	21.9	1234	8.61	6.40
	JUN	507000S	5327	20.1	1234	8.20	5.90
	JUL	321000	5220	22.2	1234	8.52	6.34
	AUG	116000	1887	25.1	12	3.24	2.41
	SEP	146000	2454	24.5	12	4.33	3.11
						TOTAL	52.29
1956	OCT	201000	3269	23.7	123	5.53	4.11
	NOV	235000	3949	23.2	123	6.70	4.83
	DEC	230000	3741	23.3	123	6.35	4.72
	JAN	225000	3659	23.4	123	6.21	4.62
	FEB	158000	2845	24.1	12	5.05	3.39
	MAR	290000	4716	22.6	1234	7.72	5.75
	APR	387000S	5327	21.3	1234	8.47	6.10
	MAY	726000S	5327	18.5	1234	7.31	5.44
	JUN	636000S	5327	19.0	1234	7.63	5.49
	JUL	174000	2830	24.1	12	5.02	3.74
	AUG	130000	2114	24.8	12	3.68	2.74
	SEP	167000	2806	24.1	12	4.98	3.58
						TOTAL	54.50
1957	OCT	230000	3741	23.3	123	6.35	4.72
	NOV	293000	4924	22.4	1234	8.05	5.80
	DEC	202000	3285	23.7	123	5.56	4.13
	JAN	151000	2456	24.5	12	4.33	3.22
	FEB	188000	3385	23.6	123	5.73	3.85
	MAR	224000	3643	23.4	123	6.18	4.60
	APR	246000	4134	23.0	123	7.01	5.05
	MAY	586000S	5327	19.6	1234	7.98	5.94
	JUN	721000S	5327	18.3	1234	7.23	5.20
	JUL	232000	3773	23.3	123	6.40	4.76
	AUG	109000	1773	25.3	12	3.02	2.25
	SEP	171000	2874	24.0	12	5.10	3.67
						TOTAL	53.19
1958	OCT	275000	4472	22.8	123	7.57	5.63
	NOV	298000	5008	22.4	1234	8.19	5.89
	DEC	238000	3871	23.2	123	6.57	4.89
	JAN	201000	3269	23.7	123	5.53	4.11
	FEB	196000	3529	23.5	123	5.93	4.02
	MAR	219000	3562	23.5	123	6.04	4.49
	APR	264000	4437	22.8	123	7.51	5.41
	MAY	558000S	5327	19.8	1234	8.13	6.05
	JUN	506000S	5327	20.1	1234	8.20	5.91
	JUL	228000	3708	23.3	123	6.29	4.68
	AUG	131000	2130	24.8	12	3.71	2.76
	SEP	153000	2571	24.3	12	4.55	3.27
						TOTAL	57.11

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1959	OCT	240000	3903	23.2	123	6.62	4.93
	NOV	258000	4336	22.9	123	7.34	5.29
	DEC	225000	3659	23.4	123	6.21	4.62
	JAN	189000	3074	23.9	123	5.18	3.85
	FEB	156000	2809	24.1	12	4.98	3.35
	MAR	238000	3871	23.2	123	6.57	4.89
	APR	281000	4722	22.6	1234	7.73	5.57
	MAY	306000	4977	22.4	1234	8.14	6.05
	JUN	693000	5327	18.6	1234	7.36	5.30
	JUL	277000	4505	22.7	1234	7.38	5.49
	AUG	100000	1626	25.5	12	2.73	2.03
	SEP	151000	2538	24.4	12	4.48	3.23
						TOTAL	54.59
1960	OCT	365000	5327	21.7	1234	8.56	6.37
	NOV	390000	5327	21.2	1234	8.46	6.09
	DEC	367000	5327	21.6	1234	8.56	6.37
	JAN	204000	3318	23.7	123	5.61	4.18
	FEB	219000	3943	23.2	123	6.69	4.50
	MAR	349000	5327	21.9	1234	8.61	6.40
	APR	419000	5327	20.9	1234	8.39	6.04
	MAY	447000	5327	20.8	1234	8.36	6.22
	JUN	422000	5327	20.9	1234	8.38	6.04
	JUL	109000	1773	25.3	12	3.02	2.25
	AUG	104000	1691	25.4	12	2.86	2.13
	SEP	143000	2403	24.5	12	4.23	3.05
						TOTAL	59.61
1961	OCT	177000	2879	24.0	12	5.11	3.80
	NOV	219000	3680	23.4	123	6.24	4.50
	DEC	199000	3236	23.7	123	5.47	4.07
	JAN	182000	2960	24.0	12	5.25	3.91
	FEB	188000	3385	23.6	123	5.73	3.85
	MAR	185000	3009	23.9	123	5.06	3.76
	APR	142000	2386	24.5	12	4.20	3.02
	MAY	192000	3123	23.8	123	5.26	3.92
	JUN	308000	5176	22.2	1234	8.45	6.08
	JUL	85000	1382	25.9	1	2.57	1.91
	AUG	66000	1073	26.4	1	1.95	1.45
	SEP	176000	2958	24.0	12	5.25	3.78
						TOTAL	44.05
1962	OCT	305000	4960	22.4	1234	8.11	6.03
	NOV	312000	5243	22.2	1234	8.55	6.16
	DEC	188000	3057	23.9	123	5.15	3.83
	JAN	153000	2488	24.4	12	4.39	3.27
	FEB	196000	3529	23.5	123	5.98	4.02
	MAR	232000	3773	23.3	123	6.40	4.76
	APR	379000	5327	21.4	1234	8.49	6.11
	MAY	480000	5327	20.5	1234	8.29	6.17
	JUN	641000	5327	19.0	1234	7.61	5.48
	JUL	270000	4391	22.8	123	7.43	5.53
	AUG	174000	2830	24.1	12	5.02	3.74
	SEP	215000	3610	23.4	123	6.13	4.41
						TOTAL	59.51

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1963	OCT	292000	4749	22.5	1234	7.77	5.78
	NOV	306000	5142	22.2	1234	8.39	6.04
	DEC	252000	4098	23.0	123	6.95	5.17
	JAN	175000	2846	24.1	12	5.05	3.76
	FEB	271000	4880	22.4	1234	7.98	5.36
	MAR	219000	3562	23.5	123	6.04	4.49
	APR	235000	3949	23.2	123	6.70	4.83
	MAY	477000S	5327	20.5	1234	8.30	6.17
	JUN	826000S	5327	17.5	1234	6.75	4.86
	JUL	272000	4424	22.8	123	7.49	5.57
	AUG	121000	1968	25.0	12	3.40	2.53
	SEP	204000	3428	23.6	123	5.81	4.18
						TOTAL	58.75
1964	OCT	247000	4017	23.1	123	6.81	5.07
	NOV	291000	4890	22.4	1234	8.00	5.76
	DEC	199000	3236	23.7	123	5.47	4.07
	JAN	199000	3236	23.7	123	5.47	4.07
	FEB	189000	3403	23.6	123	5.76	3.87
	MAR	208000	3383	23.6	123	5.73	4.26
	APR	249000	4185	23.0	123	7.10	5.11
	MAY	470000S	5327	20.6	1234	8.31	6.18
	JUN	1063000S	5327	15.9	1234	6.19	4.46
	JUL	417000S	5327	21.1	1234	8.42	6.27
	AUG	159000	2586	24.3	12	4.57	3.40
	SEP	219000	3680	23.4	123	6.24	4.50
						TOTAL	57.02
1965	OCT	250000	4066	23.1	123	6.90	5.13
	NOV	297000	4991	22.4	1234	8.16	5.87
	DEC	232000	3773	23.3	123	6.40	4.76
	JAN	256000	4163	23.0	123	7.06	5.25
	FEB	228000	4105	23.0	123	6.96	4.68
	MAR	230000	3741	23.3	123	6.35	4.72
	APR	390000S	5327	21.2	1234	8.46	6.09
	MAY	612000S	5327	19.3	1234	7.84	5.83
	JUN	1069000S	5327	15.9	1234	6.18	4.45
	JUL	604000S	5327	19.4	1234	7.88	5.86
	AUG	242000	3936	23.2	123	6.68	4.97
	SEP	279000	4689	22.6	1234	7.68	5.53
						TOTAL	63.16
1966	OCT	349000S	5327	21.9	1234	8.61	6.40
	NOV	379000S	5327	21.4	1234	8.49	6.11
	DEC	250000	4066	23.1	123	6.90	5.13
	JAN	230000	3741	23.3	123	6.35	4.72
	FEB	209000	3763	23.3	123	6.39	4.29
	MAR	239000	3887	23.2	123	6.60	4.91
	APR	261000	4386	22.8	123	7.42	5.35
	MAY	271000	4407	22.8	123	7.46	5.55
	JUN	238000	4000	23.1	123	6.79	4.89
	JUL	121000	1968	25.0	12	3.40	2.53
	AUG	77000	1252	26.1	1	2.31	1.72
	SEP	121000	2033	24.9	12	3.52	2.54
						TOTAL	54.13

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1967	OCT	250000	4066	23.1	123	6.90	5.13
	NOV	286000	4806	22.5	1234	7.87	5.66
	DEC	202000	3285	23.7	123	5.55	4.13
	JAN	209000	3399	23.6	123	5.75	4.28
	FEB	188000	3385	23.6	123	5.73	3.85
	MAR	197000	3204	23.7	123	5.41	4.02
	APR	211000	3546	23.5	123	6.01	4.33
	MAY	569000S	5327	19.7	1234	8.07	6.01
	JUN	1269000S	5116	14.6	1234	5.42	3.91
	JUL	461000S	5327	20.7	1234	8.33	6.20
	AUG	147000	2391	24.5	12	4.21	3.13
	SEP	199000	3344	23.6	123	5.66	4.07
						TOTAL	54.73
1968	OCT	302000	4911	22.4	1234	8.03	5.98
	NOV	309000	5193	22.2	1234	8.47	6.10
	DEC	228000	3708	23.3	123	6.29	4.68
	JAN	225000	3659	23.4	123	6.21	4.62
	FEB	254000	4573	22.7	1234	7.49	5.03
	MAR	278000	4521	22.7	1234	7.40	5.51
	APR	299000	5025	22.3	1234	8.21	5.91
	MAY	460000S	5327	20.7	1234	8.33	6.20
	JUN	1041000S	5327	16.1	1234	6.24	4.49
	JUL	360000S	5327	21.7	1234	8.58	6.38
	AUG	233000	3789	23.3	123	6.43	4.78
	SEP	298000	5008	22.4	1234	8.19	5.89
						TOTAL	65.58
1969	OCT	321000	5220	22.2	1234	8.52	6.34
	NOV	322000	5411	22.0	1234	8.81	6.34
	DEC	244000	3968	23.1	123	6.73	5.01
	JAN	226000	3675	23.4	123	6.23	4.64
	FEB	240000	4321	22.9	123	7.32	4.92
	MAR	306000	4977	22.4	1234	8.14	6.05
	APR	600000S	5327	19.3	1234	7.80	5.62
	MAY	894000S	5327	17.2	1234	6.65	4.94
	JUN	652000S	5327	18.9	1234	7.55	5.44
	JUL	434000S	5327	20.9	1234	8.39	6.24
	AUG	189000	3074	23.9	123	5.18	3.85
	SEP	202000	3395	23.6	123	5.75	4.14
						TOTAL	63.52
1970	OCT	327000	5318	22.1	1234	8.66	6.45
	NOV	302000	5075	22.3	1234	8.29	5.97
	DEC	249000	4050	23.1	123	6.87	5.11
	JAN	230000	3741	23.3	123	6.35	4.72
	FEB	214000	3050	23.2	123	6.54	4.39
	MAR	235000	3822	23.3	123	6.49	4.83
	APR	259000	4353	22.8	123	7.37	5.31
	MAY	714000S	5327	18.6	1234	7.37	5.48
	JUN	1117000S	5327	15.6	1234	6.07	4.37
	JUL	467000S	5327	20.6	1234	8.32	6.19
	AUG	186000	3025	23.9	123	5.09	3.79
	SEP	262000	4403	22.8	123	7.45	5.37
						TOTAL	61.97

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1971	OCT	332000	5399	22.1	1234	8.79	6.54
	NOV	339000S	5327	21.8	1234	8.68	6.19
	DEC	259000	4212	23.0	123	7.14	5.31
	JAN	259000	4212	23.0	123	7.14	5.31
	FEB	266000	4790	22.5	1234	7.84	5.27
	MAR	241000	3919	23.2	123	6.65	4.95
	APR	402000S	5327	21.1	1234	8.42	6.07
	MAY	784000S	5327	18.0	1234	7.05	5.24
	JUN	1080000S	5327	15.8	1234	6.15	4.43
	JUL	510000S	5327	20.2	1234	8.23	6.12
	AUG	214000	3480	23.5	123	5.90	4.39
	SEP	290000	4874	22.5	1234	7.97	5.74
						TOTAL	65.57
1972	OCT	348000S	5327	21.9	1234	8.61	6.40
	NOV	339000S	5327	21.8	1234	8.60	6.19
	DEC	248000	4033	23.1	123	6.84	5.09
	JAN	252000	4098	23.0	123	6.95	5.17
	FEB	261000	4699	22.6	1234	7.70	5.17
	MAR	331000	5383	22.1	1234	8.76	6.52
	APR	398000S	5327	21.1	1234	8.43	6.07
	MAY	574000S	5327	19.7	1234	8.05	5.99
	JUN	957000S	5327	16.6	1234	6.43	4.63
	JUL	296000	4814	22.5	1234	7.88	5.86
	AUG	189000	3074	23.9	123	5.18	3.85
	SEP	239000	4016	23.1	123	6.81	4.91
						TOTAL	65.85
1973	OCT	354000S	5327	21.8	1234	8.59	6.39
	NOV	357000S	5327	21.6	1234	8.55	6.16
	DEC	225000	3659	23.4	123	6.21	4.62
	JAN	225000	3659	23.4	123	6.21	4.62
	FEB	216000	3889	23.2	123	6.60	4.43
	MAR	254000	4131	23.0	123	7.01	5.21
	APR	286000	4806	22.5	1234	7.87	5.66
	MAY	432000S	5327	20.9	1234	8.39	6.24
	JUN	442000S	5327	20.7	1234	8.34	6.00
	JUL	206000	3350	23.6	123	5.67	4.22
	AUG	120000	1952	25.0	12	3.36	2.50
	SEP	222000	3731	23.3	123	6.33	4.56
						TOTAL	60.62
1974	OCT	272000	4424	22.8	123	7.49	5.57
	NOV	316000	5310	22.1	1234	8.65	6.23
	DEC	250000	4066	23.1	123	6.90	5.13
	JAN	223000	3627	23.4	123	6.15	4.58
	FEB	219000	3943	23.2	123	6.69	4.50
	MAR	272000	4424	22.8	123	7.49	5.57
	APR	412000S	5327	21.0	1234	8.40	6.05
	MAY	539000S	5327	20.0	1234	8.17	6.08
	JUN	1032000S	5327	16.1	1234	6.26	4.51
	JUL	324000	5269	22.2	1234	8.59	6.39
	AUG	181000	2944	24.0	12	5.22	3.88
	SEP	204000	3428	23.6	123	5.81	4.18
						TOTAL	62.67

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1975	OCT	294000	4781	22.5	1234	7.83	5.82
	NOV	268000	4504	22.7	1234	7.38	5.31
	DEC	256000	4163	23.0	123	7.06	5.25
	JAN	209000	3399	23.6	123	5.76	4.28
	FEB	194000	3493	23.5	123	5.92	3.98
	MAR	252000	4098	23.0	123	6.95	5.17
	APR	291000	4890	22.4	1234	8.00	5.76
	MAY	620000	5327	19.3	1234	7.80	5.81
	JUN	1164000	5116	15.3	1234	5.70	4.10
	JUL	876000	5327	17.4	1234	6.69	4.98
	AUG	352000	5327	21.8	1234	8.60	6.40
	SEP	283000	4756	22.5	1234	7.79	5.61
						TOTAL	62.46
1976	OCT	382000	5327	21.5	1234	8.52	6.34
	NOV	375000	5327	21.4	1234	8.50	6.12
	DEC	351000	5327	21.8	1234	8.60	6.40
	JAN	283000	4602	22.7	1234	7.54	5.61
	FEB	244000	4393	22.8	123	7.44	5.00
	MAR	301000	4895	22.4	1234	8.01	5.96
	APR	524000	5327	20.0	1234	8.17	5.88
	MAY	1132000	5327	15.7	1234	6.12	4.55
	JUN	896000	5327	17.0	1234	6.56	4.72
	JUL	393000	5327	21.3	1234	8.48	6.31
	AUG	350000	5327	21.8	1234	8.60	6.40
	SEP	314000	5277	22.1	1234	8.60	6.19
						TOTAL	69.48
1977	OCT	417000	5327	21.1	1234	8.42	6.27
	NOV	378000	5327	21.4	1234	8.49	6.11
	DEC	286000	4651	22.6	1234	7.62	5.67
	JAN	227000	3692	23.4	123	6.26	4.66
	FEB	214000	3853	23.2	123	6.54	4.39
	MAR	220000	3578	23.4	123	6.07	4.51
	APR	292000	4907	22.4	1234	8.03	5.78
	MAY	211000	3432	23.6	123	5.81	4.32
	JUN	315000	5294	22.1	1234	8.63	6.21
	JUL	123000	2000	24.9	12	3.46	2.57
	AUG	104000	1691	25.4	12	2.86	2.13
	SEP	188000	3159	23.8	123	5.33	3.84
						TOTAL	56.46
1978	OCT	285000	4635	22.6	1234	7.59	5.65
	NOV	276000	4638	22.6	1234	7.59	5.47
	DEC	243000	3952	23.1	123	6.70	4.99
	JAN	226000	3675	23.4	123	6.23	4.64
	FEB	207000	3727	23.3	123	6.32	4.25
	MAR	324000	5269	22.2	1234	8.59	6.39
	APR	428000	5327	20.8	1234	8.37	6.03
	MAY	591000	5327	19.5	1234	7.96	5.92
	JUN	679000	5327	18.7	1234	7.43	5.35
	JUL	421000	5327	21.0	1234	8.41	6.26
	AUG	172000	2797	24.1	12	4.00	3.69
	SEP	279000	4689	22.6	1234	7.68	5.53
						TOTAL	64.16

AVERAGE ANNUAL ENERGY = 56.44 MKWH

BROADWATER HYDROELECTRIC PROJECT
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
RUN # : CT4X2.5-50YEARS FEBRUARY 27, 1979
CONVENTIONAL CONFIGURATION

* MONTHLY POWER OPERATION STUDY *

UNIT #	RATED CAPACITY (KW)	DESIGN CAPACITY (KW)	DESIGN FLOW (CFS)	DESIGN HEAD (FT)
1	2500	2500	1594	22
2	2500	2500	1594	22
3	2500	2500	1594	22
4	2500	2500	1594	22

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1929	OCT	262000	4261	22.9	123	6.86	5.10
	NOV	308000	5176	22.2	1234	8.02	5.78
	DEC	229000	3724	23.3	123	6.00	4.46
	JAN	217000	3529	23.5	123	5.67	4.22
	FEB	180000	3241	23.7	123	5.19	3.48
	MAR	218000	3545	23.5	123	5.70	4.24
	APR	231000	3882	23.2	123	6.25	4.50
	MAY	213000	3464	23.5	123	5.56	4.14
	JUN	528000S	5766	19.9	1234	8.47	6.10
	JUL	285000	4635	22.6	123	7.44	5.54
	AUG	136000	2212	24.7	12	3.66	2.72
	SEP	147000	2470	24.4	12	4.13	2.97
						TOTAL	53.26
1930	OCT	271000	4407	22.8	123	7.09	5.28
	NOV	281000	4722	22.6	123	7.57	5.45
	DEC	211000	3432	23.6	123	5.51	4.10
	JAN	184000	2992	23.9	12	5.04	3.75
	FEB	188000	3385	23.6	123	5.43	3.65
	MAR	230000	3741	23.3	123	6.02	4.48
	APR	417000S	5766	20.9	1234	8.71	6.27
	MAY	469000S	5766	20.6	1234	8.63	6.42
	JUN	343000	5764	21.8	1234	8.90	6.41
	JUL	121000	1968	25.0	12	3.21	2.39
	AUG	103000	1675	25.4	12	2.66	1.98
	SEP	113000	1899	25.1	12	3.08	2.22
						TOTAL	52.39

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1931	OCT	315000	5123	22.3	1234	7.94	5.91
	NOV	287000	4823	22.5	1234	7.49	5.39
	DEC	200000	3253	23.7	123	5.21	3.87
	JAN	189000	3074	23.9	12	5.18	3.85
	FEB	141000	2539	24.4	12	4.25	2.86
	MAR	234000	3806	23.3	123	6.13	4.56
	APR	255000	4285	22.9	123	6.90	4.97
	MAY	151000	2456	24.5	12	4.10	3.05
	JUN	350000S	5766	21.7	1234	8.89	6.40
	JUL	77000	1252	26.1	1	2.19	1.63
	AUG	36000	585	27.4	1	0.86	0.64
	SEP	79000	1328	26.0	1	2.33	1.68
						TOTAL	44.82
1932	OCT	186000	3025	23.9	12	5.10	3.79
	NOV	217000	3647	23.4	123	5.87	4.23
	DEC	176000	2862	24.0	12	4.82	3.59
	JAN	180000	2927	24.0	12	4.93	3.67
	FEB	150000	2701	24.2	12	4.54	3.05
	MAR	225000	3659	23.4	123	5.89	4.38
	APR	232000	3899	23.2	123	6.28	4.52
	MAY	389000S	5766	21.4	1234	8.81	6.56
	JUN	736000S	5766	18.2	1234	7.43	5.35
	JUL	214000	3480	23.5	123	5.59	4.16
	AUG	100000	1626	25.5	12	2.57	1.91
	SEP	150000	2521	24.4	12	4.22	3.04
						TOTAL	48.24
1933	OCT	240000	3903	23.2	123	6.29	4.68
	NOV	253000	4252	22.9	123	6.85	4.93
	DEC	176000	2862	24.0	12	4.82	3.59
	JAN	182000	2960	24.0	12	4.93	3.71
	FEB	155000	2791	24.1	12	4.70	3.16
	MAR	228000	3708	23.3	123	5.97	4.44
	APR	266000	4470	22.8	123	7.19	5.17
	MAY	317000	5155	22.2	1234	7.99	5.95
	JUN	763000S	5766	18.0	1234	7.29	5.25
	JUL	148000	2407	24.5	12	4.02	2.99
	AUG	92000	1496	25.7	1	2.66	1.98
	SEP	132000	2218	24.7	12	3.67	2.64
						TOTAL	48.48
1934	OCT	240000	3903	23.2	123	6.29	4.68
	NOV	237000	3993	23.1	120	6.42	4.62
	DEC	189000	3074	23.9	12	5.18	3.85
	JAN	200000	3253	23.7	123	5.21	3.87
	FEB	216000	3889	23.2	123	6.26	4.21
	MAR	176000	2862	24.0	12	4.82	3.59
	APR	222000	3731	23.3	123	6.01	4.32
	MAY	233000	3789	23.3	123	6.10	4.54
	JUN	143000	2403	24.5	12	4.01	2.89
	JUL	128000	2082	24.8	12	3.42	2.54
	AUG	49000	797	27.0	1	1.23	0.96
	SEP	77000	1294	26.0	1	2.27	1.63
						TOTAL	41.71

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1935	OCT	180000	2927	24.0	12	4.93	3.67
	NOV	191000	3210	23.7	123	5.13	3.70
	DEC	172000	2797	24.1	12	4.71	3.50
	JAN	222000	3610	23.4	123	5.81	4.32
	FEB	172000	3097	23.8	12	5.22	3.51
	MAR	190000	3090	23.8	12	5.21	3.87
	APR	276000	4638	22.6	123	7.45	5.36
	MAY	208000	3383	23.6	123	5.43	4.04
	JUN	421000	5766	20.9	1234	8.70	6.26
	JUL	93000	1512	25.7	1	2.69	2.00
	AUG	84000	1366	25.9	1	2.41	1.79
	SEP	106000	1781	25.3	12	2.86	2.06
						TOTAL	44.09
1936	OCT	183000	2976	23.9	12	5.01	3.73
	NOV	213000	3580	23.4	123	5.76	4.14
	DEC	170000	2765	24.1	12	4.65	3.46
	JAN	138000	2244	24.7	12	3.72	2.77
	FEB	152000	2737	24.2	12	4.61	3.10
	MAR	259000	4212	23.0	123	6.78	5.05
	APR	413000	5766	21.0	1234	8.71	6.27
	MAY	677000	5766	18.8	1234	7.82	5.82
	JUN	326000	5479	22.0	1234	8.47	6.10
	JUL	85000	1382	25.9	1	2.44	1.82
	AUG	105000	1708	25.4	12	2.72	2.03
	SEP	109000	1832	25.2	12	2.96	2.13
						TOTAL	46.41
1937	OCT	170000	2765	24.1	12	4.65	3.46
	NOV	179000	3008	23.9	12	5.07	3.65
	DEC	174000	2830	24.1	12	4.77	3.55
	JAN	138000	2244	24.7	12	3.72	2.77
	FEB	151000	2719	24.2	12	4.58	3.07
	MAR	204000	3318	23.7	123	5.32	3.96
	APR	220000	3697	23.4	123	5.95	4.29
	MAY	186000	3025	23.9	12	5.10	3.79
	JUN	223000	3748	23.3	123	6.03	4.34
	JUL	91000	1480	25.7	1	2.63	1.95
	AUG	87000	1415	25.8	1	2.50	1.86
	SEP	117000	1966	25.0	12	3.20	2.31
						TOTAL	39.00
1938	OCT	189000	3074	23.9	12	5.18	3.85
	NOV	185000	3109	23.8	12	5.24	3.77
	DEC	166000	2700	24.2	12	4.54	3.38
	JAN	199000	3236	23.7	123	5.18	3.85
	FEB	156000	2809	24.1	12	4.73	3.18
	MAR	206000	3350	23.6	123	5.37	4.00
	APR	319000	5361	22.1	1234	8.30	5.97
	MAY	403000	5766	21.2	1234	8.77	6.53
	JUN	644000	5766	18.9	1234	7.80	5.67
	JUL	335000	5448	22.0	1234	8.42	6.26
	AUG	133000	2163	24.7	12	3.57	2.66
	SEP	133000	2235	24.7	12	3.70	2.67
						TOTAL	51.79

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1939	OCT	278000	4521	22.7	123	7.27	5.41
	NOV	246000	4134	23.0	123	6.66	4.79
	DEC	216000	3513	23.5	123	5.64	4.20
	JAN	214000	3480	23.5	123	5.59	4.16
	FEB	149000	2683	24.2	12	4.51	3.03
	MAR	208000	3383	23.6	123	5.43	4.04
	APR	357000S	5766	21.6	1234	8.87	6.38
	MAY	652000S	5766	19.0	1234	7.94	5.91
	JUN	460000S	5766	20.5	1234	8.61	6.20
	JUL	196000	3188	23.8	12	5.37	4.00
	AUG	120000	1952	25.0	12	3.18	2.36
	SEP	117000	1966	25.0	12	3.20	2.31
						TOTAL	52.79
1940	OCT	221000	3594	23.4	123	5.78	4.30
	NOV	258000	4336	22.9	123	6.98	5.02
	DEC	195000	3171	23.8	12	5.35	3.98
	JAN	193000	3139	23.8	12	5.29	3.94
	FEB	192000	3457	23.5	123	5.55	3.73
	MAR	255000	4147	23.0	123	6.68	4.97
	APR	306000	5142	22.2	1234	7.97	5.74
	MAY	392000S	5766	21.3	1234	8.80	6.55
	JUN	380000S	5766	21.3	1234	8.80	6.34
	JUL	116000	1887	25.1	12	3.06	2.27
	AUG	97000	1578	25.6	1	2.81	2.09
	SEP	136000	2286	24.6	12	3.79	2.73
						TOTAL	51.66
1941	OCT	208000	3383	23.6	123	5.43	4.04
	NOV	225000	3781	23.3	123	6.09	4.38
	DEC	188000	3057	23.9	12	5.15	3.83
	JAN	195000	3171	23.8	12	5.35	3.98
	FEB	180000	3241	23.7	123	5.19	3.48
	MAR	211000	3432	23.6	123	5.51	4.10
	APR	273000	4588	22.7	123	7.37	5.31
	MAY	259000	4212	23.0	123	6.78	5.05
	JUN	384000S	5766	21.3	1234	8.79	6.33
	JUL	136000	2212	24.7	12	3.66	2.72
	AUG	141000	2293	24.6	12	3.81	2.83
	SEP	208000	3496	23.5	123	5.62	4.04
						TOTAL	50.10
1942	OCT	270000	4391	22.8	123	7.06	5.26
	NOV	255000	4285	22.9	123	6.90	4.97
	DEC	246000	4001	23.1	123	6.44	4.79
	JAN	183000	2976	23.9	12	5.01	3.73
	FEB	186000	3349	23.6	123	5.37	3.61
	MAR	246000	4001	23.1	123	6.44	4.79
	APR	519000S	5766	20.0	1234	8.48	6.11
	MAY	622000S	5766	19.3	1234	8.09	6.02
	JUN	943000S	5650	16.7	1234	6.55	4.71
	JUL	286000	4651	22.6	123	7.47	5.55
	AUG	112000	1821	25.2	12	2.94	2.18
	SEP	159000	2672	24.2	12	4.49	3.23
						TOTAL	54.96

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1943	OCT	200000	3253	23.7	123	5.21	3.87
	NOV	242000	4067	23.1	123	6.55	4.72
	DEC	234000	3806	23.3	123	6.13	4.56
	JAN	191000	3106	23.8	12	5.24	3.90
	FEB	259000	4663	22.6	123	7.49	5.03
	MAR	325000	5286	22.1	1234	8.19	6.09
	APR	515000S	5766	20.0	1234	8.49	6.12
	MAY	577000S	5766	19.6	1234	8.34	6.20
	JUN	1151000S	5537	15.4	1234	5.94	4.28
	JUL	479000S	5766	20.5	1234	8.61	6.40
	AUG	212000	3448	23.6	123	5.54	4.12
	SEP	185000	3109	23.8	12	5.24	3.77
						TOTAL	59.05
1944	OCT	224000	3643	23.4	123	5.86	4.36
	NOV	244000	4100	23.0	123	6.60	4.76
	DEC	233000	3789	23.3	123	6.10	4.54
	JAN	225000	3659	23.4	123	5.89	4.38
	FEB	201000	3619	23.4	123	5.82	3.91
	MAR	216000	3513	23.5	123	5.64	4.20
	APR	220000	3697	23.4	123	5.95	4.29
	MAY	279000	4537	22.7	123	7.29	5.43
	JUN	823000S	5650	17.5	1234	6.05	4.93
	JUL	427000S	5766	21.0	1234	8.71	6.48
	AUG	180000	2927	24.0	12	4.93	3.67
	SEP	196000	3294	23.7	123	5.28	3.80
						TOTAL	54.74
1945	OCT	207000	3366	23.6	123	5.40	4.02
	NOV	219000	3680	23.4	123	5.92	4.26
	DEC	198000	3220	23.7	123	5.15	3.83
	JAN	237000	3854	23.2	123	6.21	4.62
	FEB	207000	3727	23.3	123	6.00	4.03
	MAR	201000	3269	23.7	123	5.23	3.89
	APR	193000	3243	23.7	123	5.19	3.74
	MAY	320000	5204	22.2	1234	8.07	6.00
	JUN	571000S	5766	19.5	1234	8.26	5.95
	JUL	268000	4359	22.8	123	7.01	5.22
	AUG	153000	2488	24.4	12	4.16	3.10
	SEP	174000	2924	24.0	12	4.93	3.55
						TOTAL	52.21
1946	OCT	213000	3464	23.5	123	5.56	4.14
	NOV	220000	3697	23.4	123	5.95	4.29
	DEC	207000	3366	23.6	123	5.40	4.02
	JAN	210000	3545	23.5	123	5.70	4.24
	FEB	208000	3745	23.3	123	6.03	4.05
	MAR	259000	4212	23.0	123	6.78	5.05
	APR	357000S	5766	21.6	1234	8.87	6.38
	MAY	467000S	5766	20.6	1234	8.63	6.42
	JUN	435000S	5766	20.8	1234	8.67	6.24
	JUL	234000	3806	23.3	123	6.13	4.56
	AUG	151000	2456	24.5	12	4.10	3.05
	SEP	215000	3613	23.4	123	5.81	4.18
						TOTAL	56.62

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1947	OCT	260000	4228	22.9	123	6.81	5.06
	NOV	267000	4487	22.7	123	7.21	5.19
	DEC	277000	4505	22.7	123	7.24	5.39
	JAN	225000	3659	23.4	123	5.89	4.38
	FEB	206000	3709	23.3	123	5.97	4.01
	MAR	316000	5139	22.3	1234	7.97	5.93
	APR	450000S	5766	20.6	1234	8.63	6.22
	MAY	797000S	5766	17.9	1234	7.25	5.39
	JUN	882000S	5650	17.1	1234	6.69	4.82
	JUL	351000	5708	21.8	1234	8.82	6.56
	AUG	183000	2976	23.9	12	5.01	3.73
	SEP	235000	3949	23.2	123	6.36	4.58
						TOTAL	61.27
1948	OCT	300000	4879	22.4	1234	7.58	5.64
	NOV	280000	4705	22.6	123	7.55	5.43
	DEC	280000	4554	22.7	123	7.32	5.44
	JAN	245000	3984	23.1	123	6.42	4.78
	FEB	220000	3961	23.1	123	6.38	4.29
	MAR	277000	4505	22.7	123	7.24	5.39
	APR	499000S	5766	20.2	1234	8.53	6.14
	MAY	895000S	5650	17.2	1234	6.74	5.01
	JUN	1213000S	5537	15.0	1234	5.78	4.16
	JUL	398000S	5766	21.3	1234	8.79	6.54
	AUG	219000	3562	23.5	123	5.73	4.26
	SEP	208000	3496	23.5	123	5.62	4.04
						TOTAL	61.12
1949	OCT	261000	4245	22.9	123	6.83	5.08
	NOV	261000	4386	22.8	123	7.06	5.08
	DEC	236000	3838	23.2	123	6.18	4.60
	JAN	197000	3204	23.7	123	5.12	3.81
	FEB	192000	3457	23.5	123	5.55	3.73
	MAR	271000	4407	22.8	123	7.09	5.28
	APR	490000S	5766	20.3	1234	8.55	6.16
	MAY	626000S	5766	19.2	1234	8.07	6.00
	JUN	521000S	5766	20.0	1234	8.48	6.11
	JUL	182000	2960	24.0	12	4.99	3.71
	AUG	130000	2114	24.8	12	3.48	2.59
	SEP	198000	3327	23.6	123	5.33	3.84
						TOTAL	55.98
1950	OCT	233000	3789	23.3	123	6.10	4.54
	NOV	236000	3966	23.1	123	6.39	4.60
	DEC	207000	3366	23.6	123	5.40	4.02
	JAN	184000	2992	23.9	12	5.04	3.75
	FEB	203000	3655	23.4	123	5.88	3.95
	MAR	241000	3919	23.2	123	6.31	4.70
	APR	294000	4941	22.4	1234	7.67	5.52
	MAY	331000	5383	22.1	1234	8.33	6.19
	JUN	708000S	5766	18.4	1234	7.56	5.44
	JUL	372000S	5766	21.6	1234	8.86	6.59
	AUG	203000	3301	23.7	123	5.29	3.93
	SEP	237000	3983	23.1	123	6.42	4.62
						TOTAL	57.86

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1951	OCT	289000	4700	22.6	123	7.54	5.61
	NOV	275000	4621	22.6	123	7.42	5.34
	DEC	267000	4342	22.9	123	6.99	5.20
	JAN	207000	3366	23.6	123	5.40	4.02
	FEB	215000	3871	23.2	123	6.24	4.19
	MAR	250000	4066	23.1	123	6.55	4.87
	APR	334000	5613	21.9	1234	8.67	6.24
	MAY	677000S	5766	18.8	1234	7.82	5.82
	JUN	550000S	5766	19.7	1234	8.39	6.04
	JUL	234000	3806	23.3	123	6.13	4.56
	AUG	201000	3269	23.7	123	5.23	3.89
	SEP	221000	3714	23.3	123	5.98	4.30
						TOTAL	60.09
1952	OCT	255000	4147	23.0	123	6.68	4.97
	NOV	251000	4218	22.9	123	6.79	4.89
	DEC	201000	3269	23.7	123	5.23	3.89
	JAN	193000	3139	23.8	12	5.29	3.94
	FEB	226000	4069	23.1	123	6.55	4.40
	MAR	259000	4212	23.0	123	6.78	5.05
	APR	499000S	5766	20.2	1234	8.53	6.14
	MAY	904000S	5650	17.1	1234	6.71	4.99
	JUN	713000S	5766	18.4	1234	7.53	5.43
	JUL	317000	5155	22.2	1234	7.99	5.95
	AUG	176000	2862	24.0	12	4.82	3.59
	SEP	215000	3613	23.4	123	5.81	4.18
						TOTAL	57.41
1953	OCT	226000	3675	23.4	123	5.91	4.40
	NOV	247000	4151	23.0	123	6.68	4.81
	DEC	254000	4131	23.0	123	6.65	4.95
	JAN	250000	4066	23.1	123	6.55	4.87
	FEB	198000	3565	23.5	123	5.73	3.85
	MAR	213000	3464	23.5	123	5.56	4.14
	APR	225000	3781	23.3	123	6.09	4.38
	MAY	283000	4602	22.7	123	7.39	5.50
	JUN	907000S	5650	16.9	1234	6.63	4.77
	JUL	291000	4733	22.0	123	7.59	5.65
	AUG	143000	2326	24.6	12	3.87	2.88
	SEP	178000	2991	23.9	12	5.04	3.63
						TOTAL	53.84
1954	OCT	254000	4131	23.0	123	6.65	4.95
	NOV	269000	4521	22.7	123	7.26	5.23
	DEC	221000	3594	23.4	123	5.78	4.30
	JAN	182000	2960	24.0	12	4.99	3.71
	FEB	211000	3799	23.3	123	6.12	4.11
	MAR	202000	3285	23.7	123	5.26	3.91
	APR	227000	3815	23.3	123	6.14	4.42
	MAY	310000	5042	22.3	1234	7.82	5.82
	JUN	365000S	5766	21.5	1234	8.85	6.37
	JUL	252000	4098	23.0	123	6.60	4.91
	AUG	139000	2261	24.6	12	3.75	2.79
	SEP	153000	2571	24.3	12	4.31	3.10
						TOTAL	53.64

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1955	OCT	224000	3643	23.4	123	5.86	4.36
	NOV	241000	4050	23.1	123	6.52	4.70
	DEC	173000	2814	24.1	12	4.74	3.52
	JAN	167000	2716	24.2	12	4.57	3.40
	FEB	147000	2647	24.3	12	4.45	2.99
	MAR	174000	2830	24.1	12	4.77	3.55
	APR	214000	3596	23.4	123	5.78	4.17
	MAY	348000	5660	21.9	1234	8.74	6.51
	JUN	507000S	5766	20.1	1234	8.51	6.13
	JUL	321000	5220	22.2	1234	8.09	6.02
	AUG	116000	1887	25.1	12	3.06	2.27
	SEP	146000	2454	24.5	12	4.10	2.95
						TOTAL	50.56
1956	OCT	201000	3269	23.7	123	5.23	3.89
	NOV	235000	3949	23.2	123	6.36	4.58
	DEC	230000	3741	23.3	123	6.02	4.48
	JAN	225000	3659	23.4	123	5.89	4.38
	FEB	158000	2845	24.1	12	4.79	3.22
	MAR	290000	4716	22.6	123	7.57	5.63
	APR	387000S	5766	21.3	1234	8.78	6.32
	MAY	726000S	5766	18.5	1234	7.59	5.64
	JUN	636000S	5766	19.0	1234	7.92	5.70
	JUL	174000	2830	24.1	12	4.77	3.55
	AUG	130000	2114	24.8	12	3.48	2.59
	SEP	167000	2806	24.1	12	4.73	3.40
						TOTAL	53.39
1957	OCT	230000	3741	23.3	123	6.02	4.48
	NOV	293000	4924	22.4	1234	7.64	5.50
	DEC	202000	3285	23.7	123	5.26	3.91
	JAN	151000	2456	24.5	12	4.10	3.05
	FEB	188000	3385	23.6	123	5.43	3.65
	MAR	224000	3643	23.4	123	5.86	4.36
	APR	246000	4134	23.0	123	6.66	4.79
	MAY	586000S	5766	19.6	1234	8.28	6.16
	JUN	721000S	5766	18.3	1234	7.50	5.40
	JUL	232000	3773	23.3	123	6.08	4.52
	AUG	109000	1773	25.3	12	2.85	2.12
	SEP	171000	2874	24.0	12	4.84	3.48
						TOTAL	51.44
1958	OCT	275000	4472	22.8	123	7.19	5.35
	NOV	298000	5008	22.4	1234	7.77	5.60
	DEC	238000	3871	23.2	123	6.23	4.64
	JAN	201000	3269	23.7	123	5.23	3.89
	FEB	196000	3529	23.5	123	5.67	3.81
	MAR	219000	3562	23.5	123	5.73	4.26
	APR	264000	4437	22.8	123	7.14	5.14
	MAY	558000S	5766	19.8	1234	8.44	6.28
	JUN	506000S	5766	20.1	1234	8.51	6.13
	JUL	228000	3708	23.3	123	5.97	4.44
	AUG	131000	2130	24.8	12	3.51	2.61
	SEP	153000	2571	24.3	12	4.31	3.10
						TOTAL	55.26

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1959	OCT	240000	3903	23.2	123	6.29	4.68
	NOV	258000	4336	22.9	123	6.98	5.02
	DEC	225000	3659	23.4	123	5.89	4.38
	JAN	189000	3074	23.9	12	5.18	3.85
	FEB	156000	2809	24.1	12	4.73	3.18
	MAR	238000	3871	23.2	123	6.23	4.64
	APR	281000	4722	22.6	123	7.57	5.45
	MAY	306000	4977	22.4	1234	7.72	5.75
	JUN	693000	5766	18.6	1234	7.64	5.50
	JUL	277000	4505	22.7	123	7.24	5.39
	AUG	100000	1626	25.5	12	2.57	1.91
	SEP	151000	2538	24.4	12	4.25	3.06
						TOTAL	52.81
1960	OCT	365000	5766	21.7	1234	8.88	6.61
	NOV	390000	5766	21.2	1234	8.77	6.32
	DEC	367000	5766	21.6	1234	8.87	6.60
	JAN	204000	3318	23.7	123	5.32	3.96
	FEB	219000	3943	23.2	123	6.35	4.27
	MAR	349000	5676	21.9	1234	8.77	6.52
	APR	419000	5766	20.9	1234	8.70	6.27
	MAY	447000	5766	20.8	1234	8.67	6.45
	JUN	422000	5766	20.9	1234	8.70	6.26
	JUL	109000	1773	25.3	12	2.85	2.12
	AUG	104000	1691	25.4	12	2.69	2.00
	SEP	143000	2403	24.5	12	4.01	2.89
						TOTAL	60.26
1961	OCT	177000	2879	24.0	12	4.85	3.61
	NOV	219000	3680	23.4	123	5.92	4.26
	DEC	199000	3236	23.7	123	5.18	3.85
	JAN	182000	2960	24.0	12	4.99	3.71
	FEB	188000	3385	23.6	123	5.43	3.65
	MAR	185000	3009	23.9	12	5.07	3.77
	APR	142000	2386	24.5	12	3.98	2.86
	MAY	192000	3123	23.8	12	5.26	3.92
	JUN	308000	5176	22.2	1234	8.02	5.78
	JUL	85000	1382	25.9	1	2.44	1.02
	AUG	66000	1073	26.4	1	1.84	1.37
	SEP	176000	2958	24.0	12	4.98	3.59
						TOTAL	42.19
1962	OCT	305000	4960	22.4	1234	7.70	5.73
	NOV	312000	5243	22.2	1234	8.12	5.85
	DEC	188000	3057	23.9	12	5.15	3.83
	JAN	153000	2488	24.4	12	4.16	3.10
	FEB	196000	3529	23.5	123	5.67	3.81
	MAR	232000	3773	23.3	123	6.08	4.52
	APR	379000	5766	21.4	1234	8.81	6.34
	MAY	480000	5766	20.5	1234	8.60	6.40
	JUN	641000	5766	19.0	1234	7.89	5.68
	JUL	270000	4391	22.8	123	7.06	5.26
	AUG	174000	2830	24.1	12	4.77	3.55
	SEP	215000	3613	23.4	123	5.81	4.18
						TOTAL	58.25

YEAR	MONTH	OUTFLOW (AF) (CFS)		AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1963	OCT	292000	4749	22.5	123	7.61	5.67
	NOV	306000	5142	22.2	1234	7.97	5.74
	DEC	252000	4098	23.0	123	6.60	4.91
	JAN	175000	2846	24.1	12	4.79	3.57
	FEB	271000	4880	22.4	1234	7.58	5.09
	MAR	219000	3562	23.5	123	5.73	4.26
	APR	235000	3949	23.2	123	6.36	4.58
	MAY	477000S	5766	20.5	1234	8.61	6.41
	JUN	826000S	5650	17.5	1234	6.84	4.93
	JUL	272000	4424	22.8	123	7.12	5.29
	AUG	121000	1968	25.0	12	3.21	2.39
	SEP	204000	3428	23.6	123	5.50	3.96
						TOTAL	56.79
1964	OCT	247000	4017	23.1	123	6.47	4.81
	NOV	291000	4890	22.4	1234	7.59	5.47
	DEC	199000	3236	23.7	123	5.18	3.85
	JAN	199000	3236	23.7	123	5.18	3.85
	FEB	189000	3403	23.6	123	5.46	3.67
	MAR	208000	3383	23.6	123	5.43	4.04
	APR	249000	4185	23.0	123	6.74	4.85
	MAY	470000S	5766	20.6	1234	8.62	6.42
	JUN	1063000S	5650	15.9	1234	6.28	4.52
	JUL	417000S	5766	21.1	1234	8.74	6.50
	AUG	159000	2586	24.3	12	4.34	3.23
	SEP	219000	3680	23.4	123	5.92	4.26
						TOTAL	55.48
1965	OCT	250000	4066	23.1	123	6.55	4.87
	NOV	297000	4991	22.4	1234	7.75	5.58
	DEC	232000	3773	23.3	123	6.09	4.52
	JAN	256000	4163	23.0	123	6.70	4.99
	FEB	228000	4105	23.0	123	6.61	4.44
	MAR	230000	3741	23.3	123	6.02	4.48
	APR	390000S	5766	21.2	1234	8.77	6.32
	MAY	612000S	5766	19.3	1234	8.14	6.05
	JUN	1069000S	5650	15.9	1234	6.27	4.51
	JUL	604000S	5766	19.4	1234	8.18	6.09
	AUG	242000	3936	23.2	123	6.34	4.72
	SEP	279000	4689	22.6	123	7.52	5.42
						TOTAL	61.99
1966	OCT	349000	5676	21.9	1234	8.77	6.52
	NOV	379000S	5766	21.4	1234	8.81	6.34
	DEC	250000	4066	23.1	123	6.55	4.87
	JAN	230000	3741	23.3	123	6.02	4.48
	FEB	209000	3763	23.3	123	6.06	4.07
	MAR	239000	3887	23.2	123	6.26	4.66
	APR	261000	4386	22.8	123	7.06	5.08
	MAY	271000	4407	22.8	123	7.09	5.28
	JUN	238000	4000	23.1	123	6.44	4.64
	JUL	121000	1968	25.0	12	3.21	2.39
	AUG	77000	1252	26.1	1	2.19	1.63
	SEP	121000	2033	24.9	12	3.33	2.40
						TOTAL	52.35

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1967	OCT	250000	4066	23.1	123	6.55	4.87
	NOV	286000	4806	22.5	1234	7.47	5.38
	DEC	202000	3285	23.7	123	5.26	3.91
	JAN	209000	3399	23.6	123	5.45	4.06
	FEB	188000	3385	23.6	123	5.43	3.65
	MAR	197000	3204	23.7	123	5.12	3.81
	APR	211000	3546	23.5	123	5.70	4.10
	MAY	569000S	5766	19.7	1234	8.38	6.23
	JUN	1269000S	5537	14.6	1234	5.63	4.05
	JUL	461000S	5766	20.7	1234	8.64	6.43
	AUG	147000	2391	24.5	12	3.99	2.97
	SEP	199000	3344	23.6	123	5.36	3.86
						TOTAL	53.33
1968	OCT	302000	4911	22.4	1234	7.63	5.67
	NOV	309000	5193	22.2	1234	8.05	5.80
	DEC	228000	3708	23.3	123	5.97	4.44
	JAN	225000	3659	23.4	123	5.89	4.38
	FEB	254000	4573	22.7	123	7.35	4.94
	MAR	278000	4521	22.7	123	7.27	5.41
	APR	299000	5025	22.3	1234	7.80	5.61
	MAY	460000S	5766	20.7	1234	8.65	6.43
	JUN	1041000S	5650	16.1	1234	6.33	4.56
	JUL	360000S	5766	21.7	1234	8.89	6.62
	AUG	233000	3789	23.3	123	6.10	4.54
	SEP	298000	5008	22.4	1234	7.77	5.60
						TOTAL	63.99
1969	OCT	321000	5220	22.2	1234	8.09	6.02
	NOV	322000	5411	22.0	1234	8.37	6.02
	DEC	244000	3968	23.1	123	6.33	4.76
	JAN	226000	3675	23.4	123	5.91	4.40
	FEB	240000	4321	22.9	123	6.95	4.67
	MAR	306000	4977	22.4	1234	7.72	5.75
	APR	600000S	5766	19.3	1234	8.10	5.83
	MAY	894000S	5650	17.2	1234	6.74	5.01
	JUN	652000S	5766	18.9	1234	7.84	5.64
	JUL	434000S	5766	20.9	1234	8.70	6.47
	AUG	189000	3074	23.9	12	5.18	3.85
	SEP	202000	3395	23.6	123	5.45	3.92
						TOTAL	62.36
1970	OCT	327000	5318	22.1	1234	8.23	6.12
	NOV	302000	5075	22.0	1234	7.87	5.67
	DEC	249000	4050	23.1	123	6.52	4.85
	JAN	230000	3741	23.3	123	6.02	4.48
	FEB	214000	3853	23.2	123	6.21	4.17
	MAR	235000	3822	23.3	123	6.16	4.58
	APR	259000	4353	22.8	123	7.00	5.04
	MAY	714000S	5766	18.6	1234	7.64	5.69
	JUN	1117000S	5650	15.6	1234	6.16	4.43
	JUL	467000S	5766	20.6	1234	8.63	6.42
	AUG	186000	3025	23.9	12	5.10	3.79
	SEP	262000	4403	22.8	123	7.08	5.10
						TOTAL	60.35

YEAR	MONTH	OUTFLOW (AF) (CFS)		AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1971	OCT	332000	5399	22.1	1234	8.35	6.21
	NOV	339000	5697	21.8	1234	8.80	6.34
	DEC	259000	4212	23.0	123	6.78	5.05
	JAN	259000	4212	23.0	123	6.78	5.05
	FEB	266000	4790	22.5	1234	7.44	5.00
	MAR	241000	3919	23.2	123	6.31	4.70
	APR	402000	5766	21.1	1234	8.74	6.29
	MAY	784000	5766	18.0	1234	7.31	5.44
	JUN	1080000	5650	15.8	1234	6.24	4.49
	JUL	510000	5766	20.2	1234	8.54	6.36
	AUG	214000	3480	23.5	123	5.59	4.16
	SEP	290000	4874	22.5	1234	7.57	5.45
						TOTAL	64.53
1972	OCT	348000	5660	21.9	1234	8.74	6.51
	NOV	339000	5697	21.8	1234	8.80	6.34
	DEC	248000	4033	23.1	123	6.50	4.83
	JAN	252000	4098	23.0	123	6.60	4.91
	FEB	261000	4699	22.6	123	7.54	5.07
	MAR	331000	5383	22.1	1234	8.33	6.19
	APR	398000	5766	21.1	1234	8.75	6.30
	MAY	574000	5766	19.7	1234	8.35	6.22
	JUN	957000	5650	16.6	1234	6.52	4.69
	JUL	296000	4814	22.5	1234	7.48	5.56
	AUG	189000	3074	23.9	12	5.18	3.85
	SEP	239000	4016	23.1	123	6.47	4.66
						TOTAL	65.13
1973	OCT	354000	5757	21.8	1234	8.89	6.62
	NOV	357000	5766	21.6	1234	8.87	6.38
	DEC	225000	3659	23.4	123	5.89	4.38
	JAN	225000	3659	23.4	123	5.89	4.38
	FEB	216000	3889	23.2	123	6.26	4.21
	MAR	254000	4131	23.0	123	6.65	4.95
	APR	286000	4806	22.5	1234	7.47	5.38
	MAY	432000	5766	20.9	1234	8.71	6.48
	JUN	442000	5766	20.7	1234	8.65	6.23
	JUL	206000	3350	23.6	123	5.37	4.00
	AUG	120000	1952	25.0	12	3.18	2.36
	SEP	222000	3731	23.3	123	6.01	4.32
						TOTAL	59.69
1974	OCT	272000	4424	22.8	123	7.12	5.29
	NOV	316000	5310	22.1	1234	8.22	5.92
	DEC	250000	4066	23.1	123	6.55	4.87
	JAN	223000	3627	23.4	123	5.83	4.34
	FEB	219000	3943	23.2	123	6.35	4.27
	MAR	272000	4424	22.8	123	7.12	5.29
	APR	412000	5766	21.0	1234	8.72	6.28
	MAY	539000	5766	20.0	1234	8.48	6.31
	JUN	1032000	5650	16.1	1234	6.35	4.57
	JUL	324000	5269	22.2	1234	8.16	6.07
	AUG	181000	2944	24.0	12	4.96	3.69
	SEP	204000	3428	23.6	123	5.50	3.96
						TOTAL	60.87

YEAR	MONTH	OUTFLOW (AF)	OUTFLOW (CFS)	AVERAGE HEAD (FT)	ON-LINE UNITS	POWER (MW)	ENERGY (MKWH)
1975	OCT	294000	4781	22.5	123	7.67	5.70
	NOV	268000	4504	22.7	123	7.24	5.21
	DEC	256000	4163	23.0	123	6.70	4.99
	JAN	209000	3399	23.6	123	5.45	4.06
	FEB	194000	3493	23.5	123	5.61	3.77
	MAR	252000	4098	23.0	123	6.60	4.91
	APR	291000	4890	22.4	1234	7.59	5.47
	MAY	620000	5766	19.3	1234	8.10	6.03
	JUN	1164000	5537	15.3	1234	5.91	4.25
	JUL	876000	5650	17.4	1234	6.78	5.05
	AUG	352000	5725	21.8	1234	8.84	6.58
	SEP	283000	4756	22.5	123	7.63	5.49
						TOTAL	61.51
1976	OCT	302000	5766	21.5	1234	8.83	6.57
	NOV	375000	5766	21.4	1234	8.81	6.35
	DEC	351000	5708	21.8	1234	8.82	6.56
	JAN	283000	4602	22.7	123	7.39	5.50
	FEB	244000	4393	22.8	123	7.07	4.75
	MAR	301000	4895	22.4	1234	7.60	5.65
	APR	524000	5766	20.0	1234	8.48	6.10
	MAY	1132000	5650	15.7	1234	6.21	4.62
	JUN	896000	5650	17.0	1234	6.65	4.79
	JUL	393000	5766	21.3	1234	8.80	6.55
	AUG	350000	5692	21.8	1234	8.80	6.54
	SEP	314000	5277	22.1	1234	8.17	5.88
						TOTAL	69.87
1977	OCT	417000	5766	21.1	1234	8.74	6.50
	NOV	378000	5766	21.4	1234	8.81	6.34
	DEC	286000	4651	22.6	123	7.47	5.55
	JAN	227000	3692	23.4	123	5.94	4.42
	FEB	214000	3853	23.2	123	6.21	4.17
	MAR	220000	3578	23.4	123	5.75	4.28
	APR	292000	4907	22.4	1234	7.62	5.49
	MAY	211000	3432	23.6	123	5.51	4.10
	JUN	315000	5294	22.1	1234	8.20	5.90
	JUL	123000	2000	24.9	12	3.27	2.43
	AUG	104000	1691	25.4	12	2.69	2.00
	SEP	188000	3159	23.8	12	5.33	3.83
						TOTAL	55.02
1978	OCT	285000	4635	22.6	123	7.44	5.54
	NOV	276000	4638	22.6	123	7.45	5.36
	DEC	243000	3952	23.1	123	6.36	4.74
	JAN	226000	3675	23.4	123	5.91	4.40
	FEB	207000	3727	23.3	123	6.00	4.03
	MAR	324000	5269	22.2	1234	8.16	6.07
	APR	428000	5766	20.8	1234	8.68	6.25
	MAY	591000	5766	19.5	1234	8.26	6.14
	JUN	679000	5766	18.7	1234	7.71	5.55
	JUL	421000	5766	21.0	1234	8.73	6.49
	AUG	172000	2797	24.1	12	4.71	3.50
	SEP	279000	4689	22.6	123	7.52	5.42
						TOTAL	63.50

AVERAGE ANNUAL ENERGY = 55.09 MKWH

APPENDIX C - COST ESTIMATES

DETAILED COST ESTIMATE

MARCH 1979 PRICES

APRON-MOUNTED ALTERNATIVE

Acct	Item	Unit	Quantity	Unit Price	Amount	Acct.Total
330	LAND AND LAND RIGHTS	LS				\$50,000
331	STRUCTURES AND IMPROVEMENTS					
331.01	Mobilization & Demobilization	LS			\$100,000	
331.02	Watercare & Diversion	LS			60,000	
331.03	Concrete Removal	CY	350	\$50.00	17,500	
331.04	Common Excavation	CY	2,600	2.50	6,500	
331.05	Rock Excavation	CY	4,500	10.00	45,000	
331.06	Foundation Preparation	SF	6,600	1.00	6,600	
331.07	Drains & Filters	LF	400	2.00	800	
331.08	Concrete Anchors	LF	1,800	12.50	22,500	
331.09	Grouting, Normal	CF	500	20.00	10,000	
331.10	Grouting, Epoxy	CF	200	50.00	10,000	
331.11	Concrete	CY	6,350	170.00	1,079,500	
331.12	Reinforcement	LB	725,000	0.40	290,000	
331.13	Miscellaneous Metal	LB	27,000	1.75	47,250	
331.14	Hatches, etc.	LB	14,500	2.25	32,625	
331.15	Waterproofing	SF	12,000	1.25	15,000	
331.16	Backfill	CY	3,800	2.50	9,500	
331.17	Disposal Fill	CY	3,650	1.00	3,650	
331.18	Overhead Crane	LS			80,000	
331.19	D/S Gantry Crane	LS			60,000	
331.20	Miscellaneous Items	LS			53,575	
	TOTAL ACCOUNT 331					1,950,000
332	RESERVOIR, DAM AND WATERWAYS					
332.01	Forebay Cleanup & Logboom	LS			50,000	
332.02	Sluiceway, Remedial Work	LS			56,000	
332.03	Tailrace Excavation, Rock	CY	1,200	10.00	12,000	
332.04	Concrete, Training walls	CY	1,500	170.00	255,000	
332.05	Reinforcement	LB	194,000	0.40	77,600	
332.06	Grouting	CF	920	20.00	18,400	

DETAILED COST ESTIMATE

MARCH 1979 PRICES

APRON-MOUNTED ALTERNATIVE

Acct	Item	Unit	Quantity	Unit Price	Amount	Acct.Total
332.07	Riprap Protection	CY	400	20.00	8,000	
332.08	Stoplogs (2 bays)	LS			20,000	
332.09	Trashracks	LB	60,000	1.75	105,000	
332.10	Trashrack Cleaner	LS			60,000	
332.11	Radial Gates	LB	302,500	2.00	605,000	
332.12	Vortex Suppressors	LS			40,000	
332.13	Fixed Wheel Gates	LB	100,000	2.25	225,000	
332.14	U/S Gantry Crane	LS			100,000	
332.15	Watercare and Diversion	LS			50,000	
332.16	Concrete Removal	CY	150	50.00	7,500	
332.17	Crane Rails	LB	66,000	0.30	19,800	
332.18	Concrete Anchors	LF	2,200	12.50	27,500	
332.19	Switchyard Work	LS			30,000	
332.20	Control Structure, Removal	LS			25,000	
332.21	Excavation	CY	450	10.00	4,500	
332.22	Control Structure Reconstruction	LS			70,000	
332.23	Control Equipment	LS			15,000	
332.24	Miscellaneous Metal	LB	6,500	1.75	11,375	
332.25	Miscellaneous Items	LS			72,325	
TOTAL ACCOUNT 332						1,965,000
333	WATERWHEELS, TURBINES & GENERATORS					
333.01	Turbines & Governors	LS			2,428,000	
333.02	Generators	LS			540,000	
333.03	Speed Increasers	LS			536,000	
333.04	Butterfly Valve		NR			
333.05	Installation	LS			350,000	
TOTAL ACCOUNT 333						\$3,854,000

DETAILED-COST ESTIMATE

MARCH 1979 PRICES

APRON-MOUNTED ALTERNATIVE

<u>Acct</u>	<u>Item</u>	<u>Unit</u>	<u>Quantity</u>	<u>Unit Price</u>	<u>Amount</u>	<u>Acct.Total</u>
334	ACCESSORY ELECTRICAL EQUIPMENT					
334.01	Transformer, Circuit Breaker, Switchgear, etc.	LS			235,000	
334.02	Station Electrical Equipment	LS			631,000	
334.03	Additional Breakers	LS			86,000	
	TOTAL ACCOUNT 334					952,000
335	MISCELLANEOUS POWER PLANT EQUIPMENT	LS				128,000
355	TRANSMISSION LINE	LS				200,000
	GRAND TOTAL ALL ACCOUNTS					\$9,099,000

DETAILED COST ESTIMATE

MARCH 1979 PRICES

CONVENTIONAL ALTERNATIVE

Acct	Item	Unit	Quantity	Unit Price	Amount	Acct.Total
330	LAND AND LAND RIGHTS					\$50,000
331	STRUCTURES AND IMPROVEMENTS					
331.01	Mobilization and Demobilization	LS			100,000	
331.01	Watercare and Diversion	LS			30,000	
331.03	Common Excavation	CY	3,000	2.50	7,500	
331.04	Rock Excavation	CY	12,500	10.00	125,000	
331.05	Foundation Preparation	SF	9,200	1.00	9,200	
331.06	Drains and Filters	LF	640	2.00	1,280	
331.07	Rock Anchors	LF	1,800	12.50	22,500	
331.08	Normal Grouting	CF	500	20.00	10,000	
331.09	Concrete	CY	6,000	170.00	1,020,000	
331.10	Reinforcing Steel	LB	685,000	0.40	274,000	
331.11	Miscellaneous Metal	LB	30,000	1.75	52,500	
331.12	Hatches, etc.	LB	27,200	2.25	61,200	
331.13	Waterproofing	SF	32,500	1.25	40,625	
331.14	Backfill	CY	3,500	2.50	8,750	
331.15	Disposal Fill	CY	12,000	1.00	12,000	
331.16	Overhead Crane	LS			80,000	
331.17	Miscellaneous Items	LS			45,445	
	TOTAL ACCOUNT 331					\$1,900,000
332	RESERVOIR, DAM & WATERWAYS					
332.01	Common Excavation	CY	10,400	2.50	26,000	
332.02	Rock Excavation	CY	42,850	10.00	428,500	
332.03	Backfill	CY	4,000	2.50	10,000	
332.04	Disposal Fill	CY	48,800	1.00	48,800	
332.05	Retaining Walls	CY	700	170.00	119,000	
332.06	Reinforcing Steel	LB	255,000	0.40	102,000	
332.07	Riprap Protection	CY	400	20.00	8,000	
332.08	Stoplogs (2 Bays)	LS			20,000	
332.09	Trashracks	LB	60,000	1.75	105,000	
332.10	Trashrack Cleaners	LS			50,000	

DETAILED COST ESTIMATE

MARCH 1979 PRICES

CONVENTIONAL ALTERNATIVE

<u>Acct</u>	<u>Item</u>	<u>Unit</u>	<u>Quantity</u>	<u>Unit Price</u>	<u>Amount</u>	<u>Acct.Total</u>
332.11	Watercare and Diversion	LS			50,000	
332.12	Concrete Removal	CY	150	50.00	7,500	
332.13	Concrete	CY	1,450	170.00	246,500	
332.14	Radial Gates	LB	302,500	2.00	605,000	
332.15	Crane Rails	LB	66,000	0.30	19,800	
332.16	Miscellaneous Metal	LB	8,500	1.75	14,875	
332.17	Concrete Anchor	LF	3,000	12.50	37,500	
332.18	Grouting, Normal	CF	850	20.00	17,000	
332.19	Switchyard Work	LS			30,000	
332.20	Control Structure, Removal	LS			25,000	
332.21	Control Structure, Construction	LS			70,000	
332.22	Gantry Crane	LS			100,000	
332.23	Control Equipment	LS			15,000	
332.24	Miscellaneous Items	LS			44,525	
	TOTAL ACCOUNT 332					\$2,200,000
333	WATERWHEELS, TURBINES AND GENERATORS					
333.01	Turbine & Governor	LS			4,800,000	
333.02	Generator				Incl	
333.03	Speed Increaser				Incl	
333.04	Butterfly Valve				Incl	
333.05	Installation	LS			350,000	
	TOTAL ACCOUNT 333					\$5,150,000

DETAILED COST ESTIMATE

MARCH 1979 PRICES

CONVENTIONAL ALTERNATIVE

<u>Acct</u>	<u>Item</u>	<u>Unit</u>	<u>Quantity</u>	<u>Unit Price</u>	<u>Amount</u>	<u>Acct.Total</u>
334	ACCESSORY ELECTRICAL EQUIPMENT					
334.01	Transformer, Circuit Breaker, Switchgear, etc.	LS			235,000	
334.02	Station Electrical Equipment	LS			631,000	
334.03	Additional Breakers	LS			86,000	
	TOTAL ACCOUNT 334					\$952,000
335	MISCELLANEOUS POWER PLANT EQUIPMENT	LS				128,000
355	TRANSMISSION LINE	LS				200,000
	GRAND TOTAL ALL ACCOUNTS					\$10,580,000