University of Minnesota
St. Anthony Falls Hydraulic Laboratory

Project Report No. 200

HYDROPOWER FEASIBILITY AT THE KETTLE RIVER DAM MN00513

by

John S. Gulliver, Robert J. Knowlton,
and Rodrick J. Garver

Prepared for

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
St. Paul, Minnesota

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ACKNOWLEDGEMENTS

This study was performed under the general supervision of Professor Roger E. A. Arndt, Director of the St. Anthony Falls Hydraulic Laboratory. Alan Rindels was responsible for the required hydrologic computations and Richard Renaud performed the economic computations.

The authors would like to thank Mr. Craig Regalia of the Minnesota Department of Natural Resources for providing input and assistance whenever needed.

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I. INTRODUCTION

The Kettle River Dam is located on the Kettle River near Sandstone, Minnesota. The existing dam and powerhouse were originally constructed in 1908 by the Kettle River Power Company for power production. The ownership of the dam and powerhouse has been transferred several times, and the current owner is the State of Minnesota, Department of Natural Resources, Parks and Recreation Division. The generation of electric power was discontinued in 1963. The purpose of this study is to assess the feasibility of redeveloping hydropower production facilities at the Kettle River Dam.

The Kettle River Dam was included in a grant agreement dated September 22, 1980, between the DNR and the St. Anthony Falls Hydraulic Laboratory for Hydroelectric Power Feasibility Studies on seven municipally owned dam sites in the State of Minnesota. Authorization to begin the Kettle River Dam Hydropower Feasibility Study was given October 16, 1980.

This study begins with a hydraulic and hydrologic analysis of the site to determine the available power. The value of the power and marketing options is then determined. The core of the study is proposed development alternatives which include preliminary layouts, project cost estimates, and the estimated power production of each alternative. Finally, the benefits and costs of each development alternative are compared and the environmental impact of the proposed development is evaluated.

II. SUMMARY AND CONCLUSIONS

The Kettle River Dam MN 00513 is located within the corporate limits of the City of Sandstone, Minnesota, approximately 1 mile south of the city center in a sparsely populated reach of the Kettle River. The existing dam and powerhouse at Kettle River were originally constructed in 1908 by the Kettle River Power Company for power production. The Kettle River Dam has two spillways (main spillway and primary spillway). The generation of electric power was discontinued in 1963. The dam, powerhouse, and approximately 197 acres of adjoining land were acquired by the State of Minnesota in 1967 as a gift from Minnesota Power and Light Company. Minnesota Power and Light retained mineral rights as well as an easement to construct and maintain transmission lines and a distribution system. The powerhouse consists of a short headrace and two turbine pits with trashracks and vertical head gates. The #1 unit, a 2 runner, 395 kW Leffel Francis Turbine is an open flume arrangement The #2 unit is a 187 kW pressure case Francis turbine manufactured by the James Leffel Company. Each turbine has a horizontal shaft leading into the generator room. The superstructure of the generator room and half of the turbine room have been removed. The generators have been removed and the existing turbines are in poor condition. The existing turbines, however, have not deteriorated beyond the point of rehabilitation, if desired.

The average annual discharge at the site is 722 cfs. The design net head is approximately 20 ft. The drainage area is 863 mi^2. A minimum flow of 25 cfs was recorded on November 11-12, 1977. The maximum recorded discharge is 17,200 cfs on July 23, 1972. Flow duration curves indicate that the flow is relatively consistent throughout the year except for the spring runoff period. There is no annual drought period where the base flows are extremely low.

The Kettle River Dam has little or no storage capability for hydropower purposes. The surface area of the reservoir is approximately 30 acres, and the total reservoir storage is 230 acre-feet. This surface area is not sufficient for any significant daily peaking of power production. Drawing the reservoir down 1 ft over 6 hours will only add 60 cfs to the turbine discharge.

The Public Utility Regulatory Policy Act of 1978 (PURPA) and the subsequent Federal Energy Regulatory Commission (FERC) regulations specify that a utility must purchase power from a small hydropower facility at the utility's avoided incremental cost, i.e., the costs the utility would otherwise incur to obtain an equivalent amount of electricity. The Minnesota Public Utilities Commission (PUC) has jurisdiction over implementing PURPA in the State of Minnesota. Proposed PUC rules are used in Section VI to determine incremental avoided costs for possible power purchasers. Currently, the greatest amount of income will be generated by selling electricity to Minnesota Power. The utility's avoided energy cost over the next five years is 1.85 cents/kWH (1981 base year). In addition, energy which is dependable and qualifies for capacity credit may be sold for an additional 3.2 cents/kWH (1982 base year).

Among the four project development alternatives outlined in detail in Section VIII, little difference in project cost and energy production is noted. The main difference occurs in the choice of an operational scheme, which greatly affects the energy generated and the corresponding capacity credits. Alternative C, on the average, appears to give marginally superior economic feasibility indicators. Therefore, Alternative C is used to develop the cost and benefit streams, private financing example, and the sensitivity analysis in Section IX. The total initial project cost for Alternative C is estimated to be $1,313,000 (1981 base year), excluding financing costs.

Five options for the facility operational scheme are described in Section VII. These five options are:

1. Strict run-of river. The most obvious operational option is simply to direct the flow of the river through the turbines when possible. At flows below the turbine operating conditions, all

river flow will pass over the spillway. When river discharge exceeds the turbine capacity, there will be flow both through the turbines and over the spillway. The remainder of the time (moderate river discharge), all river flow will be through the turbines and the spillway will be dry.

2. Flow over spillway. Since the Kettle River Dam is a scenic attraction, another operational option is to dictate that a given discharge must pass over the spillway at all times. The authors' qualitative judgement is that 50 cfs discharge over the spillway is sufficient to maintain the "falling water" appearance without detracting from the spillway's scenic qualities.

3. Reservoir drawdown. Power may be generated at flows below minimum turbine flows if water is alternatively stored and released. With this procedure power is generated with a turbine flow which is at or above the allowable minimum until the headwater elevation is $\sim$0.5 ft below the spillway crest. The turbines are then shut down to allow the reservoir to fill up to the spillway crest. Finally, the turbine gates are again opened and power production resumes.

   This operational procedure can be set up so that the turbines are shut down for only 1 to 2 hours at a time. For most dam sites, eliminating river discharge for two hours will not have a significant detrimental effect upon the downstream biota, because the corresponding change in tailwater elevation is not great. The environmental impact of this operational procedure at the Kettle River Dam is considered in Section X.

   Reservoir drawdown will increase the energy produced at the Kettle River Dam and will greatly increase the capacity payment for dependable capacity, as described in Section VI.

   The disadvantage to reservoir drawdown is that there can be no flow over the spillway except when the discharge capacity of the turbines is exceeded.

4. Off-season drawdown. An operation procedure which combines Options 2 and 3 is 1) to require a minimum flow over the spillway during tourist season, May through September, when the scenic attraction of the spillway is most important, and 2) to allow a 0.5 ft reservoir drawdown during the off-season, October through April, when the recreational use of the region is limited.

5. Off-season and night drawdown. An operational procedure which combines Options 2 and 3 and maximizes the energy production of the facility is 1) to require a minimum flow over the spillway during the daylight hours of the tourist season, May through September, and 2) to allow a 0.5 ft reservoir drawdown during the nighttime hours of the tourist seasons and during the off-season, October through April.

The importance of operational scheme on the estimated economic return of a hydropower facility at the Kettle River Dam is indicated below for Development Alternative C (1981 base year):

	Operational Option				
	1	2	3	4	5
Average Annual Energy Production (GWH)	3.53	3.28	4.78	3.78	4.12
Annual Capacity Credit ($)	13,200	11,200	65,600	38,400	38,400
Annual Gross Income ($)	78,500	60,700	154,000	108,300	114,600
First Year Cost of Power (¢/kWH)	4.9	5.2	3.6	4.6	4.2
35-Year Benefit-Cost Ratio	1.36	1.25	2.68	1.88	1.99
35-Year Present Net Value (Million $)	.79	.56	3.44	1.84	2.06
35-Year Internal Rate of Return (percent)	16.0	14.8	30.0	21.1	22.2

Without capacity credit, each of the feasibility indicators show a less attractive investment. The 35-year benefit-cost ratio, for example, of Alternative C, Operation Options 2, 3, and 4 are reduced from 1.25, 2.68, and 1.88 to 1.06, 1.54, and 1.22, respectively.

The potential environmental impacts of the proposed development at Kettle River can be mitigated. The mode of operation chosen will not (in any case) alter water level fluctuations beyond ≃0.5 ft and as a run-of-river plant, instream flows will not be significantly limited beyond their natural frequency. If Options 3, 4, or 5 are chosen for plant operation, the amount of littoral zone in the tailwater which would be exposed with store-release operation may be determined from predawn field tests. With these field tests the flow is shut off for a specified length of time before dawn or in the early morning. Photographs may then be used to map the exposed area. Construction activities should be performed such that water quality is maintained and the activities scheduled so that there will be no impact upon spawning activities or other facets of the surrounding environment, as described in Section X. The Kettle River is a State Wild and Scenic River, and the retrofitting of the existing powerhouse should not affect this designation. An option has been included which makes it possible to retain a flow over the spillway for scenic purposes, if considered necessary. As with any project of this nature, close correspondence should be maintained with all applicable state and federal agencies during the final design phase and construction phases.

III. RECOMMENDATIONS

1. The Kettle River Dam is an economically feasible prospect for hydro-power development with tax-exempt financing.
2. If Operational Option #3 is undesirable for recreational uses of the region, Operational Option #4 is recommended.
3. The energy and power from the proposed development should be sold to Minnesota Power, unless later information obtained from the two utilities differs from that given herein.
4. Any of the four project development alternatives discussed herein will give acceptable economic feasibility.
5. The private financing example given herein is not generally applicable. If private financing is to be seriously considered, each potential private developer should perform an economic analysis of the data provided herein based upon their own criteria.
6. Close coordination with applicable state and federal agencies in the final design phase is strongly recommended to insure that all potential environmental impacts are evaluated and mitigated.

IV. SITE CHARACTERISTICS AND EXISTING FACILITIES

A. Site Description and Location

The Kettle River Dam MN 00513 is located within the corporate limits of the City of Sandstone, Minnesota, approximately 1 mile south of the city center in a sparsely populated reach of the Kettle River. The site location is given in Figs. 1 and 2. The dam is located in Sec. 22, T42N, R20W, approximately 80 miles north of St. Paul, Minnesota.

The existing dam is a combination of various types of structures across the river valley, separated by rock outcroppings. The components of the existing dam (from right to left) consist of 1) an earth embankment with a concrete core wall, 72 feet long, 2) a concrete and masonry powerhouse structure, 35 feet long and acting as a dam, 3) a sandstone masonry primary spillway with a concrete capped crest, 125 feet long and an overflow spillway, 223 feet long, constructed from timber cribs filled with rock and concrete, and 4) a left earth embankment, 160 feet long [1].* The total length is approximately 900 feet, as measured from end to end of embankments. The dam is presently operated as an uncontrolled overflow spillway. The roof and walls of the old powerhouse were removed during repairs in recent years. The maximum structural height of the dam is 34 feet as measured at the powerhouse (from foundation to top of embankment). A site plan is given in Fig. 3. Photographs of the site are given in Fig. 4. Typical sections of the main spillway and the overflow spillway are given in Figs. 5 and 6.

The existing impoundment consists of a slight widening of the river for about 1/2 mile and has the following characteristics [1] :

a)	Surface area, top of dike -	43 acres
b)	Surface area, spillway crest -	30 acres
c)	Storage, top of dike -	380 acre-feet
d)	Storage, spillway crest -	230 acre-feet
e)	Normal maximum surface elevation -	956.3 ft.

*Numbers in brackets refer to references in Section XII.

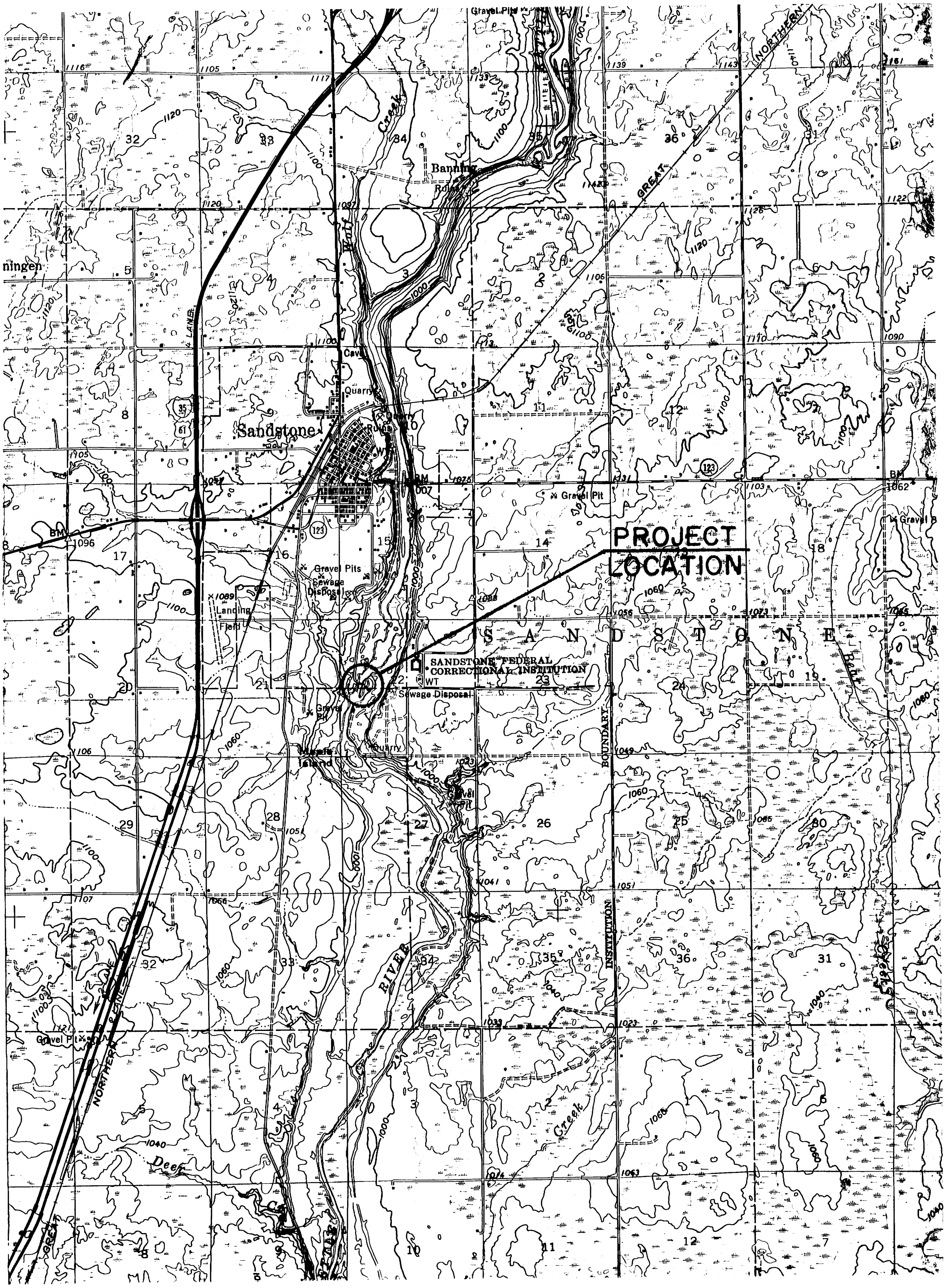


Fig. 1. Location of Kettle River Dam on U.S.G.S. Quadrangle Map.

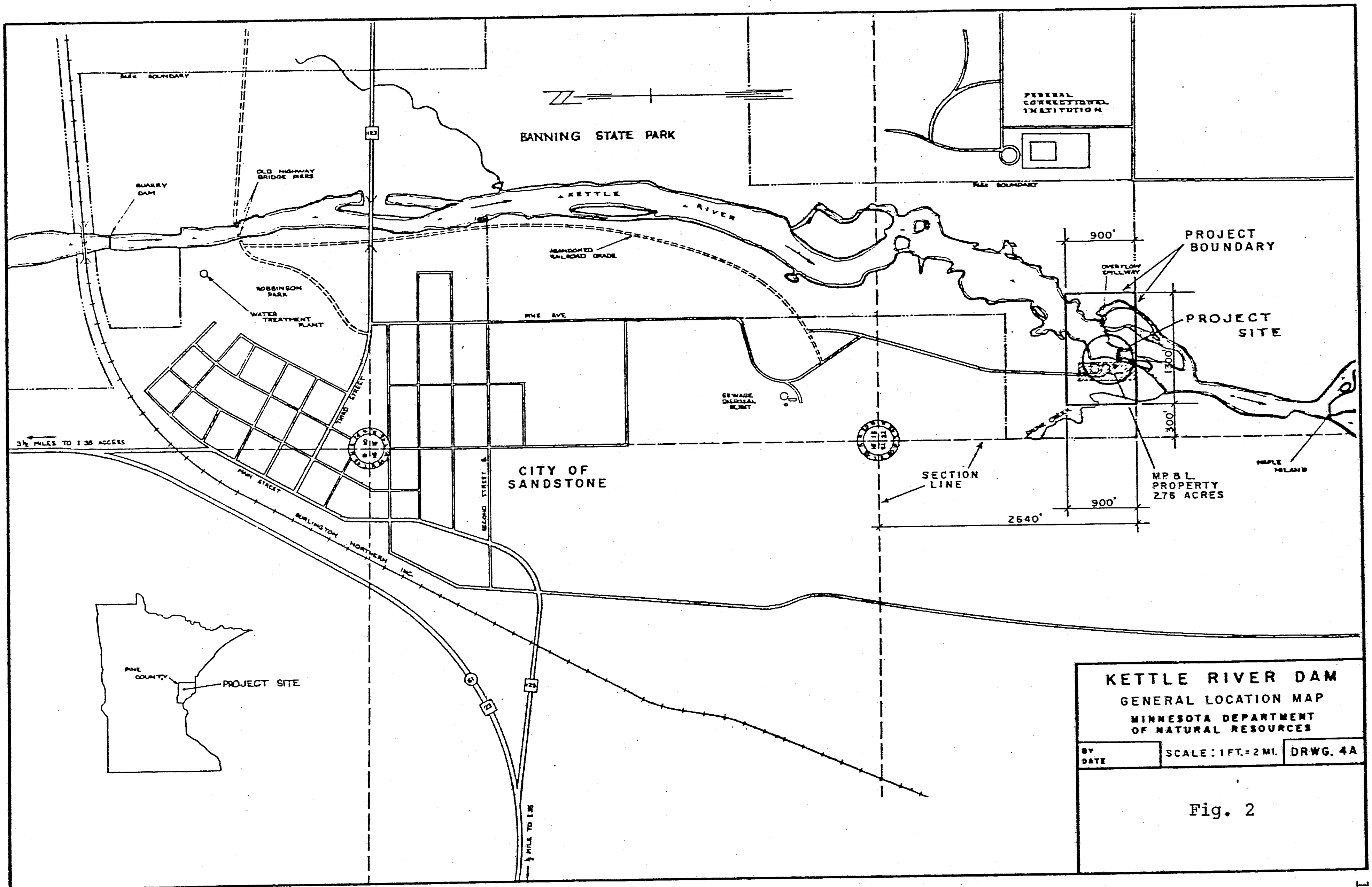
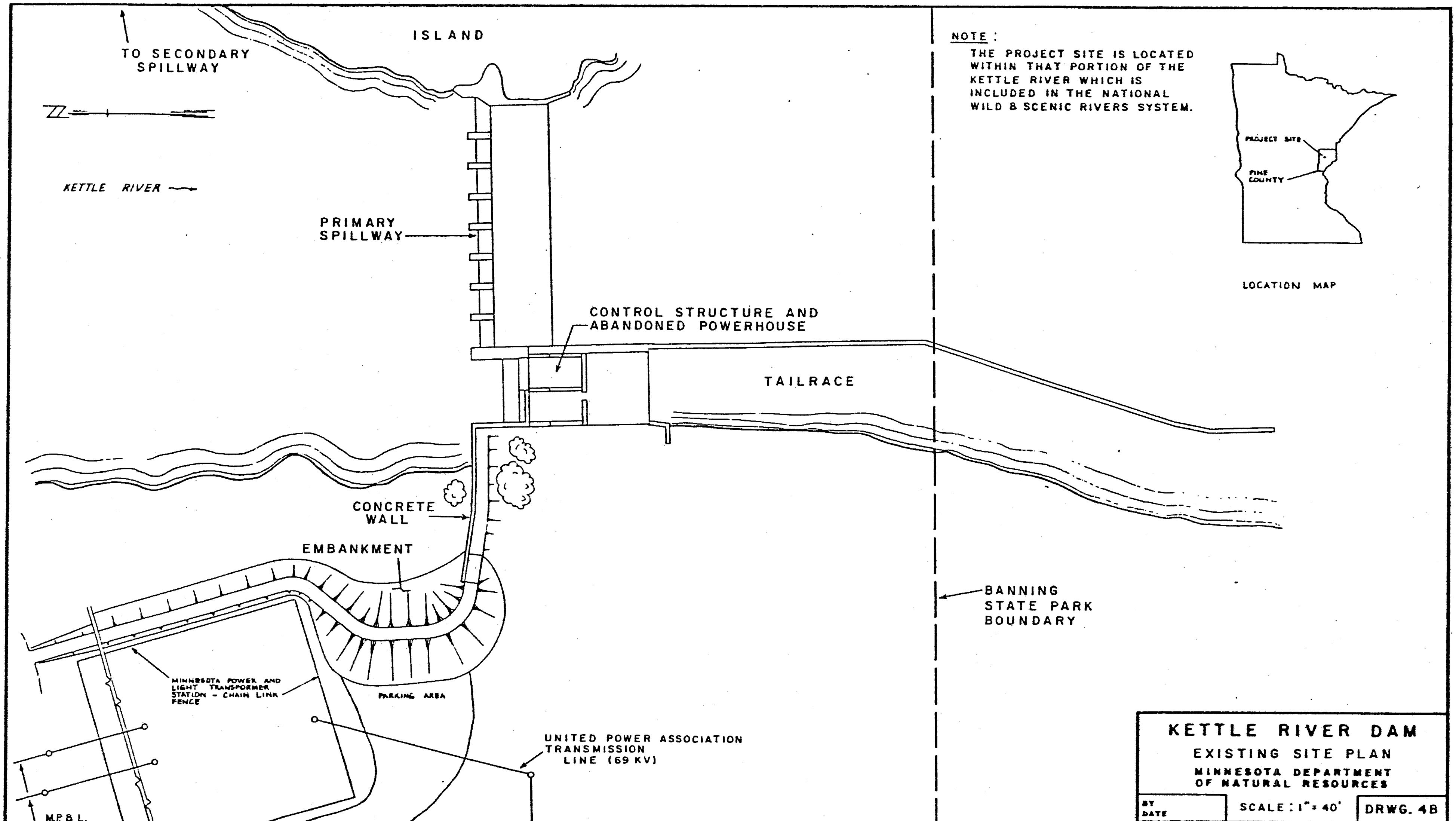

BANNING STATE PARK
PARK BOUNDARY
QUARRY DAM
OLD HIGHWAY BRIDGE PIERS
KETTLE RIVER
ABANDONED RAILROAD GRADE
ROBBINSON PARK
WATER TREATMENT PLANT
PINE AVE.
FEDERAL CORRECTIONAL INSTITUTION
SEWAGE DISPOSAL PLANT
900'
PROJECT BOUNDARY
OVERFLOW SPILLWAY
PROJECT SITE
1300'
300'
SECTION LINE
M.P. & L. PROPERTY 2.76 ACRES
2640'
CITY OF SANDSTONE
THIRD STREET
SECOND STREET
MAIN STREET
BURLINGTON NORTHERN INC.
PINE COUNTY
PROJECT SITE
KETTLE RIVER DAM
GENERAL LOCATION MAP
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
BY
DATE
SCALE: 1 FT.=2 MI.
DRWG. 4A

Fig. 2



ISLAND
TO SECONDARY SPILLWAY
KETTLE RIVER
PRIMARY SPILLWAY
CONTROL STRUCTURE AND ABANDONED POWERHOUSE
TAILRACE
CONCRETE WALL
EMBANKMENT
MINNESOTA POWER AND LIGHT TRANSFORMER STATION - CHAIN LINK FENCE
PARKING AREA
UNITED POWER ASSOCIATION TRANSMISSION LINE (69 KV)
M.P.& L. TRANSMISSION LINES (46 KV)
ENTRANCE ROAD
BANNING STATE PARK BOUNDARY
NOTE: THE PROJECT SITE IS LOCATED WITHIN THAT PORTION OF THE KETTLE RIVER WHICH IS INCLUDED IN THE NATIONAL WILD & SCENIC RIVERS SYSTEM.
PROJECT SITE
PINE COUNTY
LOCATION MAP
KETTLE RIVER DAM
EXISTING SITE PLAN
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
BY
DATE
SCALE: 1" = 40'
DRWG. 4B

Fig. 3

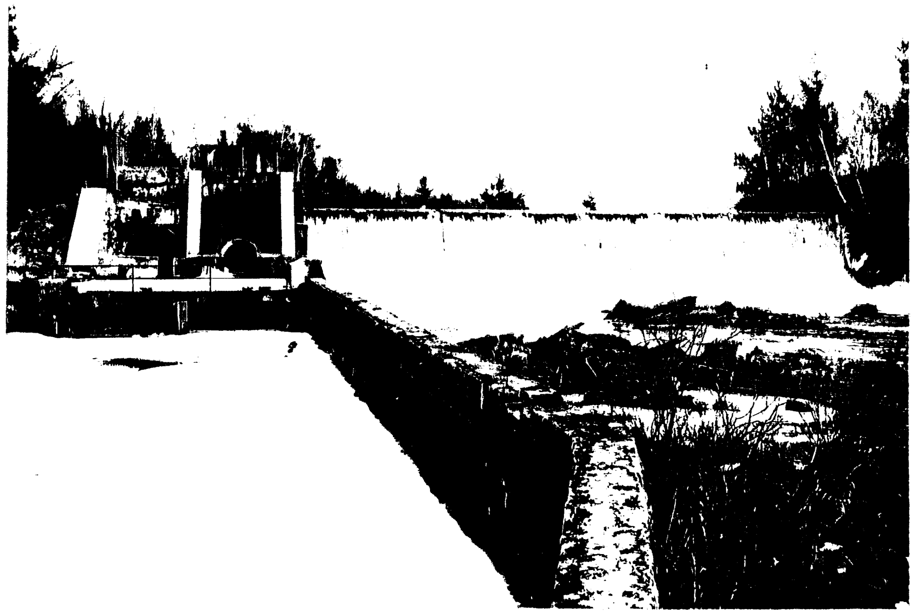


Fig. 4a. Photograph of Kettle River Dam and Existing Powerhouse. February 19, 1981.

Fig. 4b. Photograph of Tailrace and Downstream Stream Reach from Generator Room. Kettle River Dam, February 19, 1981.

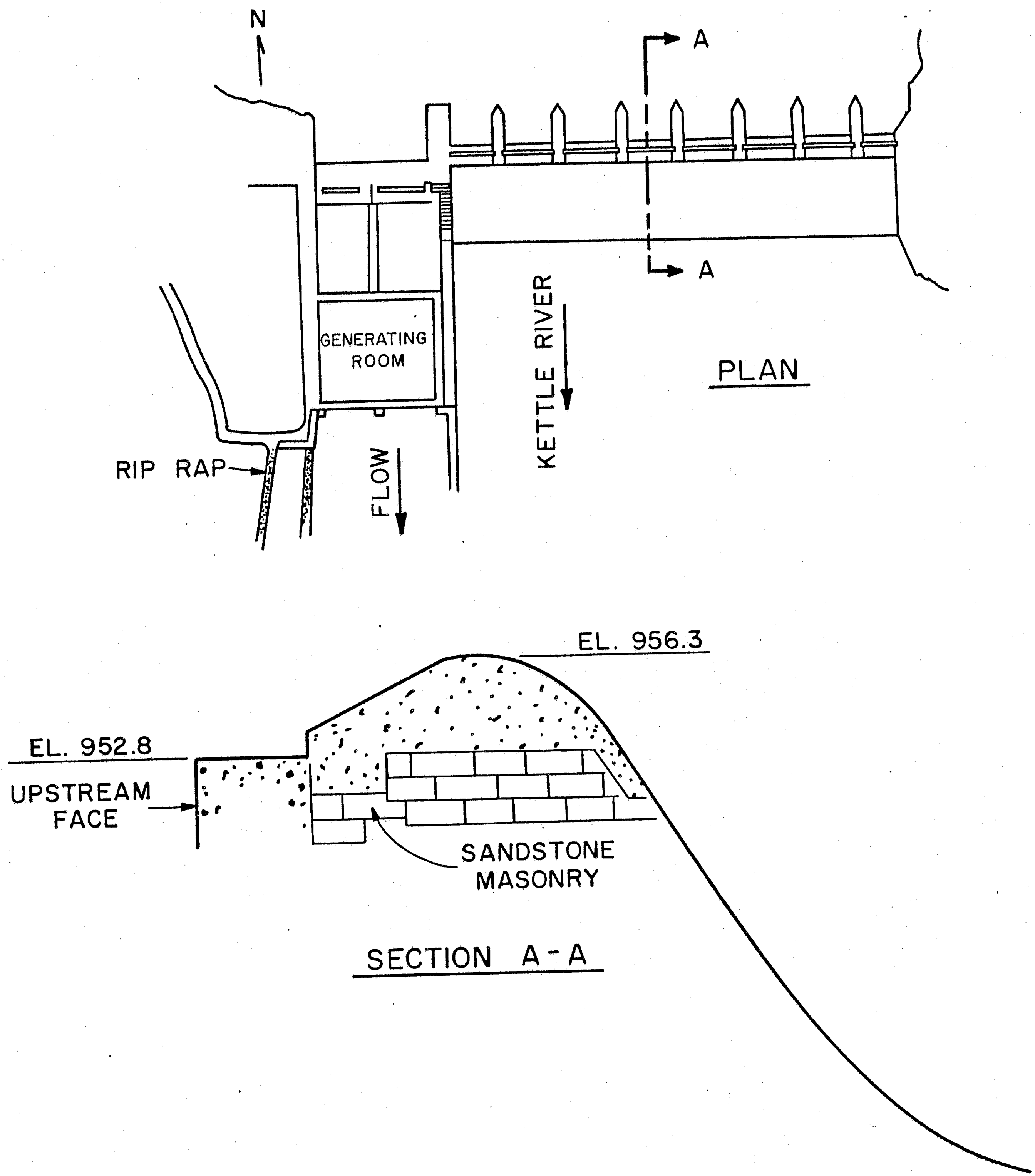


Fig. 5. Plan and Section of Main Spillway.

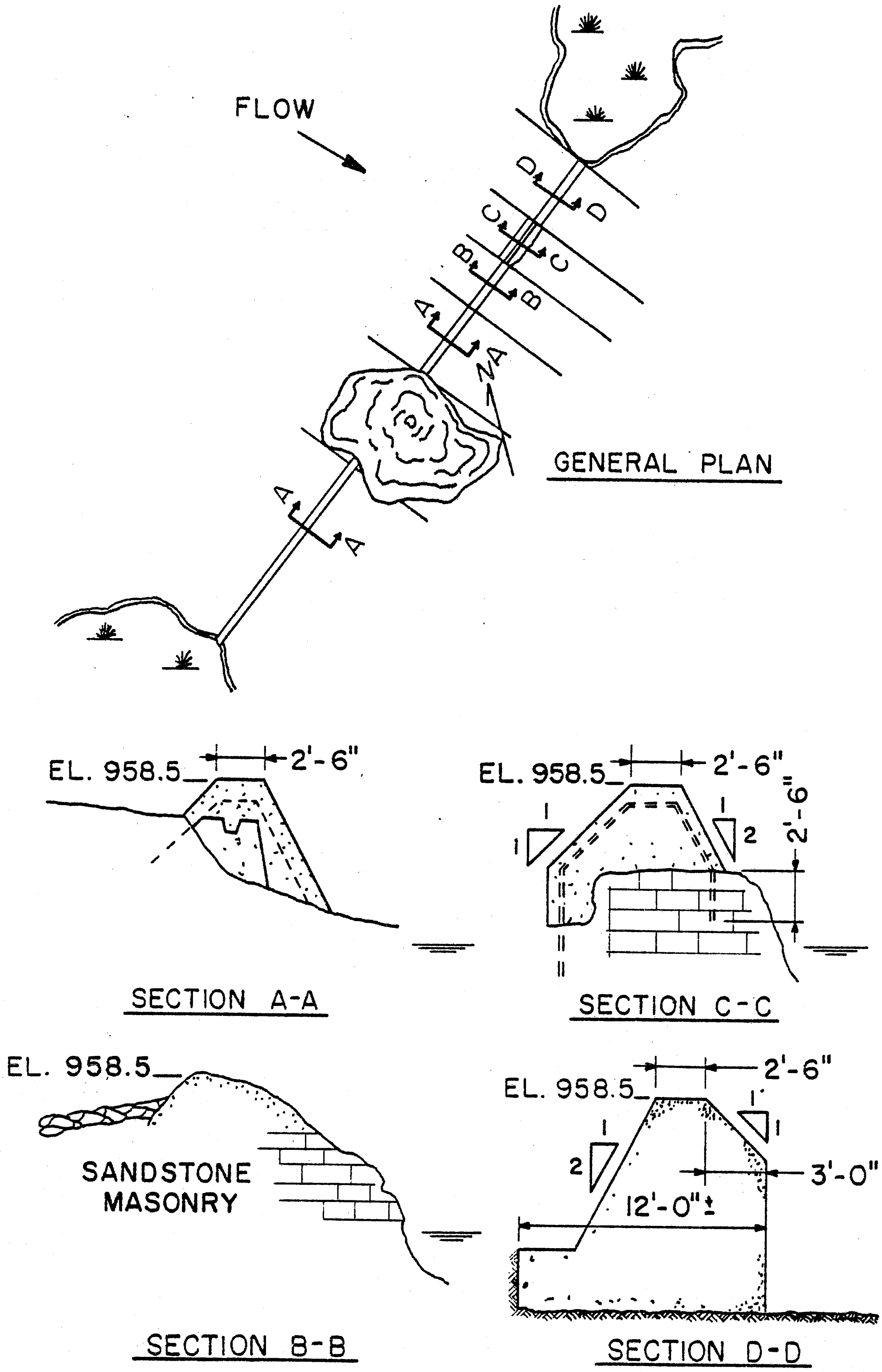


Fig. 6. Plan and Sections of Overflow (Secondary) Spillway.

A transformer substation is located near the right embankment within 300 ft of the powerhouse. This substation is the interconnection between United Power Association (UPA) and Minnesota Power (MP). Transmission lines existing at the station are as follows: UPA - one line at 69 kV, MP - 2 lines at 46 kV each.

B. Historical Background

In 1885 a temporary rock crib dam was built near the sandstone quarries of the City of Sandstone, on the Kettle River, to supply power for a stone-sawmill. In 1888, another dam was constructed on the same site which 20 years later was used for the abutment of the present structure.

A chronology of developments of the Kettle River Dam since 1888 is presented below based on information from three reports: "Kettle River Dam Inventory #513" of the National Dam Safety Program Inspection Report[1]; "Report on Abandonment and Transfer of Ownership of Dams" by Harza Engineering Company and a Minnesota Power Company report on the Kettle River Dam (Sandstone Hydroelectric Station). This chronology is as follows: follows:

1902 The existing dam site was acquired by the Kettle River Quarry Company.

1908 The site was acquired by the Kettle River Power Company which built the present powerhouse and dam. A 400 kW generator and a 4 runner, 500 HP (373 kW), horizontal S. Morgan Smith Francis turbine were installed at this time.

1916 The developed property was purchased by the Hinckley Electric Company.

1917 The property was transferred to the General Light and Power Company. A second turbine was installed: a horizontal shaft, single runner 30" diameter 250 HP (187 kW) Francis turbine manufactured by James Laffel and Company.

1923 The property was acquired by the Minnesota Power and Light Company (now called Minnesota Power).

1924 -1925 The original #1 unit, installed in 1908 was replaced by a 2 runner, 5' - 7-1/2" diameter, 530 HP (395 kW) Laffel Turbine.

1929 A concrete crest was poured in the old stop log section.

1940 Substantial repairs to the structure were started.

1943 Repairs to all four piers were completed.

1950 On May 6th a 19,500 cfs flood breached the powerhouse and crested 6-1/2 feet above the deck forcing personnel to abandon the unit. The generators were damaged.

1952 A sixty-two foot section of the overflow spillway was replaced.

1963 Twenty-five additional feet of the overflow spillway was rebuilt two feet lower to 867.8 feet. At this time the entire length of the dam had been replaced. Also, in this year power production was discontinued and the generators were removed from the site. The turbines are still in place.

1967 The dam, powerhouse, and approximately 197 acres of adjoining land were acquired by the State of Minnesota as a gift from Minnesota Power and Light Company. Minnesota Power and Light retained mineral rights as well as an easement to construct and maintain transmission lines and a distribution system.

1975 The generator room and half of the turbine flume superstructure were removed. Other modifications were also made to the dam.

Today the dam is used for recreation. It has been designated as a 'low-risk' structure. The Kettle River is designated as a State Wild and Scenic River.

C. Dam Integrity

The Kettle River Dam is classified in the small size category as defined in the "Recommended Guidelines for Safety Inspection of Dams" published by the U.S. Army Corps of Engineers. The dam has also been given a low hazard classification since there are no permanent structures located within 7 miles downstream of the dam. A National Dam Safety Program Inspection Report [1] completed in September 1979 made the following observations:

1. The existing Kettle River Dam does not meet accepted dam safety criteria because it is not capable of passing the spillway design flood as recommended by the guidelines for the safety inspection of dams. The Kettle River Dam is of small size with a low hazard potential. The spillway design flood as recommended by the dam safety guidelines is the 100-year frequency event or 28,500 cfs. It was estimated that the spillway discharge capacity is approximately 9,700 cfs, which has a probability of occurrence of 24 per cent in any one year.

2. The Kettle River Dam is operated as an uncontrolled overflow spillway. The slide gates for the abandoned turbines can regulate the pool elevation during low flow conditions. Operation of these gates has been infrequent and the control mechanism currently appears to be operational with difficulty. The sluice gates beneath the turbine pit head gates are reported to be inoperative. No flood warning system or pool monitoring procedures during flood conditions exist for the dam.

3. The Kettle River Dam is currently inspected on an irregular basis and maintenance plans for the old powerhouse have been developed. A formal documented inspection plan is not known to exist.

4. The foundation of the dam is reported to be bedrock. The right earth embankment is apparently constructed of sand with a concrete core wall. The channel downstream of the dam could not be checked for scour during the field inspection due to high water conditions; however, it was reported that part of

the apron has deteriorated. Unchecked scour could lead to undermining problems.

5. The abutment wall on the right end of the powerhouse has been overtopped recently, which resulted in a minor amount of erosion on the right embankment.

6. There are a number of large trees and bushes on both earth embankments. The trees could cause failure of the embankment due to development of piping along the roots or disruption of the embankments as a result of windfallen trees.

7. It was noted during the field inspection that the left concrete abutment wall of the primary spillway appeared to be cracked and water was flowing behind it.

8. During the field inspection, seepage was noted between the concrete overflow spillway and the ledge rock spillway.

9. The structure appears to be in relatively good condition. The most serious structural condition appears to be the movement of the sandstone blocks reported and repaired in 1930 and the condition of the left abutment on the primary spillway.

In addition, the Safety Inspection Report [1] made the following recommendations:

1. That the spillway design flood be determined on the basis of a more detailed evaluation of the hydrologic and hydraulic characteristics of the stream and the potential for development downstream.

2. That the right earth embankment be raised to prevent frequent overtopping and the powerhouse substation located upstream of the dam be protected from flood damage.

3. That the outlet facilities be inspected and appropriate action taken to ensure that the outlet facilities function as intended.

4. That a documented program of inspection and maintenance be developed and implemented. The inspection program should

be specifically designed to detect deficiencies related to seepage and erosion.

5. That the responsibility for maintenance of the structure be assigned to an individual and that this individual be supplied with proper training.

6. That a more detailed investigation of the scour protection be performed and appropriate action taken.

7. That the abutment wall be corrected to prevent frequent overtopping and that the embankment slope be protected.

8. That the trees and bushes be removed from the earth embankments.

9. That the left abutment wall be inspected in more detail and appropriate action taken.

10. That this seepage be investigated in more detail to determine the effect this has on the structure and appropriate action taken.

11. That the construction that took place in 1930 to stop the movement of the sandstone blocks be investigated in more detail to ensure that the repair adequately stabilized the structure and no adverse effects were caused by the movement.

12. That the left abutment wall be inspected in more detail and appropriate action taken.

The Minnesota DNR has recently contracted a consulting firm* to perform a reconnaissance study for dam rehabilitation for the Kettle River Dam. Means of alleviating the safety problems indicated in the safety inspection report will be addressed in the reconnaissance study and costs of the proposed solutions will be estimated.

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*INDECO, 1500 S. Lilac Drive, Minneapolis, Minnesota 55416.

D. Powerhouse and Conveyance Facilities

The existing powerhouse consists of a short headrace and two turbine pits with trashracks and vertical head gates. The #1 unit is a 2 runner, 395 kW Leffel open flume unit with Francis Turbines. The #2 unit is a 187 kW pressure case Francis turbine manufactured by the James Leffel Company. Each turbine had a horizontal shaft leading into the generator room. A plan and three sections of the existing powerhouse structure are given in Figs. 7, 8, 9, and 10. The superstructure of the generator room and half of the turbine room have been removed. The generators have been removed and the existing turbines are in poor condition. The existing turbines, however, are not beyond the point of rehabilitation, if desired. Photographs of the powerhouse and existing turbines are given in Figs. 11 and 12.

The powerhouse substructure is constructed of concrete and sandstone block. The integrity of this substructure is questionable. The upstream portion of the powerhouse acts as a dam and is constructed of concrete with the exception of the head gates.

The head gates are difficult to operate and are in poor condition. Inoperable sluice gates are reported to exist below the head gates in the sluiceway, which discharges into the draft tube. There is currently no flow discharging through the sluiceway.

A 390 ft long tailrace exists below the powerhouse, which adds approximately 2 ft of head at normal flows. The tailrace walls are constructed of sandstone block and significant erosion of the block has occurred at and below water level. Some sections of the wall have collapsed due to the erosion. The tailrace and wall are shown in Fig. 4. The bottom elevation of the tailrace is approximately 935 ft above mean sea level. This high elevation is due to a large amount of sediment deposition which has occurred in the tailrace. The downstream end of the tailrace is nearly closed off due to this sediment deposition.

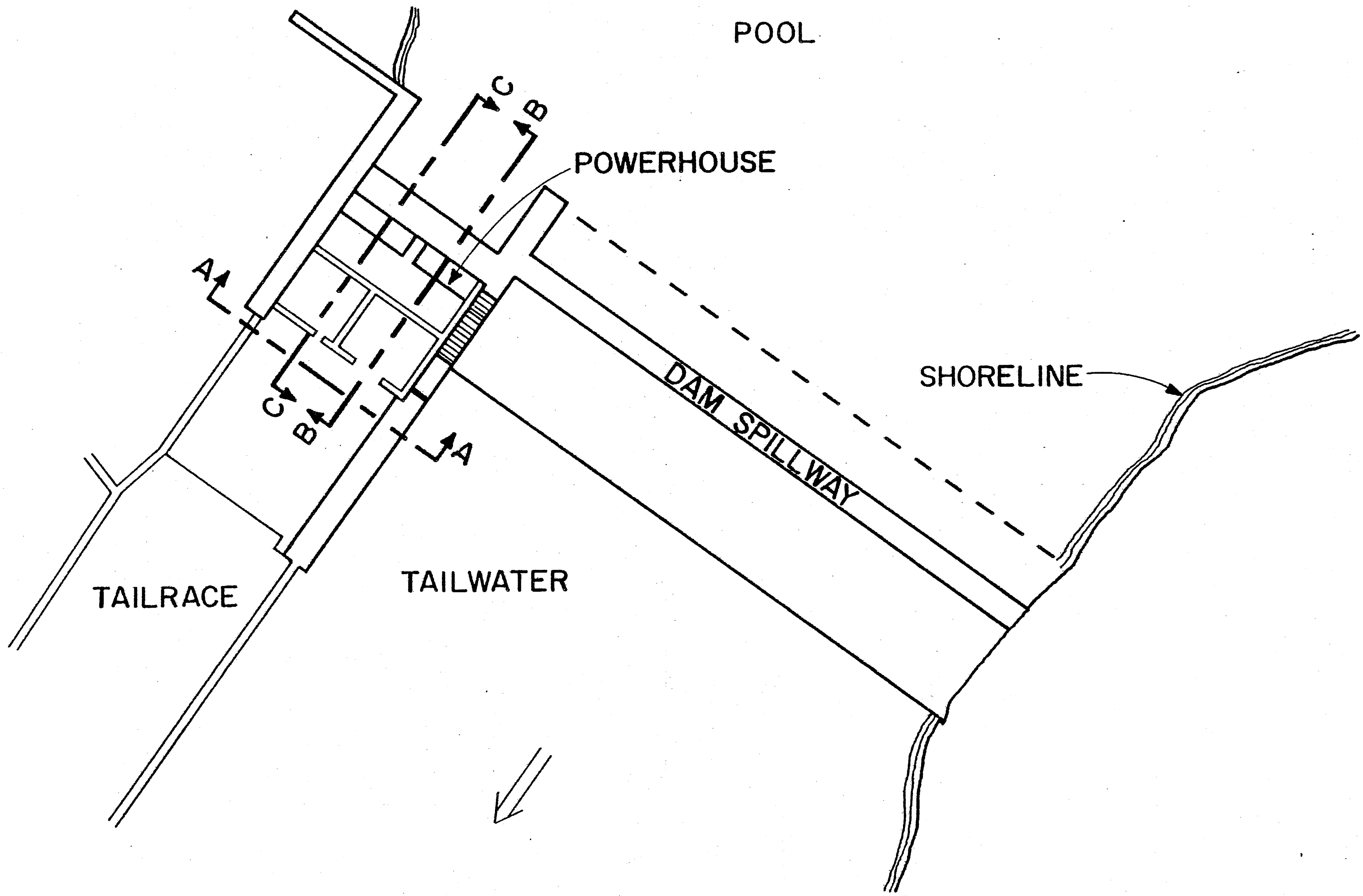


Fig. 7. Plan of Existing Powerhouse and Spillway at the Kettle River Dam.

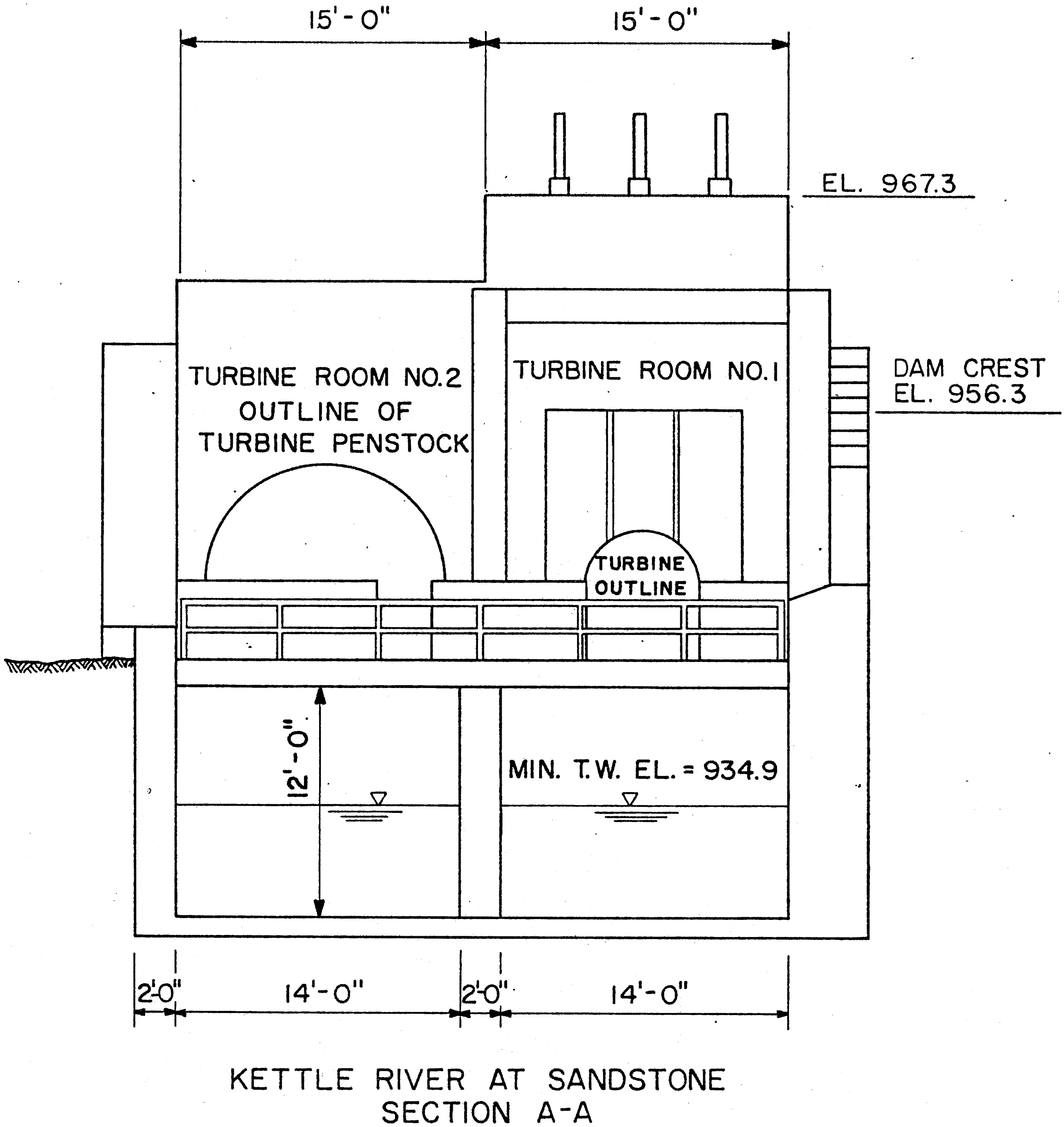


Fig. 8. Section A-A of Existing Kettle River Dam Powerhouse.

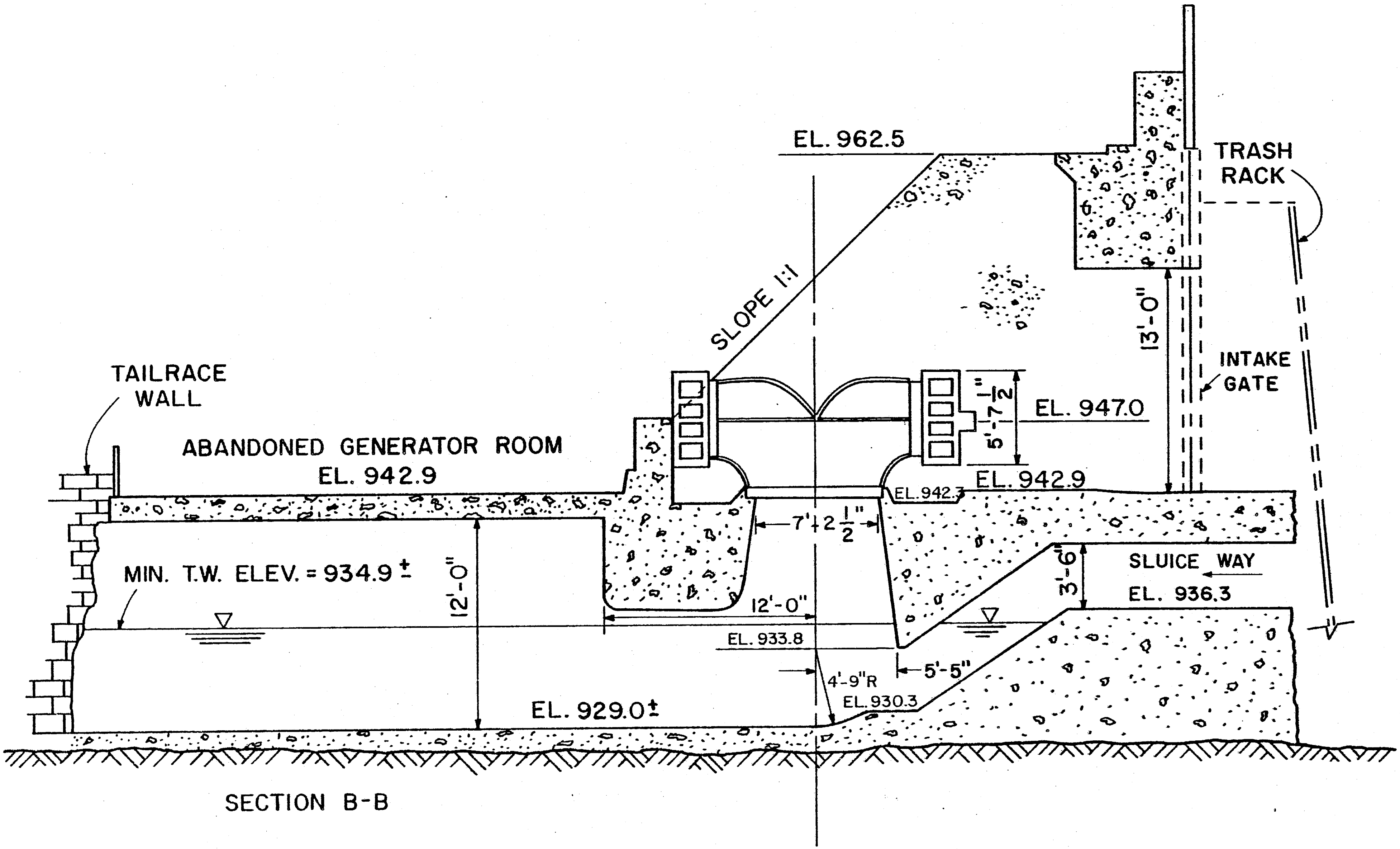
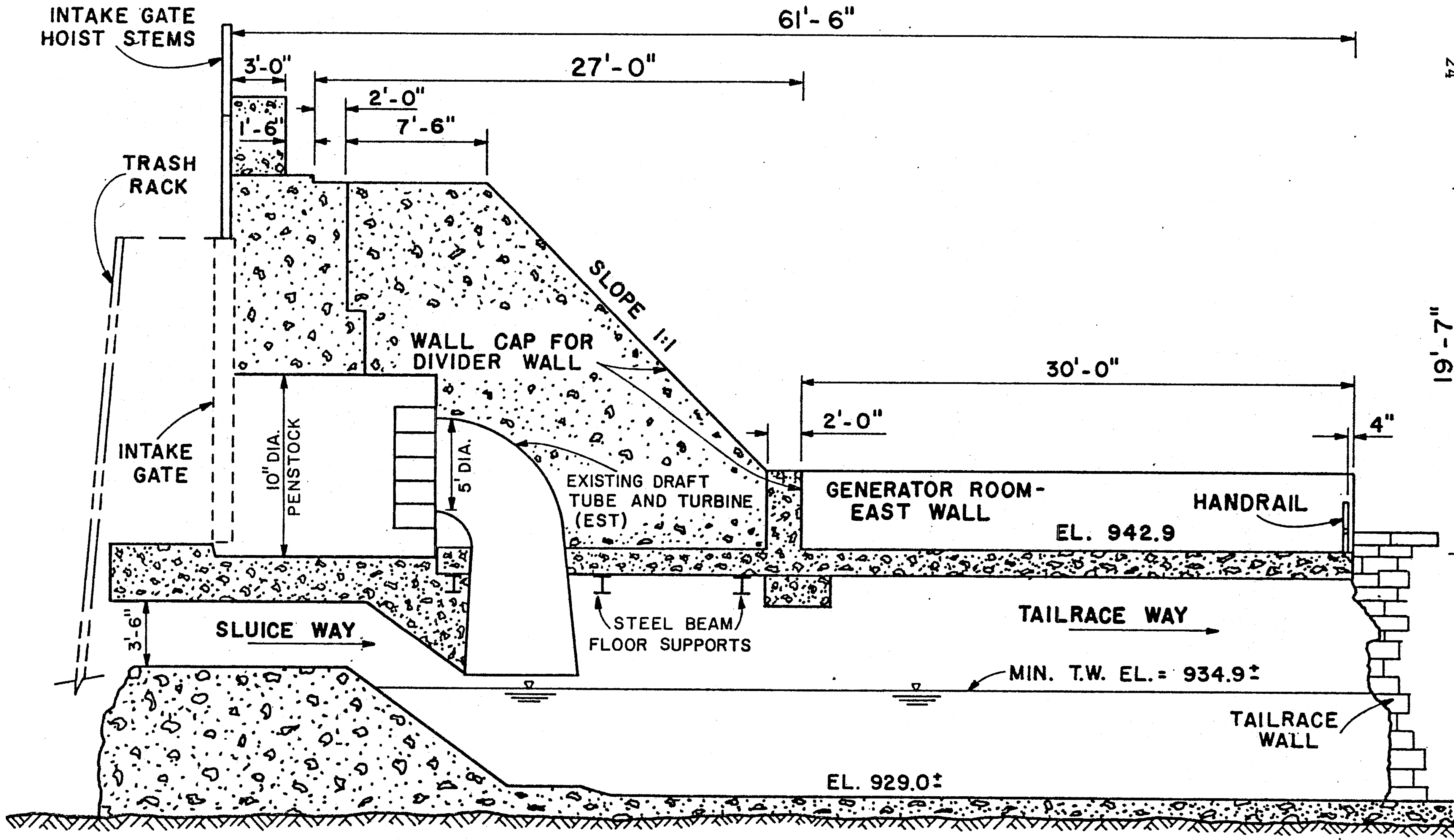


Fig. 9. Section B-B of Existing Powerhouse at the Kettle River Dam.



SECTION C-C

NOTE: EXISTING DRAFT TUBE AND TURBINE DIMENSIONS ARE ESTIMATED. DIMENSIONS AND CONDITIONS BELOW ELEV. 942.9 ARE ESTIMATED AND VERIFICATION WAS NOT POSSIBLE.

Fig. 10. Section C-C of the Existing Powerhouse at the Kettle River Dam.

Fig. 11a. Existing Powerhouse at the Kettle River Dam View from West Bank.

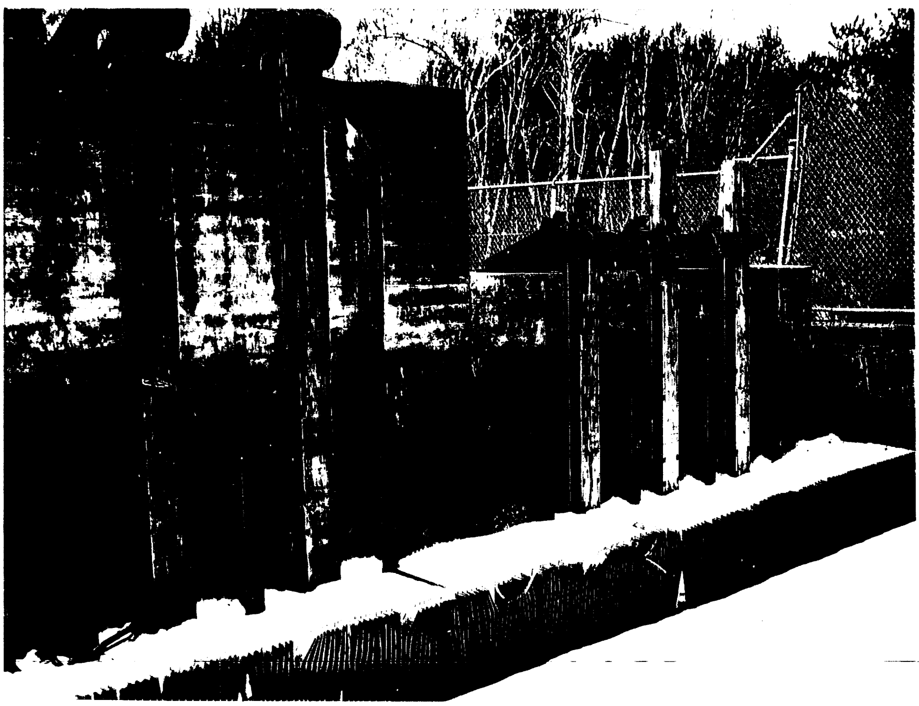


Fig. 11b. Existing Headgates and Trashracks at the Kettle River Dam. View from Upstream.

Fig. 12a. Existing No. 2 Unit. A 189 kW Leffel Francis Turbine. Closed Flume Horizontal Arrangement.

Fig. 12b. Existing No. 1 Unit. A 395 kW Double-Hung Camelback Leffel Turbine with Two Francis Runners. Open Flume Horizontal Arrangement.

V. HYDRAULICS AND HYDROLOGY

A. Flow Duration and Reservoir Storage

The Kettle River Dam MN00513 is on the Kettle River which is part of the St. Croix River Basin. A U. S. Geological Survey stage-discharge gaging station 05336700 is located approximately 900 ft downstream from the dam. Stage-discharge recording was initiated in October 1967. These records provide an accurate data base for hydrologic computations.

The average annual discharge at the site is 722 cfs. The drainage area is 863 mi^2 [2]. A minimum flow of 25 cfs was recorded on November 11-12, 1977. The maximum recorded discharge is 17,200 cfs on July 23, 1972. A flow duration curve is given in Fig. 13. Flow duration curves were also computed for each month over the period of record. The results, summarized in Fig. 14, indicate that the flow is relatively consistent throughout the year except for the spring runoff period. There is no annual drought period where the base flows, Q_{90} and Q_{100}*, are extremely low.

The driest and wettest years of record are water years (October through September) 1977 and 1972. The flow duration curves for those years are given in Fig. 15.

The Kettle River Dam has little or no storage capability for hydropower purposes. The surface area of the reservoir is approximately 30 acres, and the total reservoir storage is 230 acre-feet. This surface area is not sufficient for any significant daily peaking of power production. Drawing the reservoir down 1 ft over 6 hours will only add 60 cfs to the turbine discharge.

B. Headwater and Tailwater Elevations

As noted in Section IV.A, the Kettle River Dam has two spillways, a main spillway at elevation 956.3 ft msl and an overflow spillway at elevation 958.5 ft msl. A headwater elevation curve developed using

*Q_{90} is the flow which is exceeded 90 per cent of the time. Q_{100} is the flow which is exceeded 100 per cent of the time, and therefore is the lowest recorded flow.

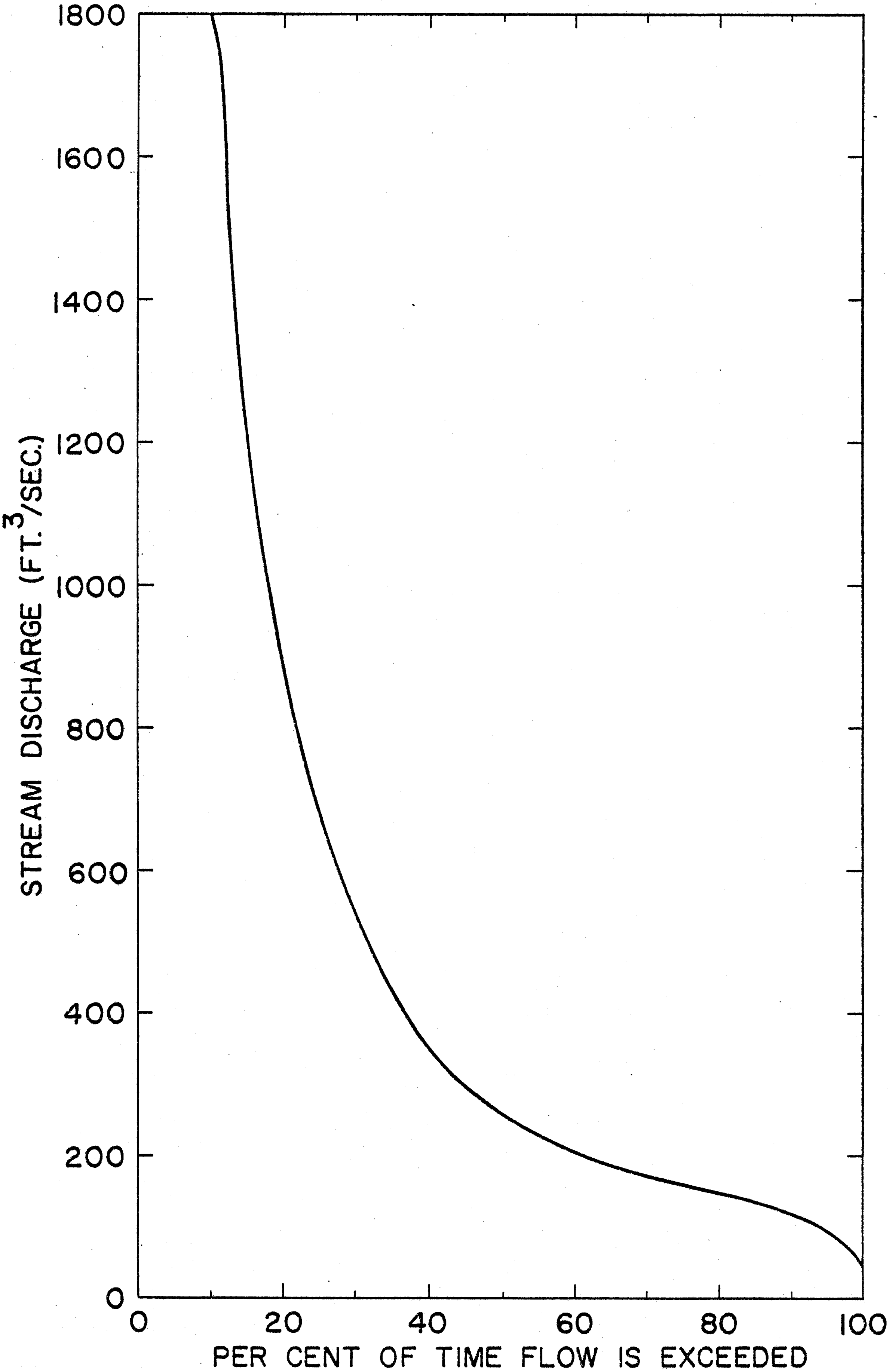


Fig. 13. Flow Duration Curve for the Kettle River Dam.

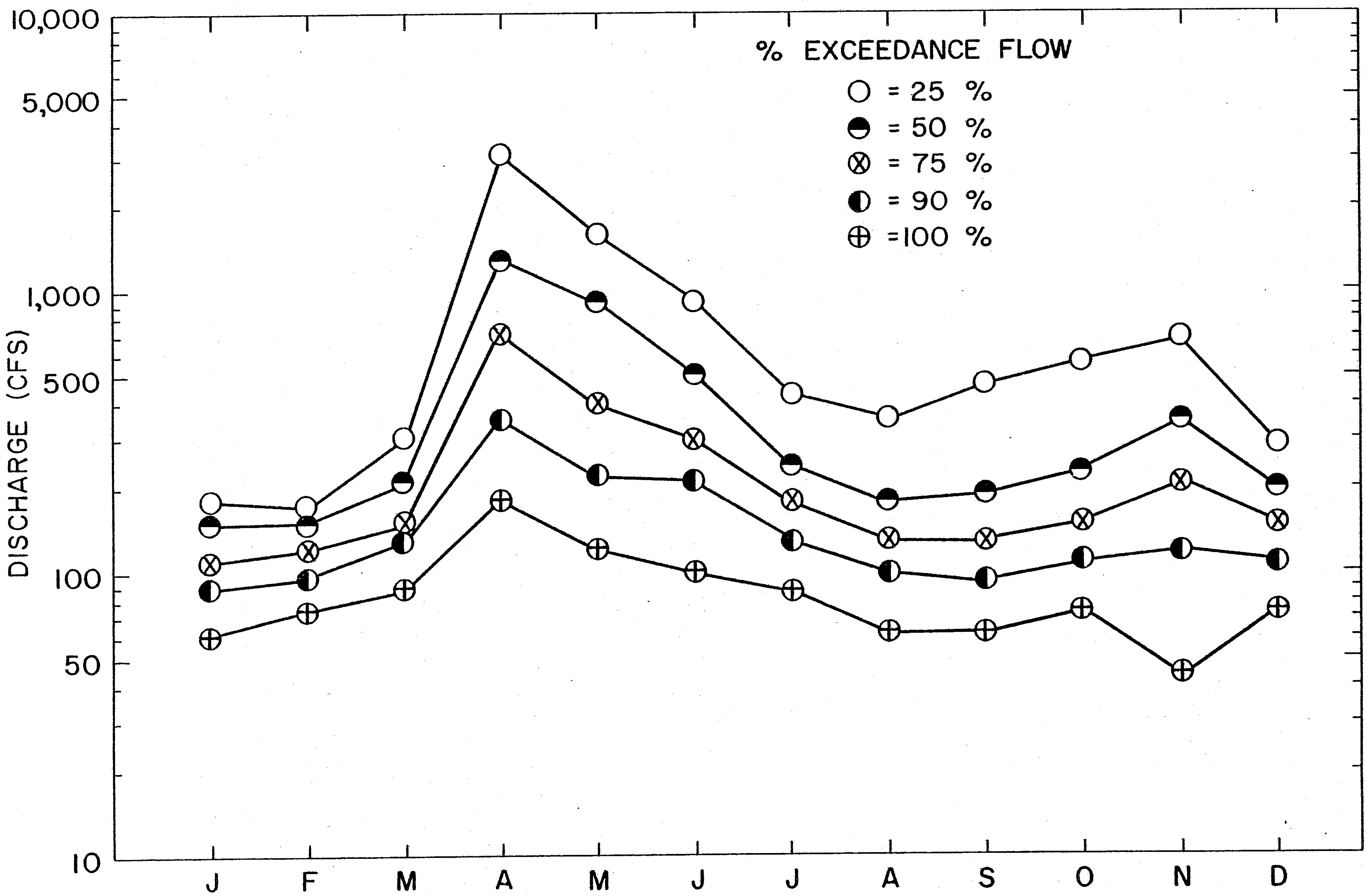


Fig. 14. Summary of Monthly Flow Duration Curves for the Kettle River Dam.

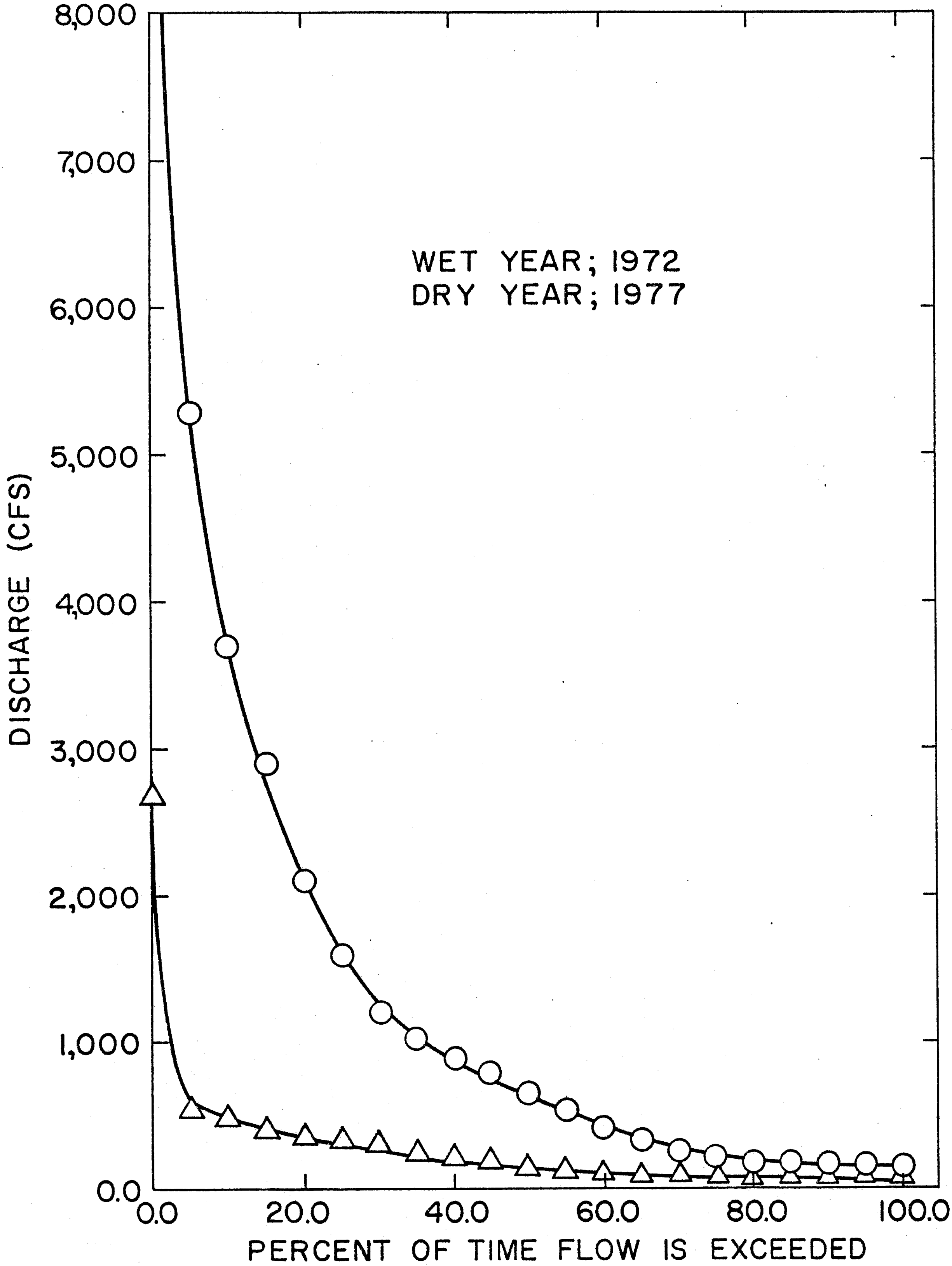


Fig. 15. Flow Duration Curve for the Wettest and Dryest Years of Record at the Kettle River Dam.

a weir equation and discharge coefficients* taken from Brater and King [2], is given in Fig. 16.

The tailwater curve was determined by adjusting the stage-discharge curve for U.S. Geological Survey gage 05336700 for the water surface slope between the gage and the powerhouse. Normal flow was assumed. A Manning's 'n' of 0.035 and 0.029 was used in the river and tailrace segments, respectively. The river cross sections were very approximate; however, the small change in water surface elevation between the gage and tailrace exit did not justify field surveys for more accurate cross sections. The adjusted tailwater curve is given in Fig. 17.

C. Spillway Design Flood

A hydraulic and hydrologic evaluation performed in a Dam Safety Inspection Report for the Kettle River Dam [1] determined the spillway design flood to be 28,500 cfs, the 100-year flood. The spillway discharge capacity was estimated as 9,700 cfs. This discharge capacity has been exceeded six times since October 1967. The Minnesota DNR has contracted a reconnaissance (or Phase 2) rehabilitation study for the dam which will include a more detailed evaluation of the design flood and make recommendations for dam rehabilitation.**

*The discharge coefficients taken from Brater and King correspond to Fig. 5.17 for the main spillway and Table 5.3 for the overflow spillway.

**INDECO, 1500 S. Lilac Drive, Minneapolis, MN. 55416.

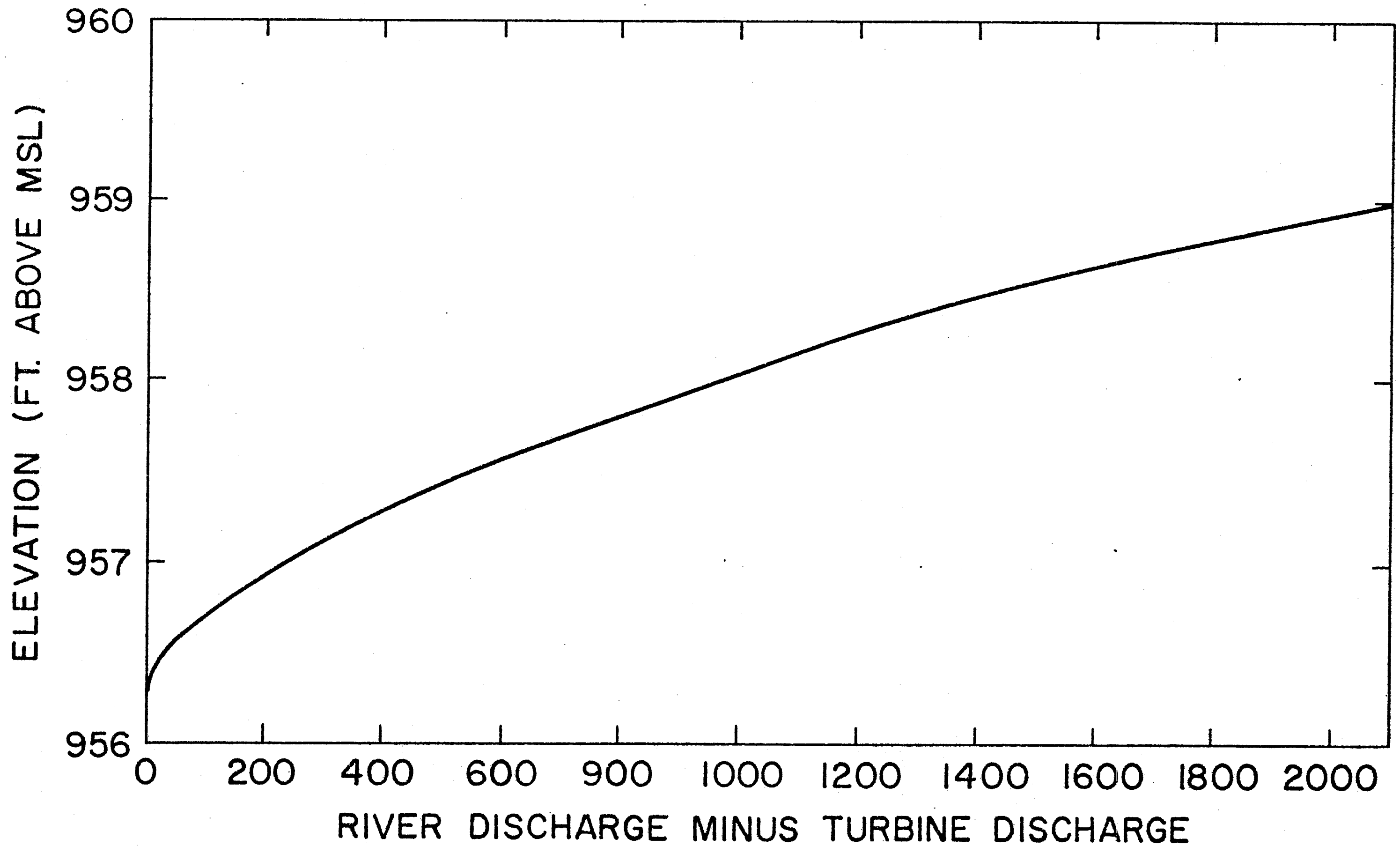


Fig. 16. Headwater Elevation Curve for the Kettle River Dam.

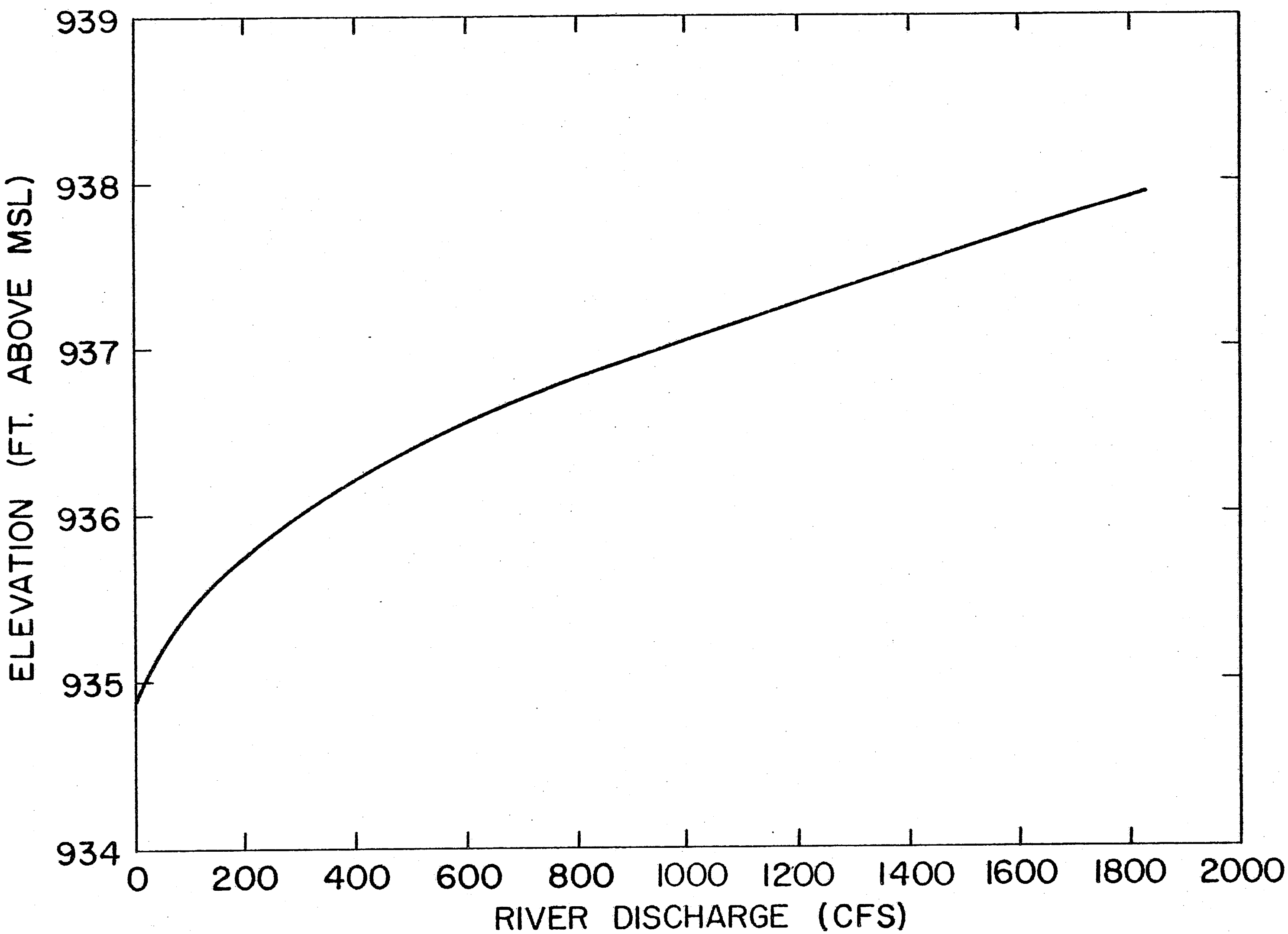


Fig. 17. Tailwater Elevation Curve for the Kettle River Dam.

VI. POWER VALUE AND MARKETING

A. Background

The Public Utility Regulatory Policy Act of 1978 (PURPA) and the subsequent Federal Energy Regulatory Commission (FERC) regulations were intended to encourage production of electric power by cogeneration and by small power producers of less than 80 MW who utilize renewable resources. These small power producers are termed "qualifying facilities" in the regulations. The regulations specify that a utility must purchase power from qualifying facilities at its avoided incremental cost, i.e., the costs the utility would otherwise incur to obtain an equivalent amount of electricity.

The FERC delegated the responsibility of determining avoided incremental costs and overseeing PURPA implementation to the public utility regulatory commission from each state. The Minnesota Public Utilities Commission (PUC) approved a draft Proposed Rule on Cogeneration and Small Power Production on February 19, 1981. In addition, the 72nd session of the State of Minnesota Legislature passed House File No. 473 which essentially extended the proposed PUC rules to all Minnesota electric utilities, including cooperative electric associations and municipal electric utilities. The proposed rules state that "for qualifying facilities with capacity greater than 100 kW, the customer shall negotiate a contract with the utility which shall set the applicable rates for payments to the customer of avoided capacity and energy costs." The proposed rule does offer guidelines, however, to use in the determination of avoided incremental costs. Those guidelines are used herein to determine the value of hydroelectric power which would be produced at the Kettle River Dam.

B. Marketing

The Kettle River Dam is remote with respect to transmission facilities except for those of Minnesota Power (MP) and the United Power Association (UPA) who share a transformer substation conveniently located next to the site. The only two viable alternatives for marketing are therefore to interconnect with either MP or UPA.

C. Value of Project Power and Energy

Both MP and UPA have interpreted avoided energy costs to be their avoided fuel cost. Estimates of avoided fuel costs for a small run-of-river hydropower facility were obtained from MP [3] for the period from 1980 to 1987. MP 's average avoided fuel cost for this period is estimated at 1.7 cents/kWH in 1980 dollars, or 1.85 cents/kWH in 1981 dollars. UPA's current avoided fuel cost is 1.13 cents/kWH [4].

The proposed rules of the Public Utilities Commission state that

> "Any Qualifying Facility offering electricity to a utility which has capacity additions planned for the ensuing ten years shall be entitled to payment for the present value of such future capacity including if the Qualifying Facility contributes to an aggregate capacity value to the utility."

For the qualifying facilities with greater than 100 kW capacity, this capacity payment is to be negotiated. The Proposed Rules do provide a method of computing a utility's avoided capacity cost in cents/kWH, which is a starting point for negotiations and will be used herein. This method is as follows:

1. The completed cost per kilowatt of the utility's next major generating facility addition shall be multiplied by the utility's Marginal Capital Carrying Charge. The Marginal Capital Carrying Charge used shall be the utility's actual calculated rate, but in no event shall the rate used be less than 20% unless the Commission shall find, after notice and hearing, that a lesser rate is appropriate.

2. The dollar amount resulting from the calculation set forth in the preceding paragraph shall then be discounted to present value from the in-service date of the generating unit. The

discount rate used shall be the utility's last authorized overall rate of return.

3. The dollar per kilowatt figure as discounted to present value shall then be divided by the projected average number of kilowatt-hours per kilowatt per year the plant will generate during its useful life. The resulting figure is the utility's Annual Avoided Capacity Cost in dollars per kilowatt hour.

Using the above method and assuming a 20 per cent scheduled and unscheduled outage rate, MP's annual avoided capacity cost is 3.2 cents/kWH (1981 base year). Similarly, UPA's annual avoided capacity cost is 3.1 cents/kWH.

A portion of the energy generated by a hydropower facility will qualify for capacity payments. There is currently no method to determine capacity payments for small hydropower facilities which is accepted throughout the industry*. Coal-fired power plants have a 10 to 15 per cent unscheduled outage rate. This would correspond to capacity credit for the hydropower available 90 per cent to 85 per cent of the time (exceeding 90% to 85% on the flow duration curve). The Bureau of Reclamation (BuRec) recognizes that a hydropower facility should also receive additional credit for intermittent capacity, e.g. capacity that is available most, but not all, of the time. The BuRec formula for energy and capacity credit is as follows:

$$AI = C_E * AAE + C_c * \left[E_{90} + \frac{1}{2}(E_{75} - E_{90}) + \frac{1}{4}(E_{50} - E_{75})\right] \quad (1)$$

where AI = annual income from sale of power to a utility ($),

C_E = value of energy (utility's avoided energy cost)($/kWH),

AAE = average annual energy production (kWH),

C_c = value of capacity (annual avoided capacity cost)($/kWH),

E_{90} = energy which is available 90 per cent of the time (annual kWH),

*Pacific Gas and Electric Company and Southern California Edison Company have developed standard criteria for capacity payments to hydropower facilities.

E_{75} = energy which is available 75 per cent of the time (annual kWH), and

E_{50} = energy which is available 50 per cent of the time (annual kWH).

For lack of a more appropriate formula, Eq. 1 will be used herein to determine the annual income from a hydropower facility at the Kettle River Dam.

MP's avoided energy cost is significantly greater than that reported by UPA. The greatest amount of income will therefore be generated by selling the power to MP. This means that C_E = 1.85 cents/kWH and C_C = 3.2 cents/kWH will be used in the economic analysis.

VII. FACILITY OPERATION

The amount of energy generated by a run-of-river hydropower facility such as the Kettle River Dam can vary greatly depending upon the operational plan. All hydroturbines have a minimum flow below which they cannot generate power. At lower flows, therefore, no power will be generated unless the water is alternatively stored and released. In addition, the Kettle River Dam is adjacent to Banning State Park and the flow over the spillway is a scenic attraction. Another desirable operational scheme is to have some flow over the spillway at all times. This operational scheme, however, severely restricts the potential income from hydropower production, as explained below.

This section will describe five operational options which may be implemented. Each option will be compared in the Economic Analysis of Section IX. The economic advantages and disadvantages of each option may then be compared to the qualitative, recreational advantages and disadvantages by individuals and agencies involved in the proposed project. The five operational options are:

1. Strict run-of-river. The most obvious operational option is simply to direct the flow of the river through the turbines when possible. At flows below the turbine operating conditions, all river flow will pass over the spillway. When river discharge exceeds the turbine capacity, there will be flow both through the turbines and over the spillway. The remainder of the time (moderate river discharge), all river flow will be through the turbines and the spillway will be dry.

2. Flow over spillway. Since the Kettle River Dam is a scenic attraction, another operational option is to dictate that a given discharge must pass over the spillway at all times. The appearance of the Kettle River Dam with a discharge of 140 cfs over the spillway is shown in Fig. 4a. The authors'

qualitative judgement is that 50 cfs discharge over the spillway is sufficient to maintain the "falling water" appearance without detracting from the spillway's scenic qualities. The authors' based this judgement on the appearance of the Minnesota Falls Dam MN 00512, at a discharge of 50 cfs. The width of the Minnesota Falls Dam is similar to that of the Kettle River Dam's primary spillway. With a specified flow over the spillway, the turbines will not be operating a greater percentage of the time. If the minimum discharge of the turbine unit is 190 cfs, for example, and the minimum spillway discharge is 50 cfs, a river discharge of 240 cfs is required before any power is generated. The minimum spillway discharge which will be used herein is 50 cfs.

3. Reservoir drawdown. Power may be generated at flows below minimum turbine flows if water is alternatively stored and released. With this procedure power is generated with a turbine flow which is at or above the allowable minimum until the headwater elevation is ~ 0.5 ft below the spillway crest. The turbines are then shut down to allow the reservoir to fill up to the spillway crest. Finally, the turbine gates are again opened and power production resumes.

   This operational procedure can be set up so that the turbines are shut down for only 1 to 2 hours at a time. For most dam sites, eliminating river discharge for two hours will not have a significant detrimental effect upon the downstream biota because the corresponding change in tailwater elevation is not great. The environmental impact of this operational procedure at the Kettle River Dam is considered in Section X.

   Reservoir drawdown will increase the energy produced at the Kettle River Dam and will greatly increase the capacity payment for dependable capacity, as described in Section VI.

   The disadvantage to reservoir drawdown is that there can be no flow over the spillway except when the discharge capacity of the turbines is exceeded.

4. Off-season drawdown. An operation procedure which combines Options 2 and 3 is to 1) require a minimum flow over the spillway during tourist season, May through September, when the scenic attraction of the spillway is most important and 2) allow a 0.5 ft reservoir drawdown during the off-season, October through April, when the recreational use of the region is limited.

   This operational procedure will increase the energy production and capacity payment at the Kettle River Dam while still allowing for flow over the spillway during the most important recreational period. Flow duration curves for the two distinct seasons are given in Fig. 18.

5. Off-season and night drawdown. An operational procedure which combines Options 2 and 3 and maximizes the energy production of the facility is 1) to require a minimum flow over the spillway during the daylight hours of the tourist season, May through September and 2) to allow a 0.5 ft reservoir drawdown during the nighttime hours of the tourist seasons and during the off-season, October through April.

The energy production, annual income, and economic viability of the five operational options will be compared in Section IX.

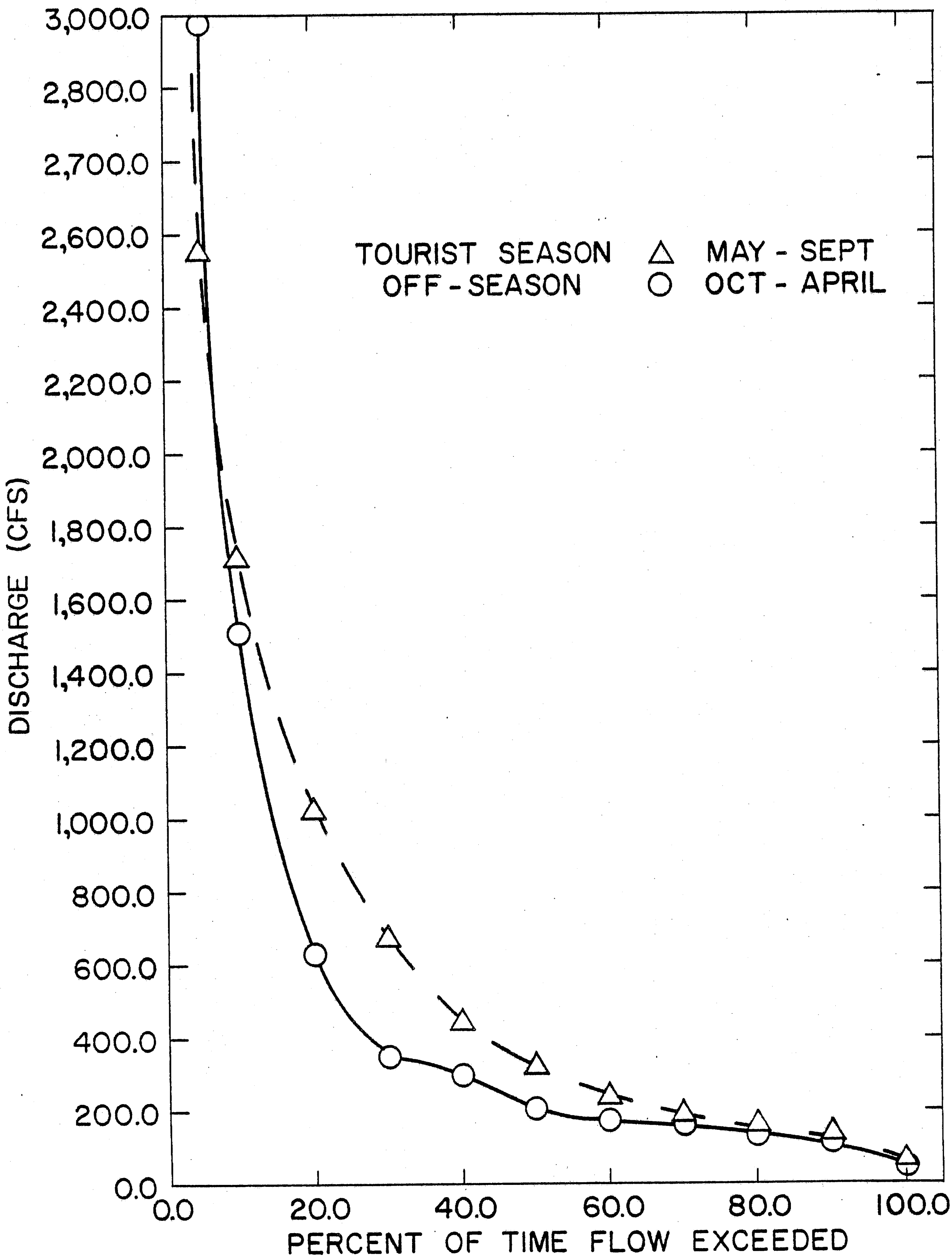


Fig. 18. Seasonal Flow Duration Curves.

VIII. PROJECT DEVELOPMENT ALTERNATIVES

In this section the costs and expected annual energy production of four development alternatives for the Kettle River Dam hydropower facility are considered. Other alternatives which were initially considered, but were ruled out of a more detailed analysis, are also described. Project development alternatives were formulated in the following manner:

- Once the hydraulic and hydrologic analysis was performed, the first step in choosing development alternatives was to determine which types of hydroturbines are most applicable to the site. Turbine and generator manufacturers were then contacted to obtain cost estimates of specific turbine/generator units, since they are the major equipment item in a hydropower facility. Turbine performance curves were also obtained.

- The expected annual energy production was computed for each of the five operational options using flow duration, headwater and tailwater information, and turbine performance curves.

- Construction costs were estimated on the basis of unit prices applied to computed quantities of work (quantity takeoffs). Preliminary layout drawings were used to determine the appropriate quantities. The unit prices used are estimates of the total cost of work including labor, materials, equipment, taxes, and overhead. Construction cost estimates included facility structural costs as well as diversion, removal, and excavation costs. A 25 per cent contingency allowance was added to cover smaller items and possible omissions. A 10 per cent profit factor was also included in the total cost.

- Freight and installation estimates for turbines and generators were based upon manufacturer's recommendations.
- When electrical equipment costs were not included in the turbine/generator cost estimates, these costs were estimated based upon information obtained from a well-known generator/switchgear/controls manufacturer. Electrical equipment costs include switchgear, transformer, control switchboard, wire and cable system, conduit, grounding, and lighting
- It is anticipated that the site will be completely automated with water level sensors, automatic start and stop, and a digital controller. With this type of remote control, the only remote communication required is an operating status indication through telephone lines. The control equipment costs were estimated from guidelines in Ref. [5]. The 1978 cost base was escalated to 1981 according to the Consumer Price Index.
- Miscellaneous power plant equipment costs were estimated according to guidelines in Ref. [6]. Equipment for ventilation, fire protection, communication, and turbine/generator bearing cooling water are included in this category. The cost estimates include 15 per cent for freight and installation. The July 1978 cost base was escalated to July 1981 according to the Consumer Price Index.
- A 15 per cent contingency was applied to equipment and installation costs *excluding* turbines, generators, and electrical equipment. A manufacturer's contingency had already been applied to the excluded items.
- A multiplier of 20 per cent was applied to the total cost of the above items for engineering, construction management, and other costs [6]. These costs include expenditures for license and permit application, preliminary and final design, construction management, and administration.

A. Alternative A: One Horizontal, Adjustable-Blade Propeller Turbine

Alternative A is one horizontal, adjustable-blade propeller turbine. The unit specifically considered is an Allis-Chalmers standardized Tube unit, with a maximum discharge of 546 cfs at 20 ft net head. The rated generator output is 725 kW. Minimum turbine discharge is 179 cfs.

The advantage to an adjustable-blade turbine is that the turbine may be operated over a range of flows, rather than at one specific design discharge. The disadvantage is that the adjustable-blade capability adds cost to the unit.

The cost estimate for Allis-Chalmers includes:

1. A 72 sq ft intake roller gate (the size is approximate for estimating purposes).
2. The 1750 mm 4XA-60° adjustable blade TUBE turbine with bell-mouth intake and draft tube extension.
3. Gear speed increaser.
4. 909 MPM induction generator rated 725 kW, 3 phase 60 hertz, 4160 volts, drip proof, Class F insulation, 80°C rise.
5. Blade positioner.
6. Hydraulic power unit for operating intake gates and blade positioners.
7. Couplings.
8. Indoor protection and control cabinet for generators including automatic control which starts and stops units in response to head level sensors.
9. Outdoor switchgear.
10. Outdoor step-up transformer, 5 kV/15 kV.
11. Outdoor disconnect switch with cubicle for utility metering equipment.

Allis-Chalmers preliminary 1981 price for the above equipment was $622,000.

A plan and section of a preliminary layout for Alternative A are given in Figs. 19 and 20. The other existing turbine pit will not be utilized. New construction is indicated by cross-hatching. The costs estimates for this development alternative are as follows:

Alternative A Cost Estimates (1981 base year)

1.	Civil works costs	$ 232,000
2.	Turbine, generator, gates, and electrical equip.	622,000
3.	Turbine and generator installation	93,000
4.	Freight	10,000
5.	Automatic control equipment	68,000
6.	Miscellaneous plant equipment	53,000
7.	15% contingency on Items 3 through 6	34,000
8.	Engineering, construction mtg., and other costs	222,000
	Total Initial Cost	$1,334,000

The average annual energy production, relative cost, and annual capacity credit for Alternative A will vary with operation plan. Table 1 gives the resulting values for each operational option.

TABLE 1. Average Annual Energy Production, Relative Project Cost, and Annual Capacity Credit for Alternative A, Kettle River Dam (1981 base year)

	Operational Option				
	1	2	3	4	5
Average Annual Energy Production (GWH)	3.41	3.26	4.26	3.39	3.53
Relative Project Cost ($/kWH)	0.39	0.41	0.31	0.39	0.38
Annual Capacity Credit ($)	18,000	12,700	64,900	39,800	39,800
Annual Gross Income ($)	81,000	73,000	143,700	102,500	105,100

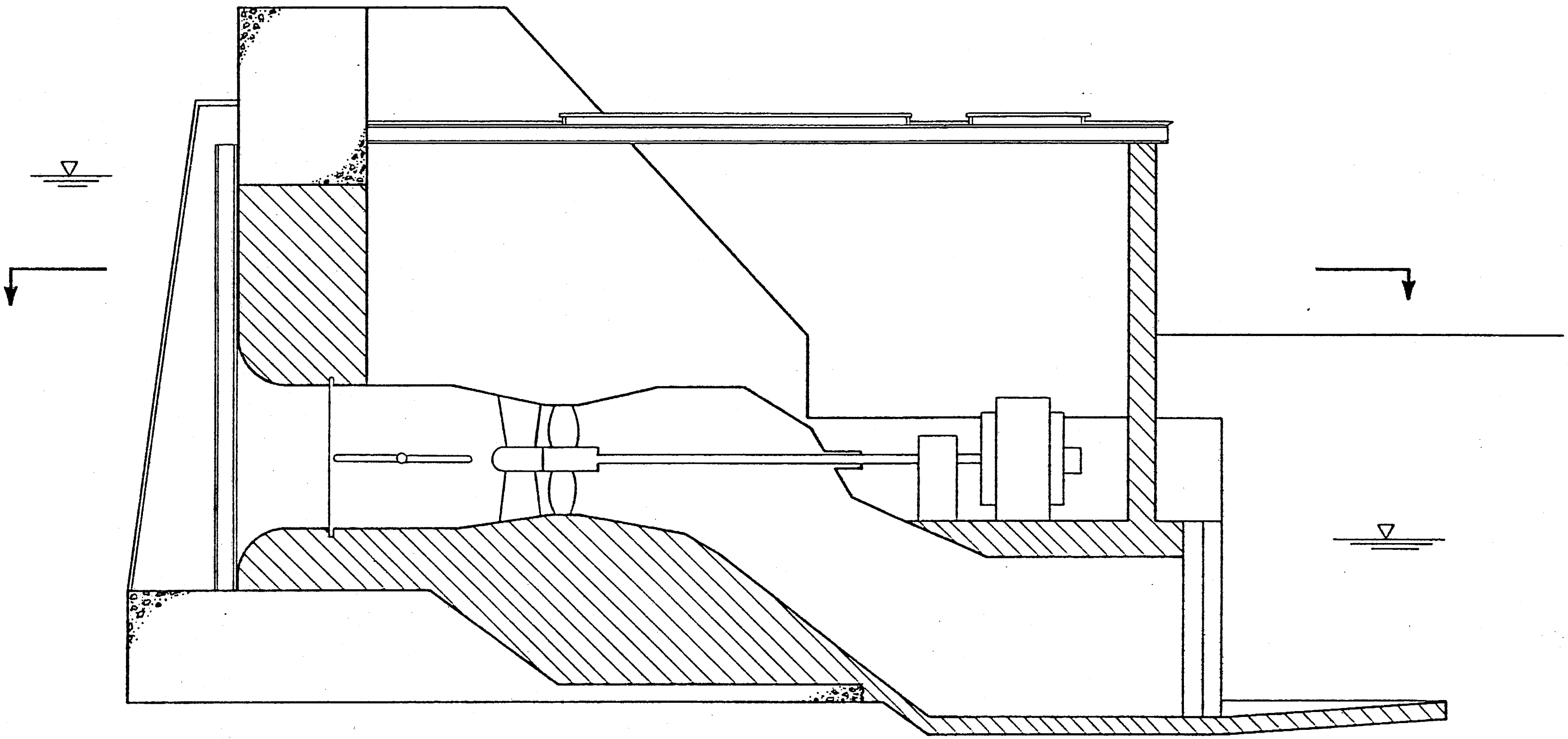


Fig. 19. Section View of Alternative A: One 1750 mm Horizontal, Adjustable-Blade Propeller Turbine. Rated Generator Output is 725 kW. Turbine Discharge is Between 179 and 546 cfs at 20 feet Net Head.

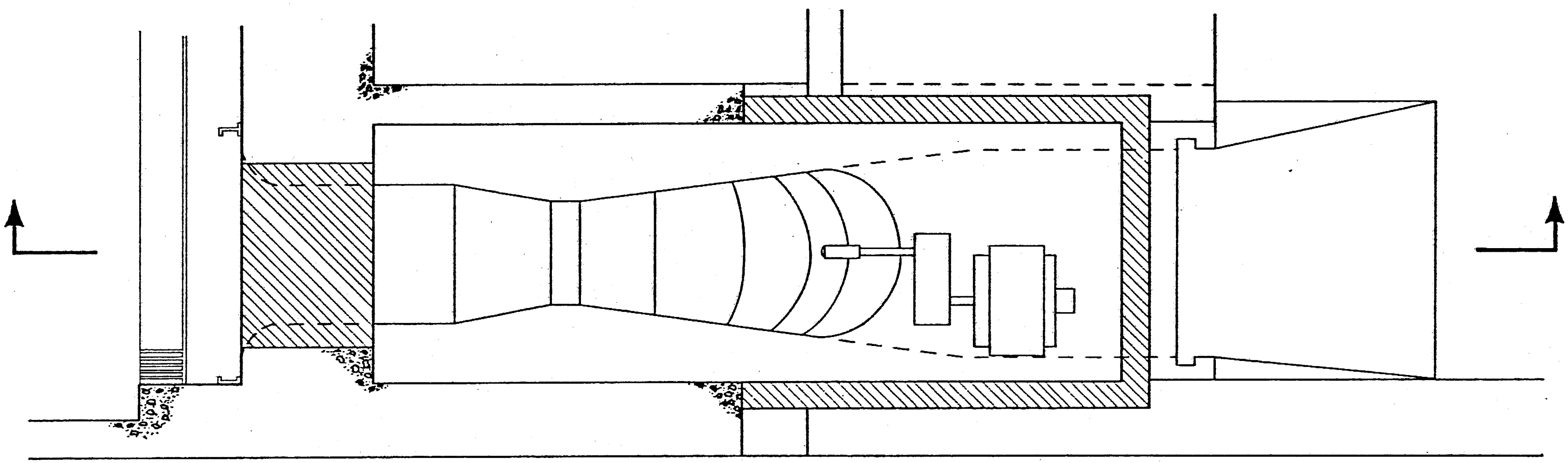


Fig. 20. Plan view of Alternative A: Only one Turbine Bay is Used.

B. Alternative B : One Vertical, Adjustable-Blade Propeller Turbine

Alternative B is the same turbine and generator as Alternative A except that the arrangement is vertical with an open flume intake. A plan and section of a preliminary layout are given in Fig. 21. There is currently no information in the literature which may be used to specify submergence of the bell-mouth intake with confidence. The possible need of vortex suppression devices should be considered during project design. Alternative B has a lower structural construction cost than Alternative A; however, the speed increaser and generator are $35,000 more expensive for Alternative B. Allis-Chalmers estimated that for the same equipment specified in Alternative A and a vertical arrangement, the 1981 price would be $657,000.

The total cost estimates for this alternative is as follows:

Alternative B Cost Estimates (1981 base year)

1.	Civil works costs	$ 188,000
2.	Turbine, generator, gates, and electrical equipment	657,000
3.	Turbine and generator installation	98,000
4.	Freight	10,000
5.	Automatic control equipment	68,000
6.	Miscellaneous plant equipment	53,000
7.	15% contingency on Items 3 through 6	34,000
8.	Engineering, construction mtg., and other costs	222,000
	Total Initial Cost	$1,330,000

The average annual energy production, annual capacity credit, and annual gross income will be precisely the same for Alternative B as for Alternative A. The relative project cost will be extremely close for the two options (.01 $/kWH) and does not justify further elaboration here. The main difference between Alternatives A and B is in the shape and appearance of the powerhouse.

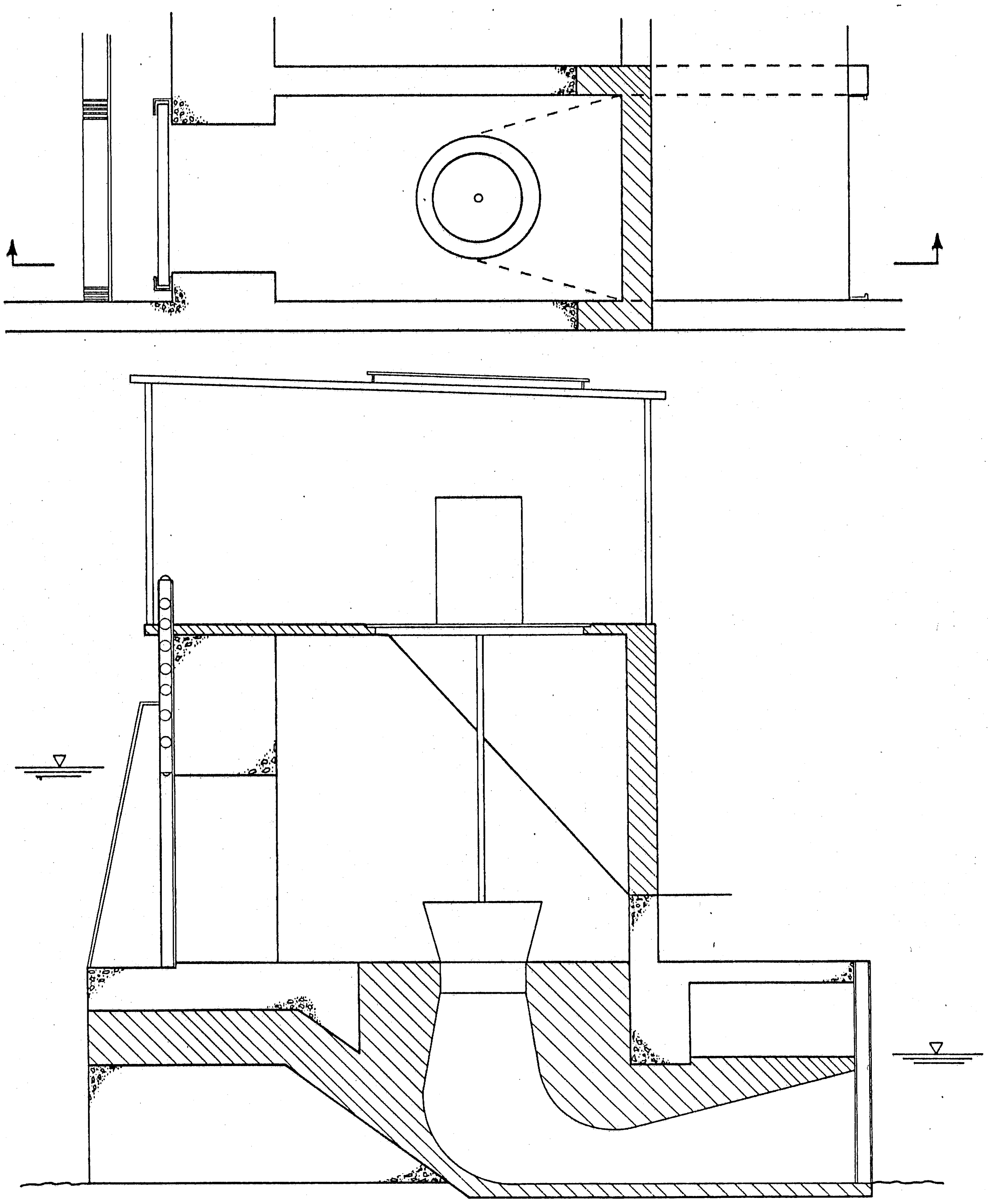


Fig. 21. Plan and Section of Alternative B: One 1750 mm, Vertical, Adjustable Blade Propeller Turbine. Only one Turbine Bay is Used.

C. Alternative C: Two Inclined, Fixed-Blade Propeller Turbines

There are two manufacturers marketing inclined, fixed-blade propeller turbines which are applicable to the Kettle River Dam: Neypric and Allis-Chalmers. Installation of two Neypric right-angle drive turbines at this site would require extensive excavation and renovation of the existing powerhouse. For this reason the Neypric alternative was not considered further. During project design, however, the Neypric right-angle drive turbines should be reconsidered as an alternative.

The two turbines to be offered as Alternative C are Allis-Chalmers Mini Tube units with fixed blade propeller turbines. Fixed-blade propeller turbines with fixed guide vanes have one operating discharge which will vary with net head. The turbine discharge cannot be controlled, so the units are either "on" or "off." The first unit has a 72 in. diameter runner with 814 kW generator output at 20.5 ft head and 554 cfs discharge. The second unit has a 42 in. diameter runner with 277 kW generator output at 20.5 ft head and 190 cfs discharge. Allis-Chalmers preliminary 1981 price for the turbines, generators, gates, and electrical equipment was $555,000. The cost estimate included the additional equipment listed under Alternative A except that no blade positioners are required, the intakes are cylindrical, and two roller gates and speed increasers are included.

A plan and two sections of a preliminary layout for Alternative C are given in Figs. 22, 23, and 24. The cost estimates for this development alternative are as follows:

Alternative C Cost Estimates (1981 base year)

1.	Civil Works costs	$ 247,000
2.	Turbine, generator, gates, and electrical equip.	555,000
3.	Turbine and generator installation	111,000
4.	Freight	10,000
5.	Automatic control equipment	80,000
6.	Miscellaneous plant equipment	53,000
7.	15% contingency on Items 3 through 6	38,000
8.	Engineering, construction mtg., and other costs	219,000
	Total Initial Project Cost	$ 1,313,000

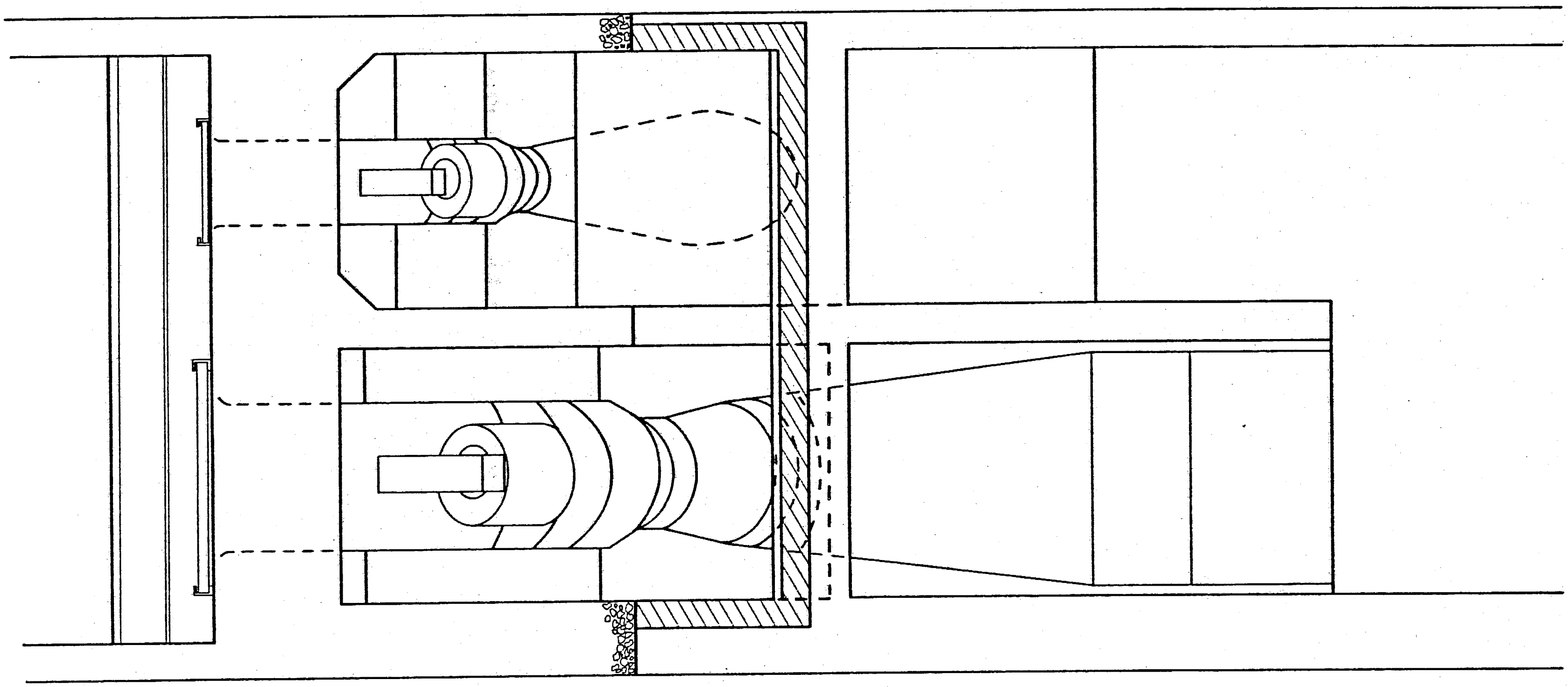


Fig. 22. Plan View of Alternative C: Two Inclined, Fixed-Blade Propeller Turbines.

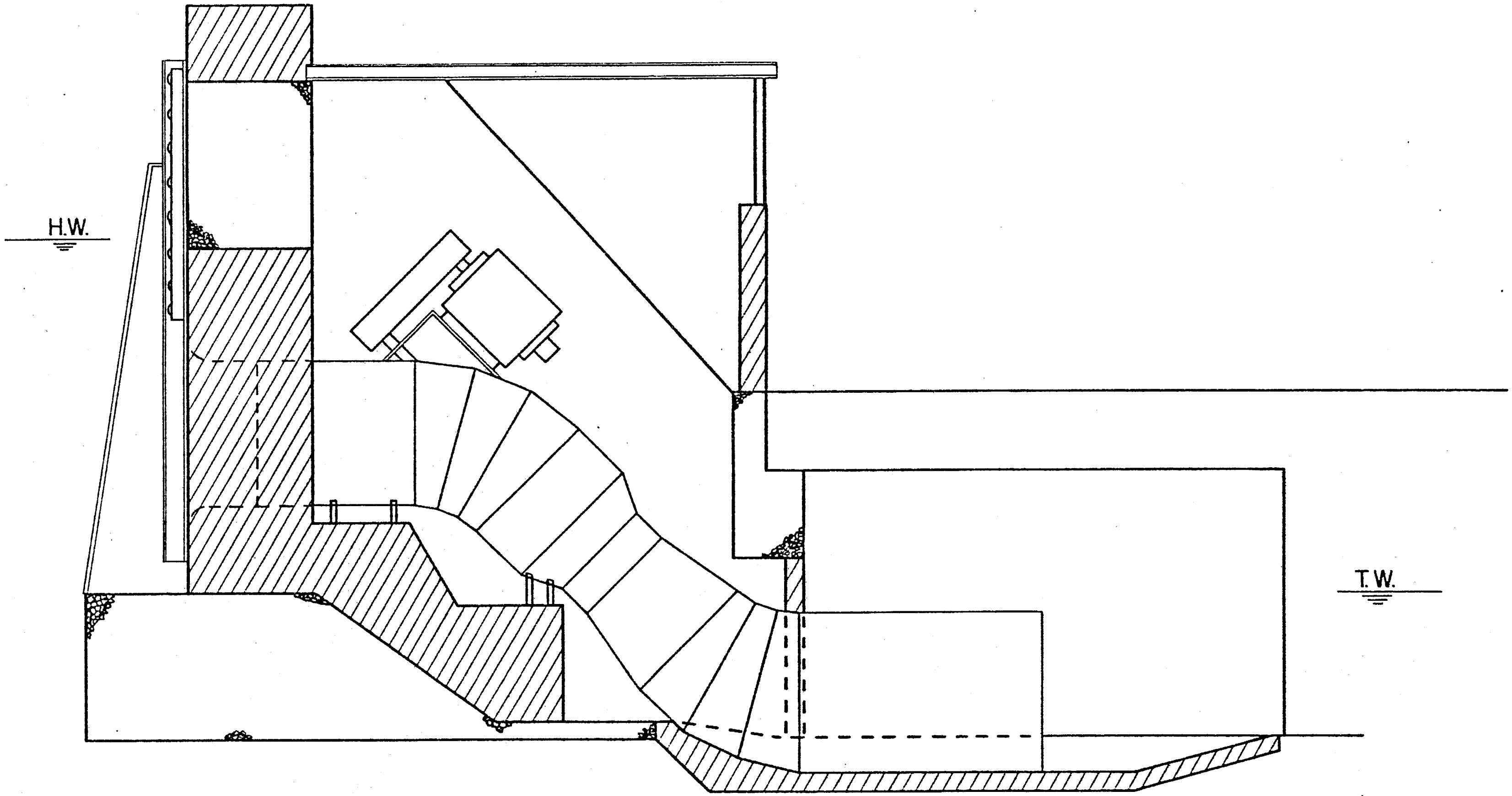


Fig. 23. Section View of Alternative C, Unit 2: 72 in. Runner Diameter. Generator Output is 814 kW at 554 cfs Rated Discharge and 20.5 feet Net Head.

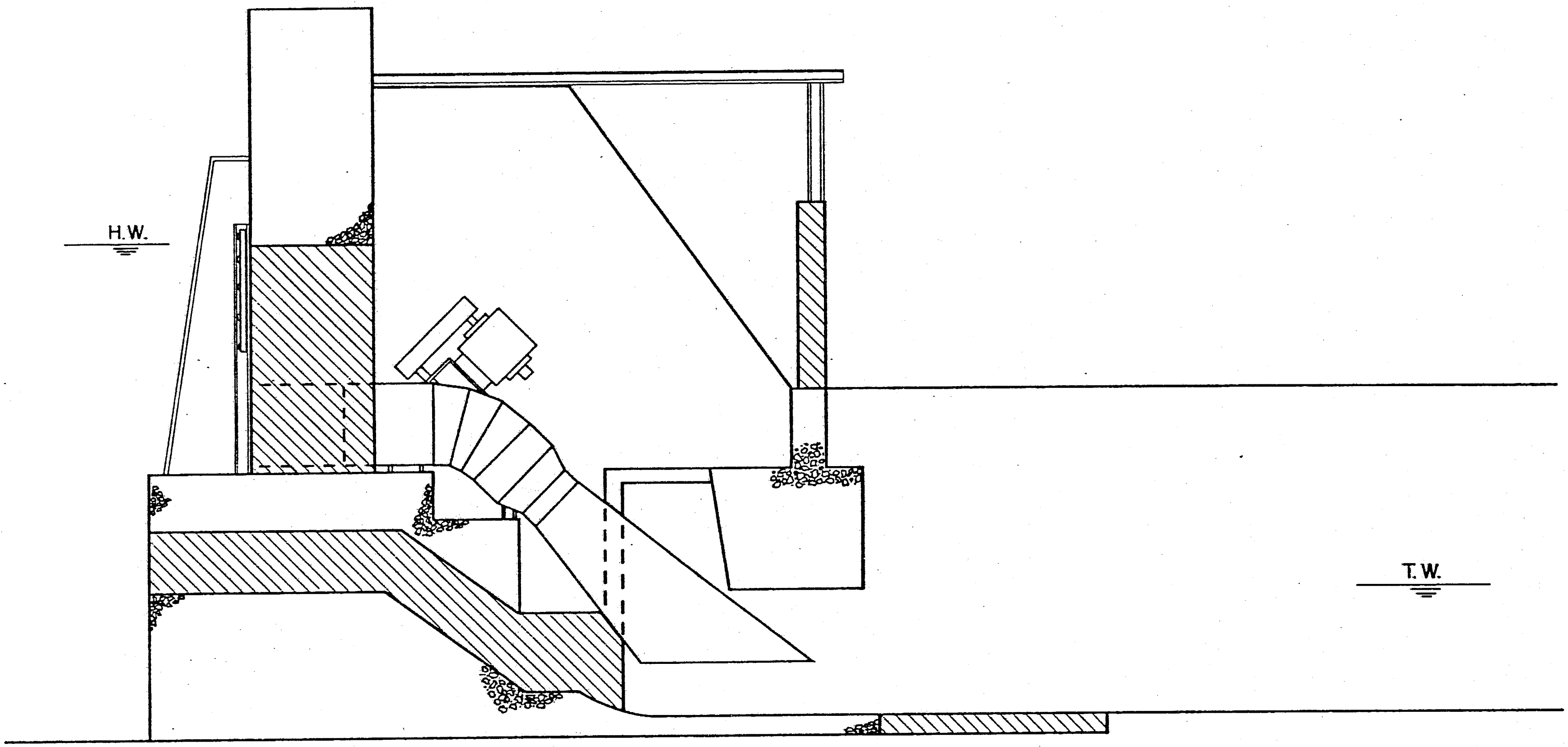


Fig. 24. Section View of Alternative C, Unit 1: 42 in. Runner Diameter. Generator Output is 277 kW at 190 cfs Rated Discharge and 20.5 feet Net Head.

Total plant capacity for Alternative C is greater than that for Alternatives A and B. The fixed blade turbines, however, do not operate over a range of flows but have one operating flow for each net head. Alternative C also requires a more costly controller than Alternative A and B because it is a two-unit facility.

The average annual energy production, relative project cost, and annual capacity credit with each operational option are given for Alternative C in Table 2.

TABLE 2. Average Annual Energy Production, Relative Project Cost, and Annual Capacity Credit for Alternative C, Kettle River Dam (1981 base year)

	Operation Option				
	1	2	3	4	5
Average Annual Energy Production (GWH)	3.53	3.28	4.78	3.78	4.12
Relative Project Cost ($/kWH)	0.37	0.40	0.28	0.34	0.32
Annual Capacity Credit ($)	13,200	11,200	65,600	38,400	38,400
Annual Gross Income ($)	78,500	60,700	154,000	108,300	114,600

D. Alternative D: One Horizontal, Adjustable-Blade Propeller Turbine with Variable Guide Vanes

Alternative D is one horizontal, adjustable-blade propeller turbine with variable guide vanes, manufactured by the James Leffel & Company. The unit specifically considered has a 1650 mm turbine with design turbine output of 700 kW at 20 ft net head and 450 cfs discharge. Minimum turbine discharge is approximately 190 cfs. The addition of variable guide vanes will give an adjustable-blade turbine better efficiency at partial load (lower discharge).

Leffel's preliminary cost estimate for the turbine, synchronous generator, speed increaser, governor, and turbine controls was $514,000. A plan and section of a preliminary layout for Alternative D are given in Figs. 25 and 26. The cost estimates for this development alternative are as follows:

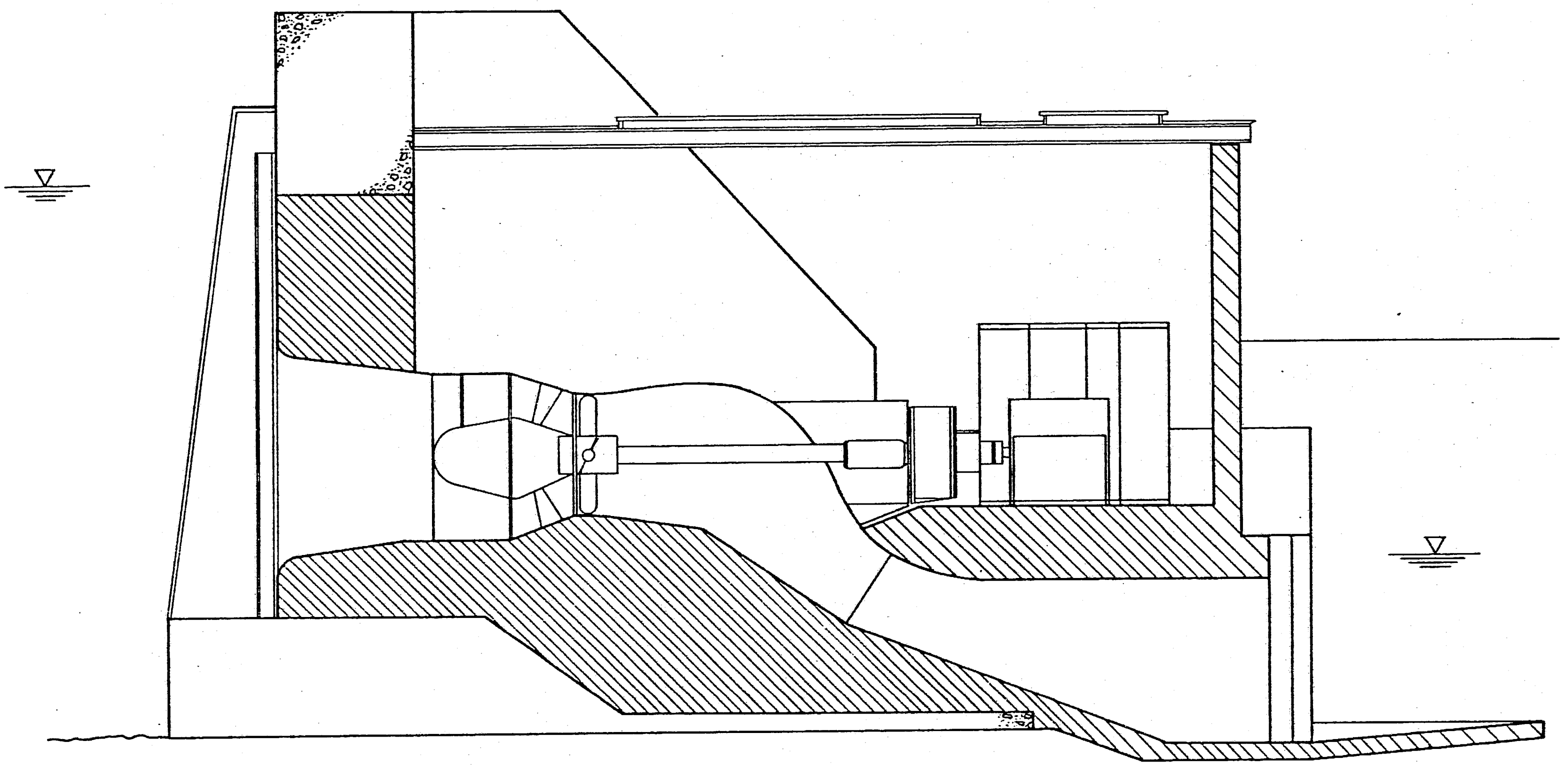


Fig. 25. Section View of Alternative D: One Horizontal, Adjustable Blade Propeller Turbine with Variable Guide Vanes. Runner diameter is 1650 mm. Design Turbine Output is 700 kW at 20 feet Net Head and 450 cfs Discharge.

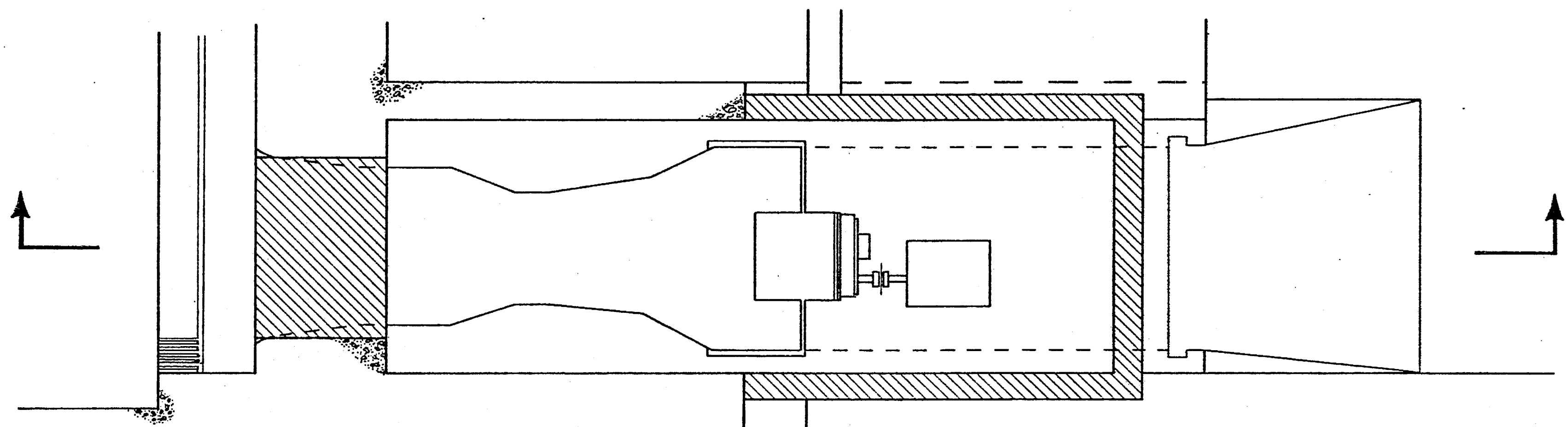


Fig. 26. Plan View of Alternative D: Only one Turbine Bay is Used.

Alternative D Cost Estimates (1981 base year)

1.	Civil works costs	$ 232,000
2.	Turbine and generator	514,000
3.	Electrical equipment	145,000
4.	72 ft^2 roller gate	16,000
5.	Turbine and generator installation	93,000
6.	Freight	10,000
7.	Automatic control equipment	68,000
8.	Miscellaneous plant equipment	53,000
9.	15% contingency on Items 5 through 8	36,000
10.	Engineering, construction mtg., and other costs	233,000
	Total Initial Cost	$1,400,000

The average annual energy production, project relative cost, and annual capacity credit for Alternative D are given in Table 3.

TABLE 3. Average Annual Energy Production, Relative Project Cost, and Annual Capacity Credit for Alternative D, Kettle River Dam (1981 base year)

	Operation Option				
	1	2	3	4	5
Average Annual Energy Production (GWH)	3.23	2.70	3.80	3.24	3.37
Relative Project Cost ($/kWH)	0.44	0.52	0.37	0.43	0.42
Annual Capacity Credit ($)	19,100	17,500	67,400	41,900	41,900
Annual Gross Income ($)	78,900	67,500	137,700	101,840	104,600

E. Other Alternatives Considered

There were two other development alternatives considered in addition to the two Neypric right-angle drive units described in Section VIII.C. The first is a Bell S-turbine with an 1900 mm variable blade-angle propeller turbine and variable guide vanes. Design turbine output is 1,125 kW at 19.9 ft net head and 750 cfs discharge. Minimum discharge is approximately 190 cfs. Although the unit is competively priced, the specified runner centerline settling (El. 935) would have required extensive excavation and an entirely new powerhouse foundation. The Bell S-turbine is marketed by Sulzer Bros.

The other development alternative considered was two variable blade-angle Allis-Chalmers tube units with 1250 mm runner diameter. Design generator output for each unit is 370 kW at 20 ft net head and 280 cfs discharge. Minimum turbine discharge is 91 cfs. Although this alternative would have required the minimum amount of civil works construction, the cost of the turbine/generator units excluded them from further consideration.

Rehabilitation of the existing turbines was considered in the early stages of this study. In addition to turbine rehabilitation costs, new roller gates, new trash racks, and extensive powerhouse modification would still be required. Rehabilitation costs are difficult to determine. The James Leffel Co. indicates that accurate cost estimates require a Phase II rehabilitation inspection which Leffel will undertake for between $3,000 and $4,000. Leffel did give a preliminary estimate of $390,000 for turbine rehabilitation, speed increasers, generators, and switchgear. This would give two operational Francis turbines and a total plant capacity of 575 kW. The efficiency of the Francis runners is low (78%) for low-head sites. In addition, the powerhouse would still need to be renovated. The authors of this study believe that the condition of the site and of the few components which remain does not justify rehabilitation of the previous hydropower facility.

There are three other turbine manufacturers marketing turbines in the United States which are applicable to the Kettle River Dam. Axel Johnson, Inc. is marketing the standardized kMW unit, which is available in vertical or horizontal arrangements. Kraerner-Moss is marketing the tubular Sorumsand-Verksted turbine, a standardized horizontal unit. Voest-Alpine is also marketing a standardized horizontal unit which is applicable to the site. Although these three manufacturers did not respond to requests for cost estimates, they should be contacted during later levels of project development.

A number of generator manufacturers also respond to requests for bids on hydroelectric projects. In this case, the generator manufacturer would submit a bid in conjunction with one of the turbine manufacturers mentioned herein. Three generator manufacturers who have made bids for low-head hydroelectric developments are General Electric, Brown-Boveri, and Westinghouse.

F. Summary of Project Development Alternatives

There is not a great deal of difference in project cost and energy production between the project development alternatives. The choice of operational plan, however, will have a major effect upon the energy generated by the facility and its corresponding capacity credits. The average annual energy production and annual capacity credit of each of the development alternatives are compared in Tables 4 and 5.

TABLE 4. Average Annual Energy Production for Project Development Alternatives A, B, C, and D (GWH)

Operational Option	Development Alternative			
	A	B	C	D
1	3.41	3.41	3.53	3.23
2	3.26	3.26	3.28	2.70
3	4.26	4.26	4.78	3.80
4	3.39	3.39	3.78	3.24
5	3.53	3.53	4.12	3.37

TABLE 5. Annual Capacity Credit for Project Development Alternatives A, B, C, and D ($, 1981 base year)

Operational Option	Development Alternative			
	A	B	C	D
1	$18,000	$18,000	$13,200	$19,100
2	12,700	12,700	11,200	17,500
3	64,900	64,900	65,600	67,400
4	39,800	39,800	38,400	41,900
5	39,800	39,800	38,400	41,900

IX. ECONOMIC ANALYSIS

A. Background and Assumptions

This section of the report will compare the benefits and costs of hydropower development at the Kettle River Dam. Certain basic assumptions, which are required in benefit/cost analysis, will be outlined before describing the results of the economic analysis. The sensitivity of the benefit/cost comparisons to these basic assumptions is investigated in Section IX.E.

1. Economic Feasibility Indicators

A number of economic feasibility indicators will be given herein to provide interested parties with a choice of decision rules and outline the economic advantages and disadvantages of each option. These indicators are:

- The first year cost of power is the cost of debt service, operation and maintenance, and other costs divided by the average annual energy production.
- The benefit-cost ratio is the present worth of project benefits divided by the present worth of initial project costs and annual costs.

$$B/C = \frac{\sum_{i=0}^{n} B_i/(1+d)^i}{C_i + \sum_{i=0}^{n} OMi/(1+d)^i} \qquad (2)$$

where B/C = benefit-cost ratio for a project economic life of n years,

B_i = benefits in year i ,

C_I = initial project cost,

OM_i = operation, maintenance, and replacement costs in year i ,

d = discount rate, and

n = project economic life.

- The net present value is the present worth of project benefits minus the present worth of project costs:

$$NPV = \sum_{i=0}^{n} NB_i/(1 + d)^i \qquad (3)$$

where NPV = net present value for a project economic life of n years, and

NB_i = net project benefits in year i (benefits minus costs).

- The internal rate of return is the discount rate which would give zero net present value at the end of the project economic life.

2. Assumptions

The project development should be considered as an investment, even if the project is financed by State of Minnesota appropriations. For this reason, the economic analysis will assume that the project is financed by 20-year tax-exempt bonds. Other assumptions used in the benefit/cost analysis herein are as follows:

- 10 per cent discount rate. Interest rates on tax-exempt bonds have been climbing since the beginning of 1980. As of March 26, 1981, Moody's A-rated municipal bond index had stabilized at approximately 10 per cent [7]. This value will be used as a discount rate herein.

- 10 per cent annual escalation in the value of energy and power. Power producing utilities in the State of Minnesota have projected that the value of electricity will increase at or near the rate of inflation over the next 20 years*. The annual increase in the Consumer Price Index between 1977 and 1981 has averaged 9.9 per cent. This figure was rounded off to a 10 per cent escalation rate for the benefit/cost analysis.

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*Minnesota Energy Agency.

- $22,000 annual operation, maintenance, and replacement costs for base year 1981. This figure was determined from Ref.[6].
- 10 per cent annual escalation in operation, maintenance, and replacement costs. This rate was chosen to follow the 1977 through 1981 average CPI.
- A two year construction period [6].
- A linear expenditure of capital during project construction.

The sensitivity of the benefit/cost analysis to discount rate and escalation rates will be described in Section IX.E.

B. Comparison of Project Development Alternatives

The first year cost of power, benefit-cost ratio, net present value, and internal rate of return of each of the development alternatives are compared for each operational plan in Tables 6 through 9. A 35-year and 50-year project economic life were used. The 35-year project economic life is commonly used for hydroelectric facilities. The useful life of a hydropower facility, however, is anywhere from 50 to 100 years. The 50-year project economic life is also used herein because it corresponds more closely to the useful life of any proposed facility.

The economic superiority of operational Option #3 is the most distinct feature of Tables 6 through 9. If operation Option #3 is unacceptable for the purposes of recreational management, operational Option #4, which is a compromise between power production and recreational management, is the next best choice. The small additional income generated by Option #5, when compared to Option #4, does not justify the added complexities of the operational scheme. Operational Option #2 has the worst economic feasibility for hydropower development at the Kettle River Dam.

There is not a great deal of difference between development Alternatives A, B, C, and D. Alternative C, on the average, appears to give marginally superior economic feasibility indicators. For this reason, Alternative C will be used in developing the cost and benefit streams, the private financing example, and the sensitivity analysis of the following three sections.

TABLE 6. First Year Cost of Power for the Kettle River Dam (cents/kWH, 1981 base year)

Operational Option	Development Alternative A	B	C	D
1	5.2	5.2	4.9	5.7
2	5.4	5.4	5.2	6.8
3	4.1	4.1	3.6	4.9
4	5.2	5.2	4.6	5.7
5	5.0	5.0	4.2	5.5

TABLE 7. Benefit-Cost Ratio for a 35-Year and 50-Year Economic Project Life, Kettle River Dam

Operational Option	Development Alternative A	B	C	D
35-Year Project Economic Life				
1	1.40	1.40	1.36	1.31
2	1.26	1.26	1.25	1.12
3	2.47	2.48	2.68	2.30
4	1.76	1.76	1.88	1.70
5	1.81	1.81	1.99	1.74
50-Year Project Economic Life				
1	1.74	1.74	1.70	1.64
2	1.56	1.57	1.55	1.41
3	3.08	3.08	3.33	2.87
4	2.20	2.20	2.34	2.12
5	2.25	2.25	2.48	2.18

TABLE 8. Present Net Value for a 35-Year and 50-Year Economic Project Life, Kettle River Dam (million $, 1981 base year)

Operational Option	Development Alternative			
	A	B	C	D
35-Year Project Economic Life				
1	.86	.86	.79	.72
2	.58	.58	.56	.32
3	3.06	3.06	3.44	2.78
4	1.61	1.61	1.84	1.53
5	1.70	1.70	2.06	1.63
50-Year Project Economic Life				
1	1.78	1.78	1.67	1.61
2	1.38	1.38	1.34	1.04
3	4.91	4.92	5.45	4.55
4	2.85	2.85	3.16	2.76
5	2.98	2.98	3.48	2.89

TABLE 9. Internal Rate of Return for a 35-Year and 50-Year Economic Project Life, Kettle River Dam (annual per cent)

Operational Option	Development Alternative			
	A	B	C	D
35-Year Project Economic Life				
1	16.3	16.3	16.0	15.4
2	14.9	14.9	14.8	13.5
3	27.3	27.4	30.0	25.1
4	19.9	19.9	21.1	19.1
5	20.3	20.3	22.2	19.5
50-Year Project Economic Life				
1	17.0	17.0	16.8	16.3
2	15.8	15.8	15.8	14.6
3	27.4	27.5	30.1	25.2
4	20.3	20.3	21.4	19.6
5	20.7	20.7	22.5	20.0

C. Cost and Benefit Streams

The cost and benefit streams for alternative C, operational options 2, 3, and 4,are given in Tables 10, 11, and 12. Table 11 indicates that if the project is funded with 20-year tax exempt bonds, it would have a negative cash flow only during the construction period with operational Option #3. This analysis, of course, is dependent upon the assumptions listed in Section IX.A. The negative cash flow of operational Option #4 (Table 12) is estimated to continue two years into plant operation. This is another indication of excellent economic feasibility.

D. Private Financing Example

This section will give an example of the benefit-cost comparisons which might apply to development of the hydropower facility at the Kettle River Dam with private financing. The following assumptions will be made in addition (or in place of) the assumptions given in Section IX.D.

- 15 per cent discount rate,
- 21 per cent investment and energy tax credit,
- 10 year depreciation of equipment,
- 20 year depreciation of structure, and
- 50 per cent tax bracket.

The economic analysis which would actually be applied to the feasibility of private financing depends upon the individual investor group.

The benefit and cost streams which would result from the above assumptions for Alternative C, operational Option #4, are given in Table 13. The present net value and benefit-cost ratio are $522,000 and 1.04. respectively, for a 35-year project economic life.

E. Sensitivity Analysis

Sensitivity analysis investigates the impact of variations in project parameters and economic assumptions on the feasibility indicators. The analysis will determine the sensitivity of the feasibility indicators to important project parameters and assumptions.

TABLE 10. Cost and Benefit Streams for Development Alternative C, Operational Option 2, at the Kettle River Dam. Base year for present worths = 1981. Two-year construction period. 10 per cent discount and escalation rates. All figures are in dollars. Year 1 = 1982.

Year	Debt Service	O & M Costs	Gross Income	Present Worths Benefits	Present Worths Costs	Present Worths Cash Flow	Present Net Value
1	77112	0	0	0	-70102	-70102	-70102
2	154224	0	0	0	-127458	-127458	-197560
3	154224	26620	95672	71880	135871	-63991	-261551
4	154224	29282	105240	71880	125337	-53457	-315009
5	154224	32210	115763	71880	115761	-43881	-358890
6	154224	35431	127340	71880	107056	-35176	-394066
7	154224	38974	140074	71880	99142	-27262	-421327
8	154224	42872	154081	71880	91947	-20067	-441394
9	154224	47159	169489	71880	85406	-13526	-454920
10	154224	51875	186438	71880	79460	-7580	-462501
11	154224	57062	205082	71880	74055	-2175	-464675
12	154224	62769	225590	71880	69141	2739	-461936
13	154224	69045	248149	71880	64673	7207	-454729
14	154224	75950	272964	71880	60612	11268	-443462
15	154224	83545	300261	71880	56920	14960	-428502
16	154224	91899	330287	71880	53564	18316	-410185
17	154224	101089	363315	71880	50512	21368	-388818
18	154224	111198	399647	71880	47739	24141	-364677
19	154224	122318	439612	71880	45217	26663	-338013
20	154224	134550	483573	71880	42924	28956	-309058
21	77112	148005	531930	71880	30420	41460	-267598
22	0	162805	585123	71880	20000	51880	-215718
23	0	179086	643635	71880	20000	51880	-163838
24	0	196995	707999	71880	20000	51880	-111958
25	0	216694	778799	71880	20000	51880	-60078
26	0	238364	856679	71880	20000	51880	-8198
27	0	262200	942346	71880	20000	51880	43682
28	0	288420	1036581	71880	20000	51880	95562
29	0	317262	1140239	71880	20000	51880	147442
30	0	348988	1244263	71880	20000	51880	199322
31	0	383887	1379689	71880	20000	51880	251202
32	0	422276	1517658	71880	20000	51880	303082
33	0	464503	1669424	71880	20000	51880	354962
34	0	510953	1836367	71880	20000	51880	406842
35	0	562049	2020003	71880	20000	51880	458722
36	0	618254	2222003	71880	20000	51880	510602
37	0	680079	2444204	71880	20000	51880	562482
38	0	748087	2688624	71880	20000	51880	614362
39	0	822896	2957487	71880	20000	51880	666242
40	0	905185	3253235	71880	20000	51880	718122
41	0	995704	3578559	71880	20000	51880	770002
42	0	1095274	3936415	71880	20000	51880	821882
43	0	1204801	4330056	71880	20000	51880	873762
44	0	1325282	4763062	71880	20000	51880	925642
45	0	1457810	5239368	71880	20000	51880	977522
46	0	1603591	5763305	71880	20000	51880	1029402
47	0	1763950	6339635	71880	20000	51880	1081282
48	0	1940345	6973599	71880	20000	51880	1133162
49	0	2134379	7670959	71880	20000	51880	1185042
50	0	2347817	8438055	71880	20000	51880	1236922
51	0	2582599	9281860	71880	20000	51880	1288802
52	0	2840859	10210046	71880	20000	51880	1340682

For 1981 Base Year:

Energy Value - 1.85¢/kWH

Annual Capacity Credit = $11,200

Average Annual Energy = 3.28 GWH

Total Initial Project Cost = $1,313,000

TABLE 11. Cost and Benefit Streams for Development Alternative C, Operation Option 3, at the Kettle River Dam. Base year for present worths = 1981. Two year construction period. 10 per cent discount and escalation rates. All figures are in dollars. Year 1 = 1982.

Year	Debt Service	O & M Costs	Gross Income	Present Worths: Benefits	Present Worths: Costs	Present Worths: Cash Flow	Present Net Value
1	77112	0	0	0	70102	-70102	-70102
2	154224	0	0	0	127458	-127458	-197560
3	154224	26620	205014	154030	135871	18159	-179401
4	154224	29282	225515	154030	125337	28693	-150709
5	154224	32210	248067	154030	115761	38269	-112440
6	154224	35431	272874	154030	107056	46974	-65466
7	154224	38974	300161	154030	99142	54888	-10577
8	154224	42872	330177	154030	91947	62083	51506
9	154224	47159	363195	154030	85406	68624	120130
10	154224	51875	399514	154030	79460	74570	194699
11	154224	57062	439466	154030	74055	79975	274675
12	154224	62769	483412	154030	69141	84889	359564
13	154224	69045	531753	154030	64673	89357	448921
14	154224	75950	584929	154030	60612	93418	542338
15	154224	83545	643422	154030	56920	97110	639448
16	154224	91899	707764	154030	53564	100466	739915
17	154224	101089	778540	154030	50512	103518	843432
18	154224	111198	856394	154030	47739	106291	949723
19	154224	122318	942033	154030	45217	108813	1058537
20	154224	123550	1036237	154030	42924	111106	1169642
21	77112	148005	1139860	154030	30420	123610	1293252
22	0	162805	1253847	154030	20000	134030	1427282
23	0	179086	1379231	154030	20000	134030	1561312
24	0	196995	1517154	154030	20000	134030	1695342
25	0	216694	1668870	154030	20000	134030	1829372
26	0	238364	1835757	154030	20000	134030	1963402
27	0	262200	2019332	154030	20000	134030	2097432
28	0	288420	2221266	154030	20000	134030	2231462
29	0	317262	2443392	154030	20000	134030	2365492
30	0	348988	2687731	154030	20000	134030	2499522
31	0	383887	2956505	154030	20000	134030	2633552
32	0	422276	3252155	154030	20000	134030	2767582
33	0	464503	3577371	154030	20000	134030	2901612
34	0	510953	3935108	154030	20000	134030	3035642
35	0	562049	4328618	154030	20000	134030	3169672
36	0	618254	4761480	154030	20000	134030	3303802
37	0	680079	5237628	154030	20000	134030	3437732
38	0	748087	5761391	154030	20000	134030	3571762
39	0	822896	6337530	154030	20000	134030	3705792
40	0	905185	6971283	154030	20000	134030	3839822
41	0	995704	7668411	154030	20000	134030	3973852
42	0	1095274	8435253	154030	20000	134030	4107882
43	0	1204801	9278778	154030	20000	134030	4241912
44	0	1325282	10206656	154030	20000	134030	4375942
45	0	1457810	11227321	154030	20000	134030	4509972
46	0	1603591	12350053	154030	20000	134030	4644002
47	0	1763950	13585059	154030	20000	134030	4778032
48	0	1940345	14943565	154030	20000	134030	4912062
49	0	2134379	16437921	154030	20000	134030	5046092
50	0	2347817	18081713	154030	20000	134030	5180122
51	0	2582599	19889884	154030	20000	134030	5314152
52	0	2840859	21878873	154030	20000	134030	5448182

For 1981 Base Year:

Energy Value = 1.85¢/kWH

Annual Capacity Credit = $65,600

Average Annual Energy = 4.78 GWH

Total Initial Project Cost = $1,313,000

TABLE 12. Cost and Benefit Streams for Development Alternative C, Operation Option 4, at the Kettle River Dam. Base year for present worths = 1981. Two year construction period. 10 per cent discount and escalation rates. All figures are in dollars. Year 1 = 1982.

Year	Debt Service	O & M Costs	Gross Income	--------- Present Worths ---------- Benefits	Costs	Cash Flow	Present Net Value
1	77112	0	0	0	70102	-70102	-70102
2	154224	0	0	0	127458	-127458	-197560
3	154224	26620	144187	108330	135871	-27541	-225101
4	154224	29282	158606	108330	125337	-17007	-242109
5	154224	32210	174467	108330	115761	-7431	-249540
6	154224	35431	191913	108330	107056	1274	-248266
7	154224	38974	211105	108330	99142	9188	-239077
8	154224	42872	232215	108330	91947	16383	-222694
9	154224	47159	255436	108330	85406	22924	-199770
10	154224	51875	280980	108330	79460	28870	-170901
11	154224	57062	309078	108330	74055	34275	-136625
12	154224	62769	339986	108330	69141	39189	-97436
13	154224	69045	373985	108330	64673	43657	-53779
14	154224	75905	411383	108330	60612	47718	-6062
15	154224	83545	452521	108330	56920	51410	45348
16	154224	91899	497773	108330	53564	54766	100115
17	154224	101089	547551	108330	50512	57818	157932
18	154224	111198	602306	108330	47739	60591	218523
19	154224	122318	662536	108330	45217	63113	281637
20	154224	134550	728790	108330	42924	65406	347042
21	77112	148005	801669	108330	30420	77910	424952
22	0	162805	881836	108330	20000	88330	513282
23	0	179086	970020	108330	20000	88330	601612
24	0	196995	1067022	108330	20000	88330	689942
25	0	216694	1173724	108330	20000	88330	778272
26	0	238364	1291096	108330	20000	88330	866602
27	0	262200	1420206	108330	20000	88330	954932
28	0	288420	1562226	108330	20000	88330	1043262
29	0	317262	1718449	108330	20000	88330	1131592
30	0	348988	1890294	108330	20000	88330	1219922
31	0	383887	2079323	108330	20000	88330	1308252
32	0	422276	2287255	108330	20000	88330	1396582
33	0	464503	2515981	108330	20000	88330	1484912
34	0	510953	2767579	108330	20000	88330	1573242
35	0	562049	3044337	108330	20000	88330	1661572
36	0	618254	3348771	108330	20000	88330	1749902
37	0	680079	3683648	108330	20000	88330	1838232
38	0	748087	4052013	108330	20000	88330	1926562
39	0	822896	4457214	108330	20000	88330	2014892
40	0	905185	4902935	108330	20000	88330	2103222
41	0	995704	5393229	108330	20000	88330	2191552
42	0	1095274	5932552	108330	20000	88330	2279882
43	0	1204801	6525807	108330	20000	88330	2368212
44	0	1325282	7178387	108330	20000	88330	2456542
45	0	1457810	7896226	108330	20000	88330	2544872
46	0	1603591	8685849	108330	20000	88330	2633202
47	0	1763950	9554434	108330	20000	88330	2721532
48	0	1940345	10509877	108330	20000	88330	2809862
49	0	2134379	11560865	108330	20000	88330	2898192
50	0	2347817	12716951	108330	20000	88330	2986522
51	0	2582599	13988646	108330	20000	88330	3074852
52	0	2840859	15387511	108330	20000	88330	3163182

For 1981 Base Year:

Energy Value = 1.85¢/kWH

Annual Capacity Credit = $38,400

Average Annual Energy = 3.78 GWH

Total Initial Project Costs = $1,313,000

TABLE 13. Cost and Benefit Streams for the Private Financing Example at the Kettle River Dam. All figures are in dollars; base year for present worths = 1981. Alternative C, Operational Option 4, Year 1 = 1982.

Year	Debt Service	O & M Costs	Gross Income and Tax Benefits	Present Worths: Benefits	Present Worths: Costs	Present Worths: Cash Flow	Present Net Value
1	104883	0	0	0	91203	-91203	-91203
2	209767	0	0	0	158614	-158614	-249817
3	209767	26620	433967	285340	155428	153386	-96431
4	209767	29282	208356	119128	136677	-17549	-113980
5	209767	32210	224217	11475	120305	-8830	-122810
6	209767	35431	241663	104478	106006	-1528	-124338
7	209767	38974	260855	98065	93511	4554	-119784
8	209767	42872	281965	92175	82588	9587	-110197
9	209767	47159	305186	86753	73034	13719	-96479
10	209767	51875	330730	81751	64674	17078	-79401
11	209767	57062	358828	77128	57353	19775	-59627
12	209767	62769	389736	72844	50939	21906	-37721
13	209767	69045	381385	61986	45315	16671	-21050
14	209767	75950	418783	59186	40380	18806	-2244
15	209767	83545	459921	56522	36046	20475	18231
16	209767	91899	505173	53875	32237	21748	39979
17	209767	101089	554951	51569	28887	22683	62662
18	209767	111198	609706	49267	25936	23332	85994
19	209767	122318	669936	47073	23334	23739	109733
20	209767	134550	736190	44981	21038	23944	133676
21	104883	148005	809069	42986	13436	29550	163227
22	0	162805	889236	41083	7522	33562	196788
23	0	179086	970020	38970	7195	31775	228563
24	0	196995	1067022	37276	6882	30394	258957
25	0	216694	1173724	35655	6583	29072	288029
26	0	238364	1291096	34105	6296	27808	315838
27	0	262200	1420206	32622	6023	37600	342437
28	0	288420	1462226	31204	5761	36554	367880
29	0	317262	1718449	29847	5510	35447	392216
30	0	348988	1890294	28549	5271	34378	415495
31	0	383887	2079323	27308	5042	33366	437761
32	0	422276	2287255	26121	4822	31398	459059
33	0	464503	2515981	24985	4613	30473	479431
34	0	510953	2767579	23899	4412	19586	498918
35	0	562049	3044337	22860	4220	18649	517557
36	0	618254	3348771	21866	4037	17839	535386
37	0	680079	3683648	20915	3861	17065	552440
38	0	748087	4052013	20006	3693	16434	568752
39	0	822896	4457214	19136	3533	16604	584355
40	0	905185	4902935	18304	3379	15936	599279
41	0	995704	5393229	17508	3232	15376	613555
42	0	1095274	5932552	16747	3092	14666	627210
43	0	1204801	6525807	16019	2947	14061	640271
44	0	1325282	7178387	15322	2829	12493	652765
45	0	1457810	7896226	14656	2706	11950	664715
46	0	1603591	8685849	14019	2588	11431	676146
47	0	1763950	9554434	13409	2476	10934	687079
48	0	1940345	10509877	12826	2368	10458	697538
49	0	2134379	11560865	12269	2265	10004	707541
50	0	2347817	12716951	11735	2167	9569	717110
51	0	2582599	13988646	11225	2072	9153	726262
52	0	2840859	15387511	10737	1982	8755	735017

For 1981 Base Year:

Energy Value = 1.85¢/kWH

Annual Capacity Credit = $38,400

Average Annual Energy = 3.78 GWH

Total Initial Project Cost = $1,313,000

1. Loss of Dependable Capacity Credit

Both MP and UPA have stated on record that qualifying facilities (such as small scale hydroelectric facilities) from which they purchase energy should receive no dependable capacity credit because they (MPA and UPA) currently have excess capacity. The final decision on rates for the purchase of power by either utility from a qualifying facility is made by the Minnesota Public Utility Commission (PUC). It is possible that the PUC will rule in favor of the utility viewpoint. In that case, a hydroelectric facility at the Kettle River Dam would receive no dependable capacity credit.

The impact of a loss of capacity credit on the various feasibility indicators is given in Table 14 for development Alternative C.

Without capacity credit, each of the feasibility indicators show a less attractive investment. The 35-year benefit-cost ratio, for example, of Operational Options 2, 3, and 4, are reduced from 1.25, 2.68, and 1.88 to 1.06, 1.54, and 1.22, respectively. In addition, the difference between the economic return which may be expected from each operational option without capacity credit is still large, but not as great as when capacity credit is included.

2. First Year Value of Energy

Hydropower feasibility is naturally dependent upon the price at which the generated electricity is sold. In Section VI, this value was estimated to be 1.85 cents/kWH for the Kettle River Dam (1981 base year). Figure 27 gives the 35-year benefit-cost ratio over a range of energy prices for development Alternative C, Operation Option #4. Project feasibility increases dramatically with an increase in energy value, as would be expected. With Operational Option #4, Alternative C would have a good feasibility even if the energy value were only 1.5 cents/kWH.

3. Discount and Escalation Rates

Economic feasibility is extremely sensitive to discount and escalation rates. The economic feasibility indicators for Alternative C, Option #4, are given in Table 15 for four combinations of discount and escalation rates.

TABLE 14. Benefit-Cost Ratio, Present Net Value, and Internal Rate of Return Without Capacity Payments for Development Alternative C, Kettle River Dam

	Operational Option				
	1	2	3	4	5
35-year Project					
Economic Life:					
Benefit-Cost Ratio	1.14	1.06	1.54	1.22	1.33
Present Net Value (million $)	0.33	0.17	1.14	0.49	0.71
Internal Rate-of-Return (%)	13.7	12.8	17.7	14.5	15.6
50-year Project					
Economic Life:					
Benefit-Cost Ratio	1.41	1.31	1.91	1.51	1.65
Present Net Value (million $)	1.01	0.78	2.17	1.24	1.56
Internal Rate of Return (%)	14.7	14.0	18.3	15.5	16.4

TABLE 15. Benefit-Cost Ratio, Present Net Value, and Internal Rate of Return at Four Combinations of Discount and Escalation Rates for Development Alternative C, Operation Option #4, Kettle River Dam

Discount Rate	8	8	10	10
Escalation Rate for Energy Value	8	10	8	10
Escalation Rate for O & M	8	10	8	10
35-year Project Economic Life:				
Benefit-Cost Ratio	2.06	3.02	1.45	2.06
Present Net Value (million $)	1.99	3.44	1.09	2.00
Internal Rate of Return (%)	20.2	23.4	20.2	23.4
50-year Project Economic Life:				
Benefit-Cost Ratio	2.53	4.33	1.58	2.53
Present Net Value (million $)	3.32	6.47	1.67	3.33
Internal Rate of Return (%)	20.5	23.6	20.5	23.6

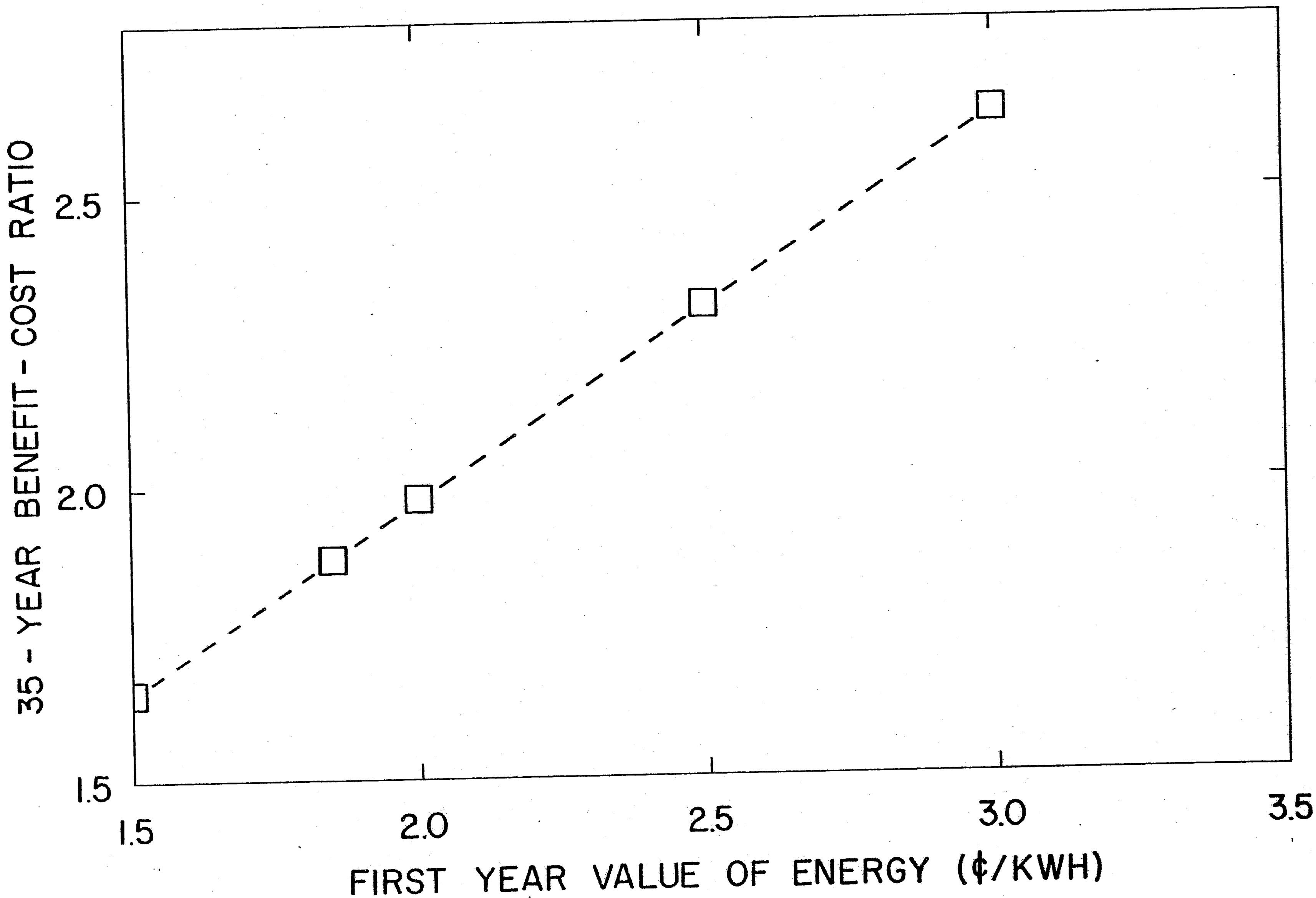

Fig. 27. 35-Year Benefit-Cost Ratio Vs. the First Year Value of Energy (1981 Base Year) for Development Alternative C, Operational Option #4, Kettle River Dam.

In all cases the energy escalation rate and the escalation rate for operation, maintenance, and replacement were assumed to be equal. The worst case is a discount rate of 10 per cent and escalation rate of 8 per cent. Alternative C, Option #4 still maintains good feasibility indicators, however, even under these adverse economic conditions.

X. ENVIRONMENTAL IMPACT OF PROPOSED DEVELOPMENT

A. Background

Because small-scale hydropower facilities are generally developed at existing dam sites, the environmental impact is usually limited: there is no land inundated due to new dam construction and the character of the stream is not greatly altered. The environmental impact of small-scale hydropower facilities should not be entirely discounted, however. There are likely to be a few cases where a fishery may be harmed, public health may be threatened due to dredge spoils, or a historic structure may be destroyed. The scope of this Section is to identify, in general, the potential environmental impacts of small-scale hydropower plants at existing dam sites. The goal of this section is to determine the potential impacts in accordance with the Federal Energy Regulatory Commission's (FERC) requirements for the filing of a Short-Form Minor License or Exemption from Licensing for hydroelectric power development.

In order to evaluate the environmental impacts of a hydropower facility, the mode of operation must be specified. Operational modes may be divided into two general catagories:

1. Run-of-River. Hydropower plants which have sufficient reservoir storage for seasonal peaking are classified as run-of-river. This catagory includes facilities which have enough reservoir storage for peaking on a daily basis. We prefer to differentiate between these two sub-catagories with the terms "strict run-of-river" and "daily storage."

2. Seasonal Peaking. If the facility will be used for store-release peaking on a seasonal basis, the river or stream will be subject to larger and more intermittent water level fluctuations. A seasonal peaking operation may therefore have a more detrimental effect on the environment.

The following aspects of the operation of a hydroelectric facility are important for environmental considerations:

1. Minimum flow.
2. Water level fluctuation.
3. Fish passage through hydraulic turbines.
4. Dredging and disposal of dredged material.
5. Water quality impacts.
6. Threatened or endangered species.

There will also be additional temporary impacts during construction. Timing of construction activities may be such that they minimize impact upon the spawning activities of fish and other facets of aquatic life.

Other construction activities which could have an adverse effect upon the environment include dredging and dust control. This is most easily controlled by installing a cofferdam to reduce excessively turbid releases to the stream. Land use impacts that should be addressed concern the fact that powerhouses and dams alter the general scenery along a river, displace streamside vegetation, and present obstacles to terrestrial wildlife species [8]. Indirect impacts of small-scale hydropower may lead to new opportunities and responsibilities for supporting recreational, commercial, agricultural, or residential activity [8].

There are also several other considerations for which the degree of severity or applicability must be determined on a site-specific basis. These include powerline construction, noise reduction, earthwork, historical and archaeological significance, endangered species (plants and animals), recreation (parks, canoe routes, etc.), and aesthetic quality. Also of prime importance in determining impacts would be the designation of a river or stream as a Wild and Scenic River on either a state or federal basis. There are usually no impacts incurred by the dam itself because if these impoundments have been in place a long time, it is likely that environmental modifications have already taken place. Fish and wildlife habitats have already adapted to the existing dam [8].

An effective means of screening the site-specific environmental impacts is by utilizing an environmental impact matrix as shown in Fig. 28 [9] for

● SIGNIFICANT IMPACT

◉ LIMITED IMPACT

☐ INSIGNIFICANT OR NO IMPACT

PROPOSED ACTIVITIES		NATURAL FACTORS												CULTURAL FACTORS																											
		TERRESTRIAL		HYDROLOGICAL				BIOLOGICAL				ATMOSPHERIC		SOCIAL														LAND USE - LAND VALUE					INFRASTRUCTURE				RECREATION					
		SOILS	LAND FORM	SURFACE WATER LEVELS	SURFACE WATER QUALITY	UNDERGROUND WATER QUALITY	WELL WATER SUPPLY	VEGETATION	FISH AND AQUATIC WILDLIFE	BIRDS	TERRESTRIAL WILDLIFE	AIR QUALITY		SCENIC VIEWS & VISTAS	OPEN SPACE QUALITIES	HISTORICAL ARCHEOLOGICAL SITES	RARE AND UNIQUE SPECIES	HEALTH AND SAFETY	AMBIENT NOISE LEVEL	RESIDENTIAL ACTIVITY	EMPLOYMENT (SHORT TERM)	EMPLOYMENT (LONG TERM)	HOUSING (SHORT TERM)	HOUSING (LONG TERM)	LOCAL GOVERNMENT FISCAL EFFECTS	BUSINESS ACTIVITY	AGRICULTURAL	RESIDENTIAL	COMMERCIAL	INDUSTRIAL	OPEN SPACE	TRANSPORTATION	UTILITIES	WASTE DISPOSAL	GOVERNMENT SERVICES	HUNTING	FISHING	BOATING	SWIMMING	PICNICKING	HIKING-BIKING
CONSTRUCTION	EARTHWORK CLEARING/GRADING/EXCAV.				◉				◉																																
	DEMOLITION/DISPOSAL				◉									◉		◉																		◉							
	INTERIM FLOOD CONTROL				◉				◉																																
	COFFER DAM/DEWATERING				◉				◉																																
	HEAVY EQUIPMENT USE													◉				◉	◉																						
	MATERIAL TRANSP./STORAGE																																								
	TEMPORARY STRUCTURES AND FACILITIES													◉																											
	WORKER AND EQUIP. ACCESS																																								
	WORKER INFLUX																				◉					◉															
PHYSICAL PLANT & OPERATION	PERMANENT STRUCTURES & FACILITIES			◉										◉		◉																									
	ELECTRIC DISTRIB. CIRCUITS													◉																											
	ELECTRIC GENERATION																																◉								
	FLOW CONTROL			◉					◉					●																							◉	◉			
	IMPOUND, MANAGEMENT			◉	◉				◉																									◉			◉	◉			
	WORKER & EQUIP. ACCESS																																								
	SECURITY & SAFETY																																								

Fig. 28. Environmental Impact Matrix for the Kettle River Dam.

the Kettle River Dam. The facility will be operated as run-of-river with a possible 1/2 foot reservoir drawdown when river discharge is below minimum turbine discharge. Interestingly, the most significant adverse impact in our opinion is scenic. The site is located in a state park and the water flowing over the spillway is a scenic attraction. With the hydropower facility, the water flowing over the spillway will either be reduced or eliminated during certain periods of the year, depending upon the facility's operational plan.

B. FERC Requirements

The Federal Energy Regulatory Commission (FERC), in its application procedure, requires an environmental report to be filed. "The environmental report should be consistent with the scope of the project and the environmental impacts of the proposed action; e.g., authorization to operate and maintain a project... using an existing dam or other facility, would require less detailed information than authorization to construct a new project" [10].

The contents of an environmental report should include [10]:

(1) Brief description of project and mode of operation (run-of-river or peaking).

(2) Description of environmental setting in or near project area. (Special attention should be given to endangered plant and animal species, critical habitats, sites on Wild and Scenic Rivers, sites eligible for or include on National Register of Historic Places.)

(3) Impact of continued operation of project or from construction of an existing dam or facility.

(4) Description of equivalent alternative power means if application is not authorized.

(5) Description of steps taken by the applicant in consulting with federal, state and local agencies during preparation of the environmental report. Indicate which agencies received the final report and provide copies of letters containing the comments of these agencies.

C. Water Level Fluctuations and Instream Flows

The significance of water level fluctuations is a function of the mode of operation of the small-scale hydroelectric facility, the magnitude and timing of fluctuations, and the site-specific environmental setting [11]. Water fluctuation due to peaking operations may be of differing amplitude or frequency than normal seasonal fluctuations, adversely affecting fauna and flora adapted to seasonal cycles [12]. In addition to the obvious aesthetic effects of fluctuating water levels, biological production can potentially be restricted. Water level fluctuations can also erode shorelines and transport nutrients from shallow zones to deepen regions of a reservoir [12]. These effects upon the reservoir apply mainly to hydropower installations which operate on a "peaking" basis, and are not of concern to run-of-river installations.

The unnatural cycles caused by water level fluctuation can also significantly modify the aquatic habitat below a hydropower facility. Streambeds and banks that were stable (neither aggrading or degrading) when streamflow was unregulated may become highly unstable and erode under a regimen of regulated flow. Areas formerly with minimal or no sedimentation farther downstream may begin to fill with sediment [13].

Hildebrand [13] have stated that "These changes in the physical environment can alter the composition and abundance of biota comprising tailwater communities. A reduction in benthic invertebrate diversity could occur as a result of the displacement of species unable to withstand high and variable current velocities or to exist in habitats where the composition of the substrate has been modified by the fluctuating flow regime. Fish species diversity and relative abundance might change for the same reasons (e.g. reduction or modification of spawning habitat) or as a result of the availability of food resources (e.g. reduced benthic production). Plant communities would also be affected by the increase in flow fluctuations, decreased bed stability, and elevated turbidity levels, which could reduce both aquatic macrophyte (vascular plants) and periphyton (primarily attached algae) production. The composition of riparian vegetation could be altered by a decrease in bank stability and modification of flooding cycles (i.e. a change in the time of occurrence, frequency, duration, and amplitude of flood flows). Such changes could, in turn, affect wildlife populations that are dependent upon riparian resources" [13]. It must be emphasized, however, that these impacts are not likely to be significant at run-of-river operations.

In conjunction with maintaining acceptable water levels is the requirement for sustaining minimum flows within a river. Minimum flows should be maintained in order to accommodate downstream recreational activities and fishery habitat [9]. A strict run-of-river hydroelectric plant would operate according to the natural stream flows, and the operation of the plant would not alter the normal downstream flows.

If peaking is considered a possibility, there are criterion established (such as the Montana Method) for determining an acceptable minimum flow in a stream or river. The criteria basically establishes seasonal flows based upon a percentage of the average annual flow. With the Montana method, the absolute minimum acceptable streamflow is 10 per cent of the average annual flow. This will sustain short-term survival habitat for most aquatic life forms. At this percentage "....riparian vegetation may suffer due to lack of water, much of the littoral zone will be exposed, fish may be vulnerable to over harvest, natural beauty and stream esthetics are badly degraded" [14]. With higher percentages of average annual flow (i.e. 30%) at the base flow will "...sustain good survival habitat for most aquatic life forms" [14]. However, since flows naturally drop to low levels, a regulated stream with a minimum flow at 10 per cent of the average annual flow will "...occasionally provide some enhancement over a natural flow regimen" [14].

Hildebrand [13] has stated that "operation of small hydroelectric facilities in a store-and-release mode may dewater a section of the river below the dam during periods of water storage. Prolonged periods of greatly reduced or no flow decrease the wetted perimeter (available habitat) of the tailwaters, thus potentially reducing the diversity and standing crop of benthic invertebrates and fishes. Sharp reduction in flow can, in some cases, result in mortality due to stranding and desiccation. Inadequate streamflow ... can adversely affect spawning success and the incubation of eggs. The rate of migration can also be altered by unnatural discharge regimes and extended periods of inadequate streamflow" [13].

Mitigation of low flow impacts can be achieved by maintaining minimum flows. In strict run-of-river plants the minimum flow released will be the same as the natural flow, so that no new impacts will be imposed upon the upstream and downstream environments. Potentially, there are two major problems associated with implementing instream flow criteria: (1) economic penalties associated with meeting the specified flow requirements, and (2) difficulties associated with determining adequate instream flows [4]. The above mentioned guidelines based upon percentages of average annual flow may be used in determining minimum flows for seasonal peaking plants. There are currently no general minimum flow criteria for hydropower plants which operate on a daily store-release mode. The most important consideration for plants with this operational mode is that tailwater elevation should not be allowed to drop to an exceedingly low elevation.

Water Level Fluctuations and Instream Flows - Kettle River

Water level fluctuations will have their most adverse impact at a seasonal peaking plant. Therefore, it follows that the magnitude of such impacts will be greatly reduced at Kettle River since it will be operated as a "run-of-river" plant. The five possible modes of operation proposed for Kettle River are summarized below:

Option 1: No drawdown

Option 2: No drawdown, 50 cfs over spillway at all times

Option 3: Allowable 1/2 ft drawdown

Option 4: From May - Sept.: Option 2
From Oct. - April: Option 3

Option 5: From May - Sept.: Option 2 during daylight hours and Option 3 at night
From Oct. - April: Option 3

Of the five proposed operational schemes, at no time will the reservoir water levels be drawn down more than 1/2 ft. Also, since the site is located within Banning State Park and Kettle River is designated as a Wild and Scenic River, Options 2, 4, and 5 include the possibility of allowing 50 cfs to flow over the spillway for aesthetic reasons. Options 4 and 5 provide for spillway discharge during the times of year when Banning State Park receives most of its visitors.

Various sources indicate the wide varying fluctuations which naturally occur in the Kettle River. For example, "the Kettle's watershed drains quickly; consequently, the water fluctuates greatly" [15]. The Kettle River "... water levels are subject to seasonal fluctuations. Boating and canoeing are frequently hampered due to low water" [16]. Therefore, the proposed operational schemes should not have a more adverse impact upon water level fluctuations and instream flows in the river than the natural river flows.

If options 3, 4, or 5 are chosen for plant operation, the amount of littoral zone in the tailwater which would be exposed with store-release operation may be determined from predawn field tests. With these field tests the flow is shut off for a specified length of time before dawn or in the early morning. Photographs may then be used to map the exposed area.

D. Water Quality

"Developing new sites or retrofitting existing sites for hydroelectric generation can alter water quality in both the impoundment and the tailwaters. The significance of this issue is primarily dependent upon operation of the facility, thermal stratification of the impoundment, and the location (depth) of the outlet. Most projects operated in a run-of-river mode will have only limited pondage, thus strong stratification will be unlikely due to short water detention time. Projects with existing dams that are operated in this manner would not be expected to significantly alter the water quality of the river over that which existed prior to retrofitting the dam for power production" [13].

Potential water quality consideration in tailwaters below dams include:

1) Alteration of temperature regimes,
2) Reduced turbidity,
3) Changes in dissolved oxygen,
4) Increases in the dissolved form of some metals, and
5) Altered nutrient and organic matter regimes [12].

Important aspects to consider are thermal and chemical stratification in the reservoir and depth of water withdrawal. If water is discharged from the hypolimnion, colder tailwaters may occur in the summer and warmer tailwaters in the winter. Possible adverse results from such discharge patterns include reductions in aquatic life, benthic invertebrate diversity, and modifications in the spawning activity of fish. This is true of very deep reservoirs. Shallow reservoirs, however, are often insufficiently deep to allow significant thermal stratification to take place. Therefore, in run-of-river projects without significant storage capacity or depth, these types of problems will not be encountered. Most low-head turbine installations intake a column of water and do not draw water off at a certain level. With this mixing of the water column, the problems associated with low dissolved oxygen will not be encountered. A stratified reservoir would require a much more detailed investigation of its possible impacts.

High concentrations of suspended sediments are also possible behind an impoundment. The result in turbidity would reduce the sunlight entering a stream or impoundment and thus reduce biological production. Such turbidity could adversely affect fish and other aquatic life [8]. However, this would not pose a problem at sites where an existing dam has been in place for many years (since the environment would already have been adjusted). The volume of water released at a run-of-river facility depends upon the natural flows and therefore would not alter the stream's ability to dissolve possible contaminants already being released downstream of the site.

Water Quality - Kettle River

The Kettle River Dam reservoir has a low storage capacity and a corresponding small hydraulic residence time. At the normal storage capacity of 10 million cubic feet, and the average annual stream discharge (700 cfs), the hydraulic residence time of the reservoir is only four hours. At 40 cfs, the minimum flow of 13 years of record, the reservoir hydraulic residence time is still only three days. In addition, reservoir depth at the spillway was measured to be only 7½ ft. With the short hydraulic residence time and shallow reservoir depth at the Kettle River Dam, a strong thermal stratification is unlikely during operating periods. It is therefore unlikely that the dissolved oxygen concentrations of the reservoir will be depleted during facility operation. The water quality problems associated with dissolved oxygen depletion, such as high nutrient levels, heavy metal and toxics released from reservoir sediments, and high biochemical oxygen demand, will not occur. In addition, the facility intakes will take water from the complete water column. This will eliminate the possibility of selective withdrawal of cold hypolimnetic water. The facility will not significantly alter the natural downstream temperature regime.

E. Fish Passage Through Hydraulic Turbines

An impoundment acts as a barrier to the migration of fish. Since the scope of this report emphasizes the rehabilitation of existing dam sites, it is evident that the environmental impact due to the impoundment has already taken place. At sites where turbines are presently operating, fish pass either over the spillway or through the hydraulic turbines, depending upon the natural river flows. At sites where power generation has been stopped, fish pass only over the spillway. Existing impoundments usually create two separate environments, namely, the two reaches upstream and downstream. The habitats and populations of fish in each reach can vary greatly.

For instance, fish populations in general (as determined through electrofishing) show that more fish exist downstream of the impoundment. This is primarily due to the fact that fish prefer the fast, rushing water to the slow moving water behind the impoundment. Therefore, fish in the downstream reach may be primarily affected by the fluctuating water levels, as well as passage through the turbines.

The mortality of fish passing through hydraulic turbines has been shown to correspond to various turbine characteristics [17]. For example, the survival of fish was found to be at a maximum when the turbine was operated at maximum efficiency. Furthermore, fish survival is greater when cavitation is eliminated in turbine operation.

Most of the new turbine designs have not been tested for fish mortality. However, many of the newer designs are of the propeller type. Studies have been conducted on similar turbines in the past. The results indicated that of the many factors affecting fish passage through turbines "... cavitation is believed to be the most serious. Decapitation and the production of 'pulpy' tissues and internal hemorrhages are examples of severe injuries attributable to cavitation. Pressure changes of a magnitude less than those producing cavitation can also be harmful to fish. In addition, shear forces produced by rapid changes in the direction of water flowing through the unit and contact between fish and the turbine's mechanical features (runner hub, runner blades, wicket gates, etc.) may cause mortality" [17]. In general, total mortality increases as the tailwater load is dropped, even though the point of cavitation is not reached. The above factors become less important at lower head sites, such as the Kettle River Dam, because the pressure changes are not as severe. Recent tests have indicated fingerling survival rates as high as 97 per cent for low-head hydropower facilities*.

It must be emphasized that turbine mortality is just one means by which a fish could die in its travel downstream. For example, at existing dams, fish have historically been passed directly over spillways as well as through turbines. Trash racks located at the intake to turbines have metal

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*NEPRIC, Inc. (1981). Personal communication on the Rock Island Hydropower Facility, Ohio River.

bars which are spaced so that only the smallest fingerlings may pass into the turbines. This partially eliminates possible fish mortality at the source.

Fish Passage Through Hydraulic Turbines - Kettle River

The hydroelectric plant at Kettle River had been operating until 1963. Therefore, it has been susceptible to fish passage problems in the past. At sites where power generation has been stopped, fish pass only over the spillway.

"It is important to put turbine related fish mortality at conventional hydroelectric facilities into perspective. Turbine related mortality is only one of many causes of mortality to downstream migrating juveniles as a result of hydropower development; other factors affecting survival are spillways, downstream passage facilities, predation and delay in migration" [18]. With the trash racks currently in place, only the smallest juveniles are capable of being passed through the turbines. All downstream migrants who are too large to pass through the trash racks will be passed over the spillway (as has been done historically).

Most fish in the Kettle River are sedentary. However, fish which do enter the turbine may be subject to mechanical injury with the turbine runner or internal injury due to pressure changes. However, it is known that the highest fish survival rates occur when the turbine is operated at maximum efficiency. This condition is a goal which will be strived for in the operation of the plant since it will produce the most efficient power production from a given stream flow. Problems encountered by fish due to cavitation will also be minimized when the turbine is operated at maximum efficiency.

The above results were obtained from tests on older model turbines. "The relationship of studies conducted to date to the newer turbine designs, which are currently being installed in small-scale hydropower operations, is unclear; more data need to be obtained on more modern small-scale prototypes" [18]. The turbines which are being considered for installation at Kettle River do not appear to pose any significant problems to fish passage.

Impingement against the trash racks is another potential source of fish mortality at the Kettle River Dam. At design discharge, the average velocity through the trash racks is 2.2 ft/sec. This trash rack velocity will not cause severe fish impingement problems, but some limited fish impingement may occur.

F. Construction Impacts

In some circumstances, it is possible that the impacts due to construction activities may be greater than impacts associated with normal plant operation [18]. The primary construction impacts are related to dredging and disposal of dredged material. An analysis of the accumulated sediments should be taken to determine whether or not the sediments contain large amounts of nutrients or significant levels of toxic substances.

Dredging is required at most existing dam sites to clear intake/ outlet structures and to repair powerhouses. Accumulation of material may occur at a dam site over a number of years, and it may be necessary to reclaim partial reservoir storage capacity. Dredging may also be needed during the operation of the plants if a significant amount of deposition occurs in the inlet/outlet works. The significance of impacts associated with dredging and dredged material disposal will be primarily influenced by the physical and chemical characteristics of the sediments and the amount of dredging required [13].

The physical effects due to dredging operations include resuspension of sediments, changes in water circulation patterns, changes in particle size and porosity of sediment, mobilization into the water column of nutrients and contaminants present in resuspended sediments [12]. Potential adverse impacts to biological systems as a result of dredging operations include loss of primary production and stress to fish due to increased turbidity, destruction of benthic habitat, and secondary effects on aquatic biota from resuspension of nutrients, heavy metals or toxic contaminants and disposal of dredged material [12].

Dumping the spoil on the river's bank might result in sediment runoff and possibly toxic pollution where chemicals are found in the dredged spoil. On the other hand, dredged spoil might well be used in nearby landfill projects which pose no threat to either the terrestrial or equatic environments [8]. If the sediments at the site are highly contaminated, it may be necessary to use specialized dredging equipment and upland disposal which may result in high transportation costs [9].

"Disturbance of bottom sediments may result in changes in the species composition, distribution, and abundance of benthic invertebrates. Re-suspension of sediments during reservoir dredging operations or runoff from the disposal site, if located adjacent to the reservoir, can increase silt deposition below the dam. Biological consequences could include (1) destruction of fish spawning areas, (2) alteration of benthic invertebrate habitats, and (3) smothering of mussels, submerged macrophytes, benthic algae, and invertebrates" [13].

Bank erosion due to hydropower operation may be significant depending upon the particular mode of operation. "Peaking plants have more potential for causing bank erosion than run-of-river plants because reservoir levels may fluctuate causing shoreline slides. Downstream, power plant discharges can cause scouring, even though power generation drastically reduces the energy left in the water compared to what would have existed without the dam and powerhouse. Nonetheless, hydroplant impoundments reduce stream velocities and therefore reduce stream bed erosion. Since erosion varies exponentially with water velocity, the erosion limiting benefits of hydroplants can be significant, particularly under flood conditions" [18].

Removal of the sediments is not only expensive, but it is potentially dangerous to aquatic organisms. Therefore, careful operations and timing of dredging is essential in eliminating contamination of downstream communities, if toxic pollutants were present in the sediments, and to avert burial of eggs and subsequent reproductive failure of fish spawning in the area. Seasonal timing of dredging operations is important because, depending upon the fish species of major concern, eggs could be present during almost any month of the year [18].

Other impacts may result from excavation and clearing activities. For example, removal of vegetation, disposal of spoil changes of land form may collectively or individually lead to erosion if not adequately protected. An interruption in releases during construction could possibly affect aquatic wildlife and downstream users. This may be considered necessary in circumstances where building in the stream bed may result in temporary increase in stream turbidity. Related impacts involving noise and dust control must also be mitigated.

Mitigation of several of the above impacts may be achieved by damping for dust control, reseeding of vegetation and spacing of blasting to avoid disturbance (e.g. if recreation users are nearby). "Depending on the design and existing outlet works, cost increases (in the mitigation effort) might also result where the releases from the reservoir must be maintained during the construction period" [19].

Construction Impacts - Kettle River

The tempory impacts due to construction activities will be temporary but could have potentially adverse impacts to the environment. The biggest problem which may occur during construction activities concerns dredging and other activities which could affect water quality. All necessary precautions should be taken so that no excessively turbid water is released to the stream. All necessary state and federal permits should be obtained. A consultation with these agencies well in advance of scheduled construction is advised to insure that all regulations will be adhered to.

Care should be taken so that construction activities will not interfere with the natural spawning activities of fish. Species and diversity taken above and below the Kettle River Dam are shown in Tables 16 and 17. The dates for the spawning season for each species are also shown. Activities such as dredging will involve clearing intake structures, repairs to the powerhouse, and clearing of sediment in the tailrace. Turbid water must not be released during the spawning season of the fish. Timing of dredging activities should be such that no communities will be contaminated.

Testing and/or sampling of the sediments should be taken to determine its physical, chemical, and biological characteristics to make a proper

TABLE 16. Species and Diversity of Fishery Taken Upstream of Kettle River Dam, 10/1/75, at 5 ft Stream Depth*

Species	Total No.	Total Wt. (lb)	Spawning Season**
North Redhorse	6	10.0	Late May, early June
Golden Redhorse	45	66.4	Late May, early June
White Sucker	6	15.8	Mid-May
Silver Redhorse	3	6.9	--
Walleye	2	0.8	Spring, shortly after spring thaw
Northern Pike	1	1.0	--
Rock Bass	1	0.3	May - early June
Yellow Perch	1	0.4	Mid-May
Largemouth Bass	1	3.2	May - July
Common Shiner	1	--	Late May
Johnny Darter	3	--	May - June
Lamprey	11	--	May

TABLE 17. Species and Diversity of Fishery Taken Downstream of Kettle River Dam, 10/1/75, at 5 ft Stream Depth*

Species	Total No.	Total Wt. (lb)	Spawning Season**
Lake Sturgeon	2	0.7	May - early June
Northern Redhorse	75	65.9	Late May, early June
Golden Redhorse	9	23.0	Late May, early June
Silver Redhorse	2	8.6	--
Walleye	3	1.2	Spring, shortly after spring thaw
White Sucker	12	7.9	Mid-May
Black Crappie	45	7.1	May-June
White Crappie	87	15.7	May-June
S. M. Bass	3	1.1	May-July
Northern Pike	3	5.4	--
Bluegill	7	1.2	Late May-early July
Chestnut Lamprey	7	--	--
Northern Hogsucker	2	2.25	Late spring
Barbot	1	0.1	--
Longnese Dace	2	--	May-July
Log Perch	6	--	May-June
Rock Bass	5	1.8	May-early June

*Source: Minnesota Department of Natural Resources, Kettle River File, Fish & Ecological Services. Principal Investigator: John W. Enblom, Aquatic Biologist. Method: Boom shocker - 1 hr (7 - 9 amps)

**Eddy, S. and J. C. Underhill (1974). Northern Fishes, University of Minnesota Press.

determination of adverse effects caused by the sediments. A suitable disposal site for the dredged material should also be chosen. A conservative estimate of the total dredging in the tailrace was determined to be 3000 cubic yards. Close coordination with state agencies is a necessity to insure that all regulations and restrictions are met, especially those regulations implemented through the State Wild and Scenic River Act.

G. Historic Preservation

In the course of FERC's licensing procedure, the Advisory Council on Historic Preservation and the State Historic Preservation Officer must be consulted to assure that no historic or cultural sites will be adversely affected. "Many older hydropower sites, while not of national significance, have played an important role in the local history of an area and thus important enough to stimulate local concerns. Additions and other needed alterations of the exterior of a structure should be designed in keeping with the historic and aesthetic value of an area, especially if other historic structures are in the close proximity" [20]. Sites on the National Register of Historic Places are given special protection by federal law. Therefore, it is important to review each site for potential archeological, cultural, and historic significance.

Correspondence with the Minnesota Historical Commission, given in the Appendix, indicates that the Kettle River site is not eligible for inclusion on the National Register of Historic Places.

H. Endangered Species

"The development of sites with existing dams could be expected to have less of an impact on populations of threatened or endangered species because the degree of habitat alteration would, in most cases, be less than usually associated with the construction of new dam/impoundment systems. Retrofitting existing dams, however, could significantly affect the mussel fauna of a river or stream where the existence of small undeveloped dams has actually enhanced these populations. These dams function as silt traps and thus have reduced downstream siltation in rivers and streams that had previously been degraded by heavy sediment loads from erosion and runoff in the watershed. As a result, remnant mussel populations often exist in the spillways below such dams. These populations are frequently the only remaining mussels in these rivers or streams and often consist of threatened or endangered species. When the dams are retrofitted for hydroelectric power production, dredging and water level fluctuations could adversely affect these species" [11].

The most difficult environmental issue to mitigate is the presence of a threatened or endangered species or its critical habitat in the vicinity of a proposed hydroelectric site. Mitigative measures will vary depending upon the distribution and abundance of the species at the site and the proposed design and operation of the project. At sites where the occurrence of an endangered species or its critical habitat is suspected, personnel in the appropriate state and federal agencies should be consulted. Such consultation should take place during the initial stages of project development.

Endangered Species - Kettle River

The operation of the Kettle River plant will not interfere with any endangered plant or animal species. The endangered animal species which occur in the project area (Pine County) were identified by the U.S. Fish and Wildlife Services as the Grey Wolf and the Peregrine Falcon (see appended correspondence). The Minnesota Natural Heritage Program (Minnesota Department of Natural Resources) performed a search of the Kettle River site. The results concluded that, at this time, the Natural Heritage Program has no recorded occurrences of rare or endangered species, priority animals, or priority plant communities at this site.

I. Recreation - Kettle River

According to Ref. [13] and a letter to FERC from the U.S. Fish and Wildlife Service (see Sect. L), Banning State Park, Robinson City Park, Sandstone National Wildlife Refuge, and the Sandstone State Game Refuge all border the Kettle River in the vicinity of the dam. The Kettle is also designated as a State Wild and Scenic River and a Boating and Canoeing River and therefore is a significant recreational resource.

The mode of operation at Kettle River will not significantly alter the streamflow or water levels (discussed in Section X.C) beyond their natural condition and therefore should not interfere with canoeists or other recreational uses (fishing, camping, etc.). Also, if Operational Options 2, 4, or 5 are chosen, 50 cfs will always be flowing over the spillway during peak tourists season, and the view will remain aesthetically pleasing at the site and should blend in quite well with the surrounding environment.

J. Agency Contacts/Correspondence

Close coordination with public agencies is essential early in the developmental phases of the project to assure that regulatory requirements and acceptable policies become known. "Both beneficial and adverse effects of small hydropower development will be a function of project design and operation as well as the nature of the existing environment that will be altered. Successful mitigation of adverse effects associated with such development will depend upon (1) accurate prediction of the magnitude of adverse impacts and (2) early awareness of potentially significant environmental issues. Ecologists and environmental scientists must be consulted during the preliminary design phase of project development. By defining the relevant environmental issues at this stage, meaningful discussions can be held with all responsible and interested agencies and groups" [11].

It should be noted that mitigation of impacts at existing dam sites should be viewed in the context of an already perturbed environment [21]. Feasibility studies completed to date have validated this assumption: "The experience of our firm in conducting feasibility studies at three hydroelectric sites indicates that identifiable adverse environmental impacts associated with restoration of the three facilities are relatively minor" [9].

The various stage contact agencies, as well as letters of correspondence, are included on the following pages [22]:

STATE AGENCIES TO BE CONTACTED FOR SMALL HYDROPOWER DEVELOPMENT

1. MINNESOTA DEPARTMENT OF NATURAL RESOURCES - Division of Waters
   a. Inquiries to the Director, Attn: Development Section
   b. EAW (Environmental Assessment Worksheet). Even if not mandatory, we strongly suggest that one be prepared by mutual cooperation within DNR. Purposes:
      - to give early and preliminary thought to any and all problems and benefits which may occur, and
      - to bring the project before the public early in development and avoid delays later in project.
   c. One permit may be issued to cover the concerns of:
      - work in public waters,
      - water appropriation,
      - dam safety - modification of dam,
      - water regulation & usage,
      - fish and wildlife habitat (including rare species),
      - recreation, and
      - water quality.

      The decision to issue single permit is made on a site specific basis.
   d. Generally DNR requires permits for raising or lowering of spillway level, fluctuating water level,and discharge which are different than historical records, dam modification, dredging and disposal of dredged material (spoil), shore protection, riprap, shoreline excavation, partial or complete drainage, water level control structure, stream or channel enlargement , or relocation.
2. MINNESOTA POLLUTION CONTROL AGENCY
   a. Inquiries to the Director, Attn: Permit Section - Water Quality
   b. The 1977 Clean Water Act gives authority to the MPCA to certify hydropower projects. This MPCA Certification is a prerequisite for permitting by FERC, COE, Coast Guard or any other Federal Agency issuing permits of this type.
   c. The MPCA has authority to become the primary agency issuing NPDES (National Pollutant Discharge Elimination Systems) permits,

replacing FERC, Corps, etc., but has not exercised this authority. They may possibly do so in the future.

d. Primarily concerned with water quality during construction and operation. These concerns include but are not limited to: maintaining minimum and constant flows, reaeration, thermal stratification dredging and downstream water-supply.

e. The MPCA must also review all secondary considerations, such as downstream flooding, effects of fish and wildlife, etc., before issuing certification according to Minnesota Statutes, Part 116B.09, Subd. 2.

3. STATE PLANNING AGENCY (including Environmental Quality Board-EQB)

a. Power Plant Siting

- Certificate of site compatibility N/A to sites less than 50 MW
- Construction permit for transmission lines if:
  - greater than 200 kV
  - greater than 50 miles

b. Environmental Planning

Current Rules

Actions Requiring Environmental Assessment Worksheet with Local Government as Responsible Agency:

- An action that will eliminate or significantly alter a wetland of Type 3, 4 or 5 (as defined in U.S. Department of Interior, Fish and Wildlife Service, Circular 39, "Wetlands of the U.S., 1956) of five or more acres in the seven-county metropolitan area, or of 50 or more acres outside the seven-county metropolitan area, either singly or in a complex of two or more wetlands.

Actions Requiring Environmental Assessment Worksheet with State Agency as Responsible Agency:

- Any new or additional impoundment of water creating a water surface in excess of 200 acres. (DNR)
- Construction of electric generating plants at a single site designed for, or capable of, operation at a capacity of 200 or more megawatts (electrical). (PCA)

- Construction of electric transmission lines and associated facilities designed for, or capable of, operation at a nominal voltage of 200 kilovolts AC or more, or operation at a nominal voltage of ± 200 kilovolts DC or more and of 50 miles or more in length. (EQB)

Proposed Rules - (possibly effective in Oct. - not yet approved)

- Impoundment of 160 acres or more
- Generating capacity 10-200 megawatts - require an EAW
- Generating capacity 200 or more megawatts - required an EIS.

c. EQB could also serve as staff agency and oversee the analysis of EAW and EIS if required.

4. WATERSHED DISTRICTS

a. Each concerned district should be contacted.

b. Permit may be required.

5. COUNTY

Individual county may have zoning or shoreline management requirements.

6. MINNESOTA ENERGY AGENCY

Certificate of Need - for sites greater than 50 MW.

7. MINNESOTA HERITAGE PROGRAM

a) Concerned with rare species.

b) Part of DNR Environmental Review Process.

XI. PROJECT FINANCING AND IMPLEMENTATION

There are a number of possible hydropower development paths for the Kettle River Dam. The Minnesota Department of Natural Resources (DNR) currently has no experience in managing and operating a hydropower facility. The operation and management, however, can be subcontracted if the DNR prefers to maintain control over the hydroelectric facility. This section will review some potential financing and implementation options which are available to the DNR.

One option is for the DNR to finance development of the project and enter into agreements with private firms on project management and on operation and maintenance. The operation and maintenance contract could be for a fixed fee or for a portion of the income generated by the hydropower facility. The project management contract could be for a fixed fee or for a portion of the project development costs. This type of development would likely have the greatest economic return for the State of Minnesota because the State is taking a major portion of the risk.

A second option is to solicit bids on development contracts. With this option either the State or the developer would provide financing and the profits (and losses) from the hydropower facility would likely be shared on some basis. The developer would be responsible for project development as well as operation, maintenance, and replacement.

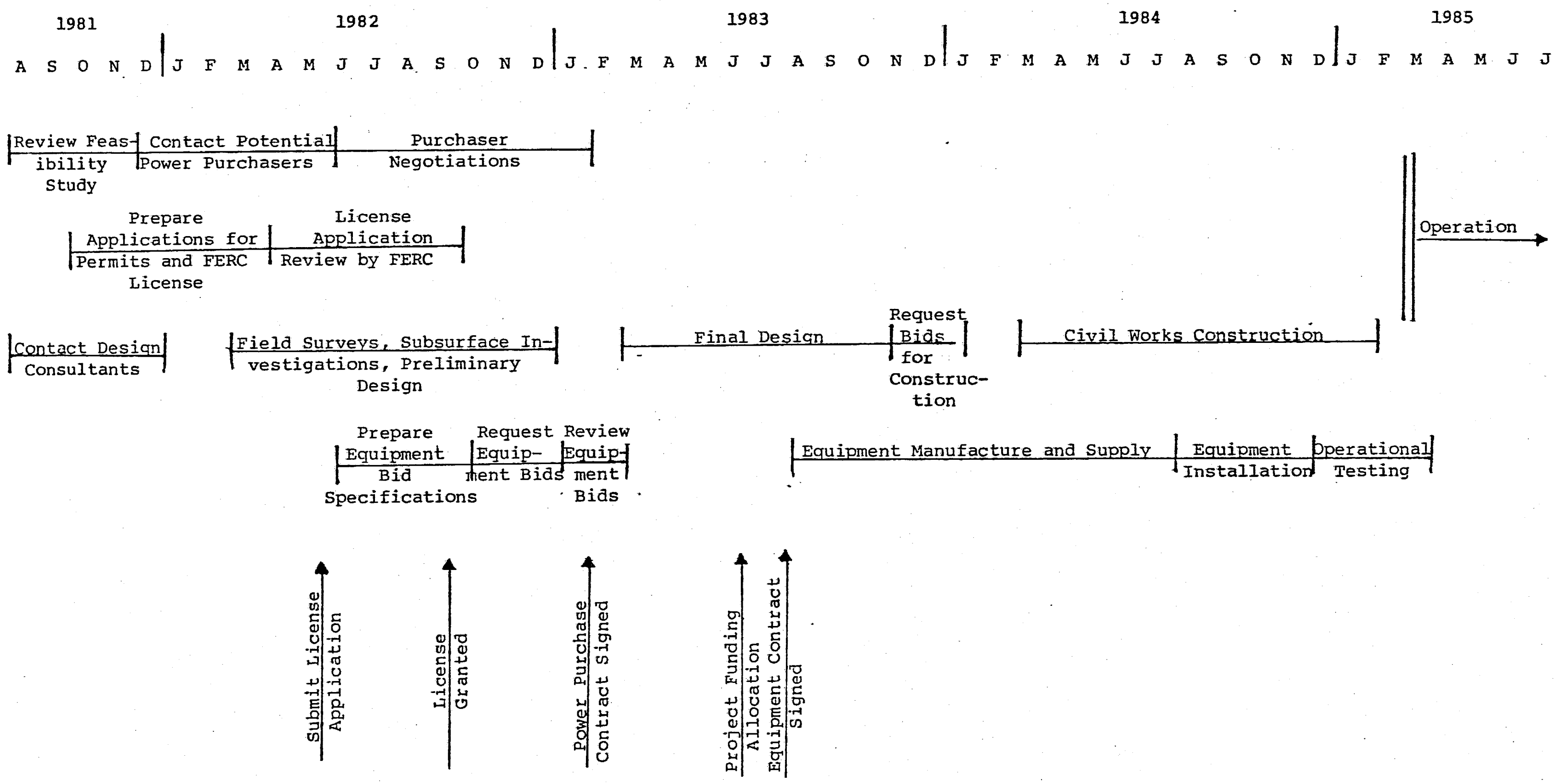
A third option would be to contract or give the right to develop the site to the local municipality, Sandstone, Minnesota. In this case the local municipality would choose the development plan which best suits its preference and financial situation.

There are many variations on the above three options. These are simply given as examples which may be expanded upon.

If the DNR is to finance the project, funds will likely be obtained through a lump-sum appropriation of the State of Minnesota Legislature.

The State of Minnesota could also (to the authors' knowledge) consider the facility as an investment and issue tax-exempt bonds specifically for the project. Table 18 gives a proposed project implementation schedule for the timely development of the site. This schedule is likely to be revised at later stages of project development. The project implementation schedule assumes that a lump-sum State appropriation will be given to the project on July 1, 1983. On July 1, 1981, the DNR Division of Waters was granted $250,000 by the Minnesota State Legislature for design and licensing of hydropower facilities proposed for the Kettle River Dam.

TABLE 18. Project Implementation Schedule for Development of a Hydropower Facility at the Kettle River Dam



XII. REFERENCES

1. U.S. Army Corps of Engineers, St. Paul District (1979). "Kettle River Dam No. 513, National Dam Safety Inspection Report," Dept. of Natural Resources, State of Minnesota.

2. Brater, E. F. and H. W. King (1976). *Handbook of Hydraulics for the Solution of Hydraulic Engineering Problems*, McGraw-Hill, Sixth Ed.

3. Anderson, M. G., Rate Research Manager (1981). Personal Communication. Minnesota Power and Light Co., 30 W. Superior St., Duluth, MN 55802.

4. Selander, S. (1981). Personal Communication. United Power Association, Elk River, MN.

5. Frick, P. A. and G. C. Alexander (1979). "Cost of Controls for Small Hydroelectric Plants or River Systems," U. S. Department of Energy, Report DOE/ET/28310-1.

6. Tudor Engineering (1980). "Reconnaissance Evaluation of Small, Low-Head Hydroelectric Installations," submitted to Water and Power Resources Service, U. S. Department of Interior.

7. The First Boston Corporation (1981). "Financing Hydroelectric Facilities.

8. Plantico, R. C. (1979). "Land Use and Small-Scale Hydropower: An Overview of Environmental Impacts and Institutional Responses," in Proceedings - Waterpower '79, U. S. Army Corps of Engineers and U.S. Dept. of Energy.

9. Carlisle, R. K. (1979). "Environmental Impact Assessment Methodology of Small-Scale Hydroelectric Projects," in Proceedings - Waterpower '79, U. S. Army Corps of Engineers and U.S. Dept. of Energy.

10. Federal Energy Regulatory Commission, Office of Electric Power Regulation. "Hydropower Licenses and Preliminary Permits".

11. Hildebrand, S. G. (1980). "Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development III - Water Level Fluctuation," Oak Ridge National Laboratory, Env. Sciences Div., Publ. No. 1591.

12. Hildebrand, S. G., G. B. Grimes, Jr. (1979). "The Department of Energy Environmental Subprogram Plan for Small Hydroelectric Development," in Proceedings - Waterpower '79, U. S. Army Corps of Engineers and U.S. Dept. of Energy.

13. Hildebrand, S. G. (1980). "A Comparison of Environmental Issues Related to Development of Small Hydropower Resources at New versus Existing Dam Sites," Proceedings, Third Miami International Conference on Alternative Energy Sources, Miami Beach, Fla., December 15-17, 1980.

14. Tennant, D. L. (1976). "Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources," Fisheries, Vol. I, No. 4, pp. 6-10.

15. Minnesota Department of Natural Resources (1977). *A Gathering of Waters - A guide to Minnesota's Rivers.*

16. U.S. Department of Interior, National Park Service (1979). "Kettle River - A Wild & Scenic River Study."

17. Turbak, S. C., D. R. Reichle, and C. R. Shriner (1981). "Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development IV - Fish Mortality Resulting from Turbine Passage," Oak Ridge National Laboratory, Env. Sciences Div., Publ. No. 1597.

18. Minnesota Environmental Quality Board (1980). "Considerations in Electric Power Plant Siting, Power from Water, Low-Head Hydroelectric Power," Power Plant Siting Program.

19. U.S. Army Corps of Engineers (1979). *Feasibility Studies for Small Scale Hydropower Additions - A Guide Manual.*

20. Novak, W. J. (1979). "Small-Scale Hydro - An Opportunity for Historic Preservation," in Proceedings - Waterpower '79, U.S. Army Corps of Engineers and U. S. Dept. of Energy.

21. Hildebrand, S. G., M. C. Bell, E. P. Richey, J. J. Anderson, and Z. E. Parkhurst (1980). "Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development II - Design Considerations for Passing Fish Upstream Around Dams," Oak Ridge National Laboratory, Env. Sciences Div., Publ. No. 1567.

22. Regalia, C. (1981). Personal Communication. Division of Waters, Minnesota Department of Natural Resources, St. Paul, MN.

APPENDIX

COMMUNICATION REGARDING DEVELOPMENT OF A HYDROPOWER FACILITY AT THE KETTLE RIVER DAM

FEDERAL ENERGY REGULATORY COMMISSION

Federal Building - Room 3130
230 South Dearborn Street
Chicago, Illinois 60604

IN REPLY REFER TO:
OEPR-CH

March 8, 1979

Mr. J. L. Dunning, Regional Director
U.S. Department of the Interior
National Park Service, Midwest Region
1709 Jackson Street
Omaha, Nebraska 68102

Dear Mr. Dunning:

We have reviewed the draft Wild and Scenic River Study Report for the Kettle River in Minnesota.

Our review of this draft is principally oriented toward determining the effect of the proposals on matters related to the Federal Energy Regulatory Commission's responsibilities. These responsibilities pertain to the development of hydroelectric power, the assurance of the reliability and adequacy of bulk electric power facilities, and the construction and operation of natural gas pipeline facilities. The comments which follow are those of the Federal Energy Regulatory Commission's Chicago Regional office and, therefore, do not necessarily reflect the views of the Federal Energy Regulatory Commission.

We note that the proposed plan does not preclude the construction of new pipeline and powerline crossings but will allow the construction of such facilities by means of an advance review process which will assure that their construction will be consistent with the National Wild and Scenic River System. We also note that there is an abandoned hydroelectric station, with its dam apparently intact, in the segment of the river which is designated for inclusion in the system. Since the U.S. Department of Energy is very actively engaged in a program for the rehabilitation of retired hydropower dams, it would be in the public's interest if the plan for preserving the wild and scenic quality of the river also enabled this hydroelectric station to be reactivated when found feasible to do so.

We have no serious objection to including the Kettle River in the Wild and Scenic River System if provision is made for the above matter.

Sincerely,

Bernard D. Murphy
Regional Engineer

(Ref. 26)

MINNESOTA HISTORICAL SOCIETY
FOUNDED IN 1849
690 Cedar Street, St. Paul, Minnesota 55101 • (612) 296-6126

5 June 1981

Mr. John Gulliver
St. Anthony Falls Hydraulic Laboratory
3rd Avenue SE at Mississippi River
Minneapolis, MN 55414

Dear Mr. Gulliver:

RE: Review of the historical significance of Granite Falls Dam (Yellow Medicine County) and Kettle Falls Dam (Pine Co.)

MHS Referral File Number: M 992

Thank you for the opportunity to review and comment on the above project. It has been reviewed pursuant to responsibilities given the State Historic Preservation Officer by the National Historic Preservation Act of 1966 and the Procedures of the National Advisory Council on Historic Preservation (36CFR800).

This review reveals that Pine County was recently surveyed for historic standing structures. As a result of this survey, the Kettle Falls dam was identified and listed as an inventory structure. Although it has historic value, it was determined at this time that it was not eligible for inclusion on the National Register of Historic Places. However, it is our opinion that the structure should be re-evaluated in the future.

With regard to the Granite Falls dam, our records indicate that Yellow Medicine County has not yet been surveyed, and, therefore, we have not assessed the historical or architectural significance of the structure. From the information that you have provided, it appears that like the Kettle Falls dam it is of historic interest, but it may not be eligible for inclusion on the National Register of Historic Places. However, prior to making a final determination, our office would like to review the photos of the original dam construction, and photos of the present dam.

This information should be submitted to Ms. Susan Hedin, Environmental Assessment Officer, State Historic Preservation Office, 240 Summit Avenue, St. Paul, MN 55102, (612) 296-0103.

Thank you for your attention to cultural resources in your planning process.

Sincerely,

Dennis A. Gimmestad

for Russell W. Fridley
State Historic Preservation Officer

RWF/sl

United States Department of the Interior

FISH AND WILDLIFE SERVICE

IN REPLY REFER TO:

St. Paul Field Office, Ecological Services
538 Federal Building and U.S. Court House
316 North Robert Street
St. Paul, Minnesota 55101

February 10, 1981

Mr. Robert Knowlton
St. Anthony Falls Hydraulics Laboratory
3rd Ave. SE at the Mississippi River
Minneapolis, Minnesota 55414

Dear Mr. Knowlton:

This provides additional comments to our February 4, 1981 meeting regarding feasibility studies for the development of hydropower facilities at existing dams in Yellow Medicine, Pine, Hubbard, Stearns, Fillmore, Dakota and Goodhue Counties, Minnesota.

The Federal Energy Regulatory Commission (F.E.R.C.) will be reviewing your permit applications for these facilities, and is required to comply with provisions of the Endangered Species Act prior to taking final action regarding those applications. We are, therefore, providing you with some of the endangered species data that FERC will require in the permit applications. Listed below are endangered and threatened species whose ranges coincide with the project areas.

SPECIES	RANGE (COUNTY)
Gray Wolf	Hubbard, Pine (peripheral range)
Peregrine Falcon	Dakota, Goodhue, Pine (potential breeding range)
Bald Eagle	Hubbard (breeding range), Dakota, Goodhue (wintering range)

While the early stage of planning makes it difficult to determine possible impacts to these species, at present we do not anticipate that the proposed work will affect the species listed. However, you should be aware that these comments constitute technical assistance only, and do not fulfill the requirements of Section 7 of the Endangered Species Act, which requires FERC and other federal agencies conducting, funding or authorizing any action to inquire of the Secretary of the Interior whether federally-Listed or Proposed Species are likely to be found in the project area. That inquiry can be made by writing to the Regional Director, U.S. Fish and Wildlife Service, Federal Building, Twin Cities, MN 55111.

We look forward to continued coordination on the proposed projects.

Sincerely,

Richard F. Berry

Richard F. Berry
Field Office Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE

St. Paul Field Office, Ecological Services
538 Federal Building and U.S. Court House
316 North Robert Street
St. Paul, Minnesota 55101

June 18, 1981

Mr. Kenneth F. Plumb
Secretary, Federal Energy Regulatory Commission
825 North Capitol Street, N.E.
Washington, D.C. 20426

Dear Mr. Plumb:

This represents the initial response of the U.S. Fish and Wildlife Service to the Notice of Application For Preliminary Permit, Kettle River Dam Project, FERC # 4044, Pine County, Minnesota. It does not preclude additional input from other Department of the Interior agencies.

Existing Resources - The Kettle River in the vicinity of Sandstone supports a great deal of recreational use while providing excellent wildlife habitat. The entire length of the river within Pine County is part of the State Wild and Scenic River System, is a state Canoeing and Boating River, and is under study for federal designation as a Wild and Scenic River as well.

Much of the shoreline from Sandstone south is undeveloped, consisting mainly of riparian hardwood forest. The bordering upland ridges support aspen, birch, oak and pine, while scattered areas of alder, willow, other shrubs and grasses and wetlands also exist. This diverse vegetation supports deer, woodcock, ruffed grouse, beaver, raptors, waterfowl, black bear, bobcats, coyote, gray and red fox, songbirds, and numerous small mammals, and presents a high-quality aesthetic experience to boaters on the river. Pine County is also within the peripheral range of the Gray Wolf (Canis lupus) and the breeding range of the Peregrine Falcon (Falco peregrinus).

The river supports an excellent warm-water fishery. Above the Sandstone Dam, walleye, northern pike and channel catfish are abundant. Sturgeon can also be found, a relatively rare fish in Minnesota. Below the dam, walleye, crappie and northern pike are caught.

Banning State Park, Robinson City Park, Sandstone National Wildlife Refuge and Sandstone State Game Refuge border the river in the general vicinity of the dam. The river and these public lands are mutually dependent upon each other for the quality of the user's experience.

Concerns - The addition of a powerhouse to the existing facilities at the Sandstone Dam will have some impacts on fish and wildlife resources. Should the project appear feasible, the extent of these impacts must be documented. Fluctuating water levels above or below the dam can have substantial shoreline impacts, rendering much fish and wildlife habitat less valuable as well as decreasing the aesthetics for recreation. Regardless of a change in water levels, the location of the generating facility and its operation could alter existing flow patterns. Concentrating a proportion of the flow through the generating facility could effect existing upstream and downstream flow patterns, terrestrial and aquatic habitats, and possibly increase scouring and erosion. We would be particularly concerned about this funneling effect during low water periods.

We are also concerned with potential injury and mortality of aquatic organisms due to entrainment through the generating facilities. Impingement of organisms may also be an important factor if screening devices are used at the intakes. Increased silt in the river below the dam due to erosion, scouring, or dredging to maintain the impoundment depths could also impact these organisms.

Other impacts would include the effect of any water quality or quantity changes on the public lands downstream including the Sandstone National Wildlife Refuge, as well as the effects on the river as part of the State Wild and Scenic River System and a Boating and Canoeing River. More specific concerns regarding the National Wildlife Refuge may be voiced when project plans become more detailed. All of the above concerns should be addressed if the project to include generating facilities in the Sandstone Dam appears economically feasible.

Sincerely,

for Richard F. Berry
Field Office Supervisor

cc: Minn. DNR, St. Paul (Larry Seymour)