Feasibility Study Bugle Lake Project

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Abstract

The proposed project site is in the Trempealeau River basin located in southwest Wisconsin. The reservoir, Bugle Lake, is located near the village of Independence. Bugle Lake is fed by Elk Creek. The drainage area of the river is 110 square miles. The gradient of Elk Creek is 18 ft/mi. The storage capacity of Bugle Lake is 300 square feet.. Control of the impoundment is by Independence Dam. This dam is operated in a run of the river mode to maintain an elevation of 778.4'. The available head was determined to be 11.4 feet. A flow duration curve was developed for the project. It was found that a flow of 40 CFS is available 80 % of the time. The average annual generation was determined to be 338,893 kWh. The predicted annual revenue based upon this generation was determined to be $14,301. If a proposed rate increase is approved, the market value could increase to $21,079. Several turbine types were compared and the reaction type was selected based upon efficiency and cost. The estimated cost to install the turbine is $207,500. Annual operating costs were estimated to be $20,005, making this project cash flow positive on an annual basis with the proposed rate increase. Since the capacity of this project is under 5 MW, it qualifies for an exemption from licensing under the Federal Energy Regulatory Commission. An environmental impact statement will not be required since the operation of the impoundment will not be significantly altered.

Development of Flow Duration Curve:

The generating capacity of a hydro plant is dependent on two important variables. The first of these is the head: the approximate vertical distance through which the water falls. The second is the flow rate: the volume flow rate of water which will pass through the plant. The power output of the plant is proportional to the product of the head and the flow rate. In order to determine the feasibility of a hydro project these variables must be thoroughly researched for the site.

The first variable that was researched for this site was the available head. The upstream elevation is determined by the water level in Bugle Lake. The water level of Bugle Lake is regulated by the Department of Natural Resources for the Sate of Wisconsin. An order issued by the Department on September 11, 1979 establishes a normal water level of 778.4 feet above sea level, USGS datum. A benchmark, labeled 'Public Service Commission of Wisconsin" 191-D, is set in the upstream end of the right wing wall of the dam. The elevation of this benchmark is 785.32 feet above sea level, USGS datum. The water level is maintained 6'11" below the benchmark by the dam operator. The dam operator opens or closes the gates at the spillway to maintain this level. Thus the upstream elevation of the water is fixed at 778.4 feet. The downstream elevation is determined by the level in the dam spillway as it reenters Elk Creek. The downstream elevation of Elk Creek is not formally measured or recorded; however, the experience of the dam operators can be used to establish the level. A masonry weir is installed in the spillway. This weir forms a stilling basin that dissipates the energy in the water before it reenters Elk Creek. Phone interviews were conducted with Mr. Jim Bisek and Mr. Allie Kabus. Mr. Bisek is the current dam operator. He has been in this position for the past 19 years. Mr. Kabus was the dam operator prior to Mr. Bisek and is now retired. It was discovered during the interviews that the water typically "breaks over the weir" in all conditions with exception of large rains or floods. Both operators agreed that the downstream section of the river and tailrace does not normally rise or fall seasonally and that weir is normally visible. The weir thus establishes the lower elevation. Referring to drawing # A-3456 "Section of Spillway and Piling Layout", the base of the weir sits at an elevation of 765 feet above sea level. The weir is 2' in height. Therefore a conservative estimate of the downstream elevation is 767 feet above sea level. It should be noted that the actual downstream elevation may be less depending on the placement of the turbine draft tube; however, for the purposes of a feasibility study the more conservative approach was chosen. The resulting available head is the difference between the upstream and downstream elevations and is 11.4 feet.

The second variable researched was the volumetric flow rate of water available. In order to accurately predict a hydro plant's capacity enough flow data must be considered so as to remove any seasonal variations. Typically 20 – 25 years worth of data are analyzed. Unfortunately only one season of flow data for Elk Creek is available. This data was collected by the USGS station #05379305 from Oct 1st 1979 to Sept 30th 1980. The station was then discontinued. The US Geological Survey office was contacted to determine the accuracy of the data from this station. The data was listed as good indicating that it should be accurate to within +/- 10%. Although the flow data is accurate it still must be tempered to remove seasonal variation. This was accomplished by analyzing the precipitation data for Trempealeau County. Precipitation normals from the National Climate Data Center for the period of 1971 to 2000 were obtained. This data was collected by the Wisconsin State Climatology Office, Blair Station # 470882. The precipitation normals were compared to the precipitation data for the season in which flow data was collected. It was discovered that an additional 9.07 inches of rain had fallen during the time the flow data was collected. This should have resulted in a 21.1 % increase in water flow. The precipitation data can be seen in figure #1.

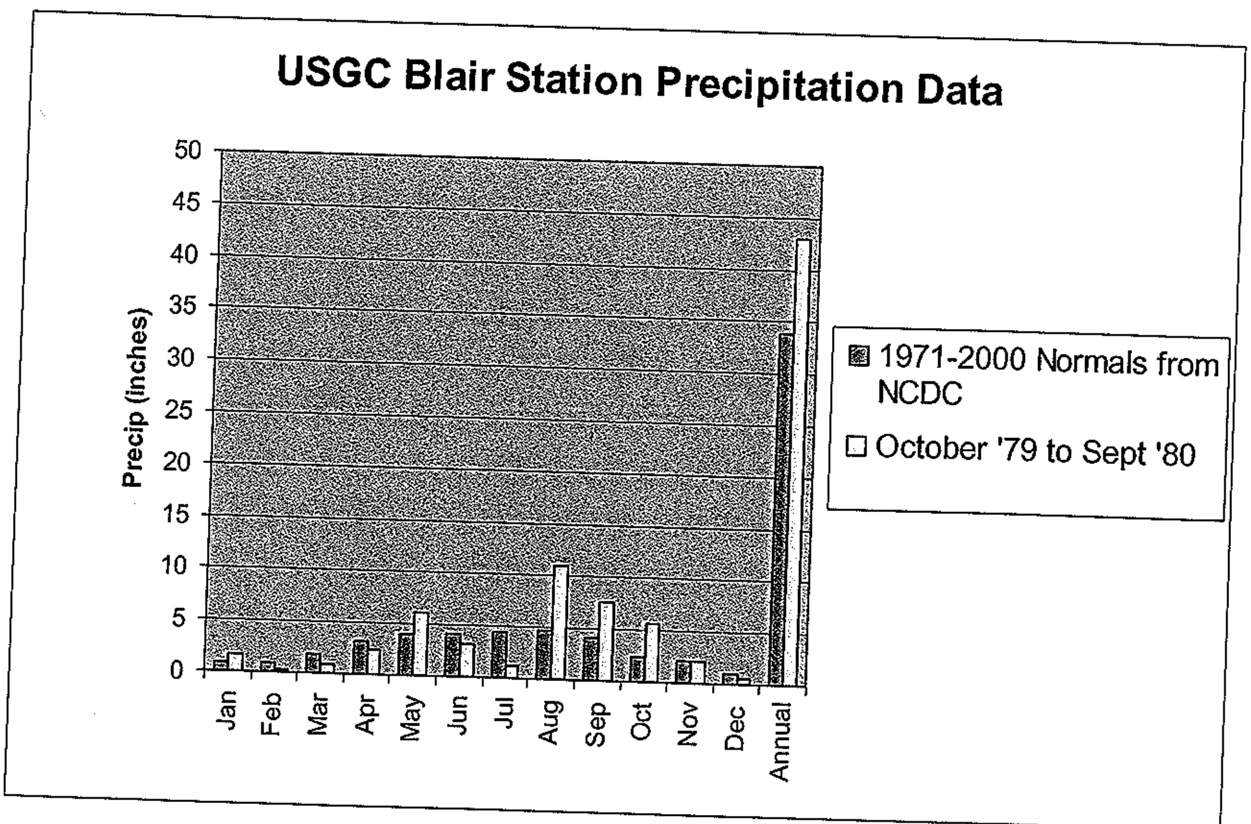

Figure #1

The flow data was adjusted down to reflect an average season. The adjusted flow data is listed in tabular form below the graph. It is represented graphically below in figure #2. Figure #2 is a flow duration curve. The shape of this curve depicts the percent of time that a given flow is exceeded. (Note: The available head is usually shown as well, however since the head is constant in this case it was omitted)

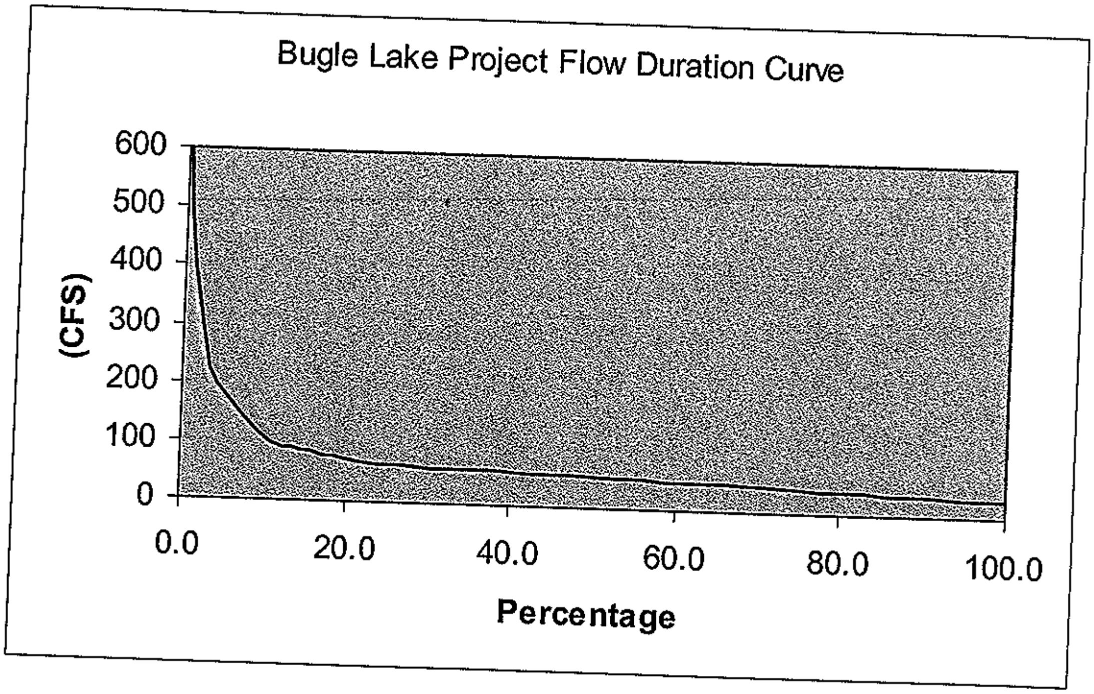

Figure #2

CFS	Percentage
600	0.3
500	0.5
400	1.1
300	2.5
200	4.1
100	10.9
90	13.7
80	16.7
70	21.6
60	33.6
50	52.7
40	80.3
30	100.0

Development and Screening of Hydropower Alternatives:

Annual Power Generation:

Now that the flow duration curve and the head have been established, the annual power generation and revenue can be determined. The gross annual power available is 598,474 kWh. This is maximum amount of the power available based on all of the water flowing through the dam, including the high water events. The market value for this power based upon the current rate of .0422 $/kWh set by Northern States Power Company is $25,256. It should be noted that a rate increase for parallel generation has been proposed for 2008 that could raise the rate to .060 $/kWh. The amount of energy captured is determined by the capacity and efficiency of the turbine. The price of the turbine increases as the size of the machine increases. The turbine operates at the highest efficiency near its' rated capacity. The correct size of a turbine or set of turbines for a project minimizes the initial capital costs while maximizing the amount of power generated. Since this project has a relatively modest potential return, a single turbine will be used. The operating point of the turbine is chosen so that the machine will be operating at maximum efficiency most of the time. A review of the flow duration curve shows that at 80% of the time the average flow available is 40 CFS. This was chosen as the operating point. Typically the turbine will be able to operate higher than the operating point but at a reduced efficiency. A reasonable expectation of the maximum flow that a turbine with this operating point could handle is 50 CFS. Turbine efficiency at the operating point was selected at 90%. Generator efficiency was selected at 95%. This makes the overall efficiency of the turbine/generator set 85.5%. Operation of a turbine with this set of characteristics on this project will produce an annual power generation of 338,893 kWh with a market value of $14,301. If the proposed rate increase is approved the market value could increase to $21,079.

Hydropower Equipment Evaluation and Sizing:

Hydro turbines can be separated into two groups, impulse and reaction. Impulse turbines are also referred to as partial turbines since the rotor is not completely flooded. Water is directed through a nozzle or a series of nozzles against the rotor blade. Impulse turbine types such as Pelton and Turgo require heads of 30 feet or more to operate. These turbines have a high efficiency. Another type of impulse turbine is the Crossflow or Banki turbine. These turbines can operate with heads as low as several feet. Crossflow turbines are also mechanically simple and considered to be self-cleaning, however; they have a low efficiency. Reaction turbines are highly efficient machines that operate under low to medium heads, 2 to 30 feet. Reaction turbines are acted on by water, which changes pressure as it moves through the turbine and gives up its energy. They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow. These turbines are usually equipped with a draft tube that allows them to fully utilize the available head at a site. Reaction turbine types include Kaplan, Propeller, and Francis. Propeller turbines have a fixed propeller shaped runner. Kaplan turbines have a propeller shaped runner with variable pitch blades. The variable pitch blades ensure that the unit will be operating at maximum efficiency over a variety of flow conditions. Kaplan turbines tend to be mechanically complex and expensive. Francis is an inward flow reaction turbine that combines radial and axial flow concepts. The runners of these turbines are scroll shaped. Francis turbines are the most common water turbines in use today. Turbine selection is based mostly on the available water head, and less so on the available flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. Since this project is located at a low head site, the selection is limited to the reaction turbines. The lower efficiency coupled with the inability to utilize all of the available head disqualify the Crossflow turbine. A comparison of the reaction turbines and their characteristics can be found in Table #1.

Table #1 Turbine Comparision

Turbine Type	**Francis**	**Kaplan**	**Propeller**
Specific Speed Ns:(rpm)	122	243	243
Synchronous Rotational Speed (rpm)	360	720	720
Number of pairs of generator poles	10	5	5
Turbine Diameter (in.)	19	19	19

Preliminary Design of Recommended Alternative:

Conceptual Design:

A reaction turbine is recommended for this application. The turbine will be situated in a newly constructed powerhouse. The powerhouse will be located on the south end of the dam on the down stream side directly behind the original water wheel flume opening. The powerhouse will be a steel frame building with the siding and roof designed to fit in with the décor of the dam. The approximate dimensions of the building are 12' x 8', with only one floor. Access to the building will be provided from the southern bank of Elk Creek as well as from the dam. The original trash rack and water wheel flume will be inspected and rehabilitated. A new penstock will be inserted into the existing water wheel flume to feed the turbine. A shut off valve will be installed on the penstock so that the turbine can be isolated for maintenance. The approximate diameter of the penstock is 20 inches. The approximate diameter of the turbine is 19 inches, making the overall length and height of the machine on the order of 3 to 4 feet. The turbine will be coupled to the generator and the set will be mounted in the center of the powerhouse. The switchgear, governor, and control panel will also be located in the powerhouse. The electrical tie in will be made to the nearest transformer and the turbine will back feed from there into the electric grid. The tailrace will be sounded and inspected to determine if any excavation will be required for the installation of the draft tube. The draft tube will extend from the turbine discharge through the powerhouse floor and down through the tailrace.

Plant operation:

The operating strategy for the facility will be to control the level of Bugle Lake to the predetermined level by adjusting the water flow through the turbine. Water will be spilled through the waste gates to control the lake level during high water events when the turbine is at maximum capacity. The waste gates could also be used when the turbine is off line for maintenance. The Dam Operator will adjust water flow through the turbine. The Dam Operator will select a flow rate setpoint on the turbine controller. The turbine controller will move the turbine wickets to achieve the desired flow rate. An alternative scenario would be that the lake level could be monitored electronically. The output from the level measurement could then be fed to the controller, which would in turn adjust the flow rate. Debris will be manually removed from the trash rack.

Estimated Costs:

The estimated installation cost for this project is $207,500. Loans are available to municipalities in Wisconsin through the State Trust Fund Loan Program. Loans with terms over 10 years but not exceeding 20 years are available with an interest rate of 5.25%. Using an interest rate of 5.25% and a term of 20 years yields an annual payment of $17,005. It should be noted that grants might be available from a variety of resources for this project. In order to be conservative this was not considered in the economic analysis. The need for an operator to spend 1 hour per day working in the plant was considered in determining the annual operating costs. The present Dam Operator works for the Independence Street Department. The additional duties should not require the hiring of additional personnel, therefore; the operator's time was not considered in the analysis. Modern hydro turbines are rugged pieces of equipment that generally need little maintenance. It is anticipated that an annual inspection would be performed on the facility. Additionally some maintenance will be required when the facility ages. The annual maintenance costs were estimated at $2,500. The total annual operating costs for the facility will be $20,005. It should be noted that once the construction loan is complete the annual operating costs would drop to $3000. The predicted annual revenue is $14,301 using the present power rate. The predicted annual revenue will increase to $20,334 if the proposed rates are adopted. This will make this project cash flow positive on an annual basis. The economic analysis can also be seen in table #2.

Table#2 Economic Analysis

Initial Project Evaluation Costs:	manhours	$/hr	total
Phase 1			
Feasibility Study	20	125	$2,500
Phase 2			
Engineering Permiting Grant wrinting	60	125	$7,500
Phase 3			
Equipment costs:			
Turbine, Generator, Switch Gear & Controls			$145,000
Power house & balance of Plant			$30,000
Installation costs:			
Project Management	60	125	$7,500
modify & install penstock & shutoff valve	20	50	$1,000
install draft tube	20	50	$1,000
erect power house	160	50	$8,000
install turbine	40	50	$2,000
install generator switchgear and controls	40	50	$2,000
pre-startup checks	10	50	$500
commisioning	10	50	$500
Municipal Loan			
Principle			$207,500
interest rate			5.25 %
Term of Loan			20 years
Annual payments			$17,005

Annual Cash Flow for project

Expenses:		
Loan Payments	$17,005	
Operation	7300	1 hr/day, 365 days/year @ 20 $/hr Note this is paid through city street dept.
Maintenance	2500	annual inspection, repairs
Utility	500	heat, lights, meter reader
Total expenses	$20,005	
Annual Power Generation (kW)	338,893	
Present Buy Back Rate ($/kWh)	0.0422	
Predicted Annual revenue	$14,301	
Potential Buy Back Rate ($,kWh)	0.06	
Predicted Annual revenue	$20,334	

Regulatory Compliance

Under the authority of the Federal Power Act, the Federal Energy Regulatory Commission, FERC, has the exclusive authority to license most nonfederal hydropower projects located on navigable waterways or federal lands, or connected to the interstate electric grid. Currently, FERC regulates approximately 1,600 hydroelectric projects in the U.S. Quoting from the FERC Handbook for Hydroelectric Project Licensing , "A license (or exemption from licensing) from the Commission is required to construct, operate, and maintain a nonfederal hydroelectric project that is or would be (a) located on navigable waters of the United States; (b) occupy U.S. lands; (c) utilize surplus water or water power from a U.S. government dam; or (d) be located on a stream over which Congress has Commerce Clause3 jurisdiction, where project construction or expansion occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce." Since this project will occupy U.S. land and will be connected to the interstate electric grid, it clearly falls under the jurisdiction of FERC.

FERC also grants exemptions from licensing. Projects that are exempt from licensing are not subject to the comprehensive development standard in the Federal Power Act and follow a streamlined approval process. One exemption is for small hydroelectric projects of 5MW or less. Quoting from the Code of Federal Regulations 18 CFR 4.31(c) 2, "A small hydroelectric project of 5 MW or less may be eligible for a 5 MW exemption. The applicant must propose to install or add capacity to a project located at a nonfederal, pre-1977 dam, or at a natural water feature. If *only federal lands are involved,* any applicant is eligible. If *some federal lands are involved*, any applicant who has all the real property interests in the nonfederal lands necessary to develop and operate the project or an option to obtain the interests is eligible." Since the proposed capacity of this project is less than 5 MW, it is eligible for exemption under this clause. It should be noted that the 5-MW exemption is issued in perpetuity.

The steps involved in the general process for license and exemption applications can be listed as follows:

- Gather needed information to identify project related effects.
- Send package describing your proposal and environmental effects to Commission staff, all relevant government and tribal agency, and non-government and public entities.
- Meet with all affected agencies and entities to explain your proposal and to request input.
- Determine whether and to what degree affected agencies are willing to expedite the consultation process or forego a consultation stage.
- Apply for and obtain a state Water Quality Certification or waiver.
- Prepare and file a license or exemption application.

The application for exemption for a small hydroelectric project of 5MW or less must include the following:

- Introductory statement.
- Exhibit A describes the small hydroelectric project and its proposed mode of operation.
- Exhibit B provides a general location map that must show the location of the physical structures and their relationship to the water body and identifiable landmarks, land ownership information, and a proposed project boundary.
- Exhibit E or a draft preliminary EA if using an alternative process, is the environmental report and must reflect prefiling consultation requirements. Commensurate with the scope and degree of environmental impact, it must include a description of the project's environmental setting, the expected environmental impacts, and proposed measures to protect the environment.
- Exhibit G is a set of drawings showing the project structures and equipment.
- Identification of all Indian tribes potentially affected.
- Appendix containing evidence that the applicant has the necessary real property interests in any nonfederal lands.**18 CFR 4.107**
- Fish and wildlife agency reimbursement fees must accompany filed applications. **18 CFR 4.302**

The Commission begins processing the application after it is received. The Commission will request comments from interested agencies and will conduct a comprehensive project review. Once an exemption is granted the applicant must comply with the terms and conditions imposed by the Commission.