An Assessment of Hydroelectric Feasibility at Colonel Charles D. Maynard Dam in Tucker, Arkansas

Connor Quigley
Portland State University

5-2013

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An Assessment of Hydroelectric Feasibility at Colonel Charles D. Maynard Dam in Tucker, Arkansas

Portland State University

Connor Quigley

5/25/2013

The primary purpose of this report is to analyze the economic feasibility of converting the Colonel Charles D. Maynard Lock and Dam to a hydroelectric facility. This report takes a traditional cost-benefit analysis approach and includes a sensitivity and scenario analysis.
Acronyms

BCR: Benefit-Cost Ratio
BOR: U.S. Bureau of Reclamation
CWCCIS: Civil Works Construction Cost Index System
DOE: Department of Energy
EIA: Energy Information Administration
EMM: Electric Market Module
ENR: Engineering News-Record
FERC: Federal Energy Regulatory Commission
GW: Gigawatt
HDC: Hydroelectric Design Center
INEEL: Idaho National Engineering and Environmental Laboratory
IRR: Internal Rate of Return
ITC: Investment Tax Credit
kW: Kilowatt
kWh: Kilowatt hour
MIRR: Modified Internal Rate of Return
MKARNS: McClellan-Kerr Arkansas River Navigation System
MW: Megawatt
MWh: Megawatt hour
NEMS: National Energy Modeling System
NPV: Net Present Value
O&M: Operating and Maintenance
PTC: Production Tax Credit
USACE: U.S. Army Corps of Engineers
USGS: United States Geological Survey
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Chapter 1  Introduction

The energy from falling water has been utilized since the Ancient Greeks nearly 2,000 years ago. The Ancient Greeks used wooden water wheels to convert the kinetic energy from falling water into mechanical energy (Castaldi, Chastain, Windram & Ziatyk, 2003). On September 30, 1882, the first hydroelectric power plant was built in the United States on the Fox River in Appleton, Wisconsin (Bureau of Reclamation, 2009). Today, hydroelectric generation (“hydropower”) is creating power in every region of the United States and is the largest source of renewable energy in America. Hydropower currently accounts for 65.9% of the nation’s renewable energy generation and 7% of the total energy generation (National Hydropower Association, 2013). Hydropower has been generated and used for over a century and currently provides more than 30 million homes with affordable power, which is equivalent to 500 million barrels of oil. In the Pacific Northwest alone, hydropower provides about two-thirds of the region's electricity supply (EPA, 2012).

Hydroelectric power plants produce electricity similar to that of combustion plants. Both hydroelectric and combustion-based power plants utilize a power source to turn a turbine, which then turns a metal shaft in an electric generator that ultimately produces the electricity. The difference is that a combustion power plant uses steam to turn the turbine, while hydroelectric power plants utilize the energy of falling water. The key is that dams permit storage of water in what is referred to as a reservoir. The stored water then enters the water intake and turns the turbine propeller. The shaft from the turbine rotates within the generator and produces the power. Power lines are connected to the generator and deliver the electricity to the transmission for movement to the desired location. The water then passes through the tailrace, which is simply a channel that carries the water from the turbine back into the river past the dam (Hydroelectric Power: How it works, 2013). The components can be seen through the graphic below provided by USGS (2013):
The demand for energy is generally not constant and fluctuates throughout the day. Batteries are not feasible for the large scale storage of energy. Thus, the reservoir’s ability to store water enables it to perform a function similar to that of a battery by storing energy in the form of water in order maintain the ability to generate at the time when end-users will actually use the energy. During the day the demand for energy is highest, and therefore leads the hydroelectric plant operators to allow water to flow through the turbines in order to produce the desired amount of energy.

Hydroelectric power plants are categorized according to their size. Each power plant fits into one of four size ranges: Micro, Mini, Small, and Large. A “Micro” sized plant is defined as a plant that generates less than 100 kW of electricity. A “Mini’ plant is one that generates 100kW-1MW of electricity. A “Small” facility generates 1MW-30MW of electricity. Lastly, a “Large” hydroelectric plant generates more than 30MW of power (Castaldi, Chastain, Windram & Ziatyk, 2003). The potential of hydroelectric power plants has yet to be fully realized throughout the United States and worldwide. It is estimated that approximately two-thirds of the economically feasible potential power plants remain undeveloped. Untapped potential hydro benefits are still abundant in Latin America, Central Africa, India and China (Hydroelectric Power Water Use, 2013). Specific hydroelectric power plant benefits will be discussed in further detail in this report. As this report addresses the feasibility of implementing hydroelectric power to an already existing dam, many of environmental effects and non-monetized benefits associated with the construction of a new dam already exist and do not directly apply to this analysis. Thus, the main body of this report will be limited in scope to costs that are applicable to hydroelectric implementation on a pre-existing dam. Supplemental information regarding the environmental effects and non-monetized benefits of a dam are outline in Appendix G of this report.

Chapter 2 Site Analysis

Site Selection & Overview

The primary purpose of this report is to analyze the feasibility of a Federal agency converting the Colonel Charles D. Maynard Lock and Dam, hereinafter Maynard Dam, to a hydroelectric facility. Maynard Dam was originally called Lock and Dam No. 5 until legislation (HR 781) passed in the Senate on June 24, 2008, to rename the Dam in honor of Colonel Maynard (Morano, 2008). Colonel Charles D. Maynard served as District Engineer of the Little Rock District of the Corps of Engineers where he directed the planning, designing, and construction of 13 locks and dams on the McClellan-Kerr Arkansas River Navigation System (Morano, 2008). The McClellan-Kerr Arkansas River Navigation System (MKARNS) is a 445 mile long water way system that runs from the Mississippi River to Catoosa, Oklahoma. There are a series of 18 locks and dams, 13 of which are in Arkansas, which allow vessels to change a total elevation of 420 feet. MKARNS provides navigation, hydroelectric power, flood control, water supply, sediment control, recreation, and fish and wildlife propagation improvements to the Arkansas River Basin (Morano, 2008). Maynard Dam is located at Navigation Mile 86.3 of the MKARNS and began operating in 1968.

Maynard Dam was chosen based on the results of the USACE National Hydropower Resource Assessment (2013) that identified an average annual generation of 24,9002.28 MWh at the 30% exceedance level. This was one of the largest potential generation values that USACE reported, and thus provided a good indication that this particular site may be feasible for hydroelectricity. Furthermore, this
site was chosen because it has not been issued a FERC license or a FERC preliminary permit, suggesting that no parties have claimed the opportunity to implement hydropower at Maynard Dam.

**Federal Energy Regulatory Commission (FERC)**

In order to implement hydroelectric capabilities at Maynard Dam a FERC license must be issued. A FERC license is a regulatory document that permits the use of public waters for energy generation. The license specifies the conditions for construction, operation, and maintenance of the project. As mentioned above, Maynard Dam does not have a FERC license or a FERC preliminary permit. A preliminary permit does not authorize construction but rather it maintains priority of application for license while the permittee studies the site and prepares to apply for a license. Furthermore, the permittee must submit periodic reports on the status of its studies (Federal Energy Regulatory Commission, 2013). The absence of a FERC preliminary permit suggests that no parties have expressed interest in the site and its potential is still available.

**Chapter 3 Methodology**

The heart of feasibility testing for a hydroelectric project is its cost-benefit analysis. This paper will utilize the data gathered by the USACE National Hydropower Resource Assessment (2013). That study gathered daily data of head and flow values for Maynard Dam for the past 10 years. Based on the data gathered, potential annual generation can be estimated in order to derive the benefits of the project. An approximation of power from a hydroelectric dam was estimated by using the following water power equation:

\[ P = \frac{QHe}{11800} \]  
\[ E = \frac{QHeT}{11800} \]

Where,

\[ E = \text{energy in Megawatt hours} \]
\[ T = \text{time defined in hours} \]
\[ Q = \text{flow, expressed in cubic feet per second (CFS)} \]
\[ H = \text{hydraulic head, expressed in feet} \]
\[ e = \text{efficiency} \]

*Source: USACE National Hydropower Resource Assessment (2013)*

Equation 1 is used to calculate a hydroelectric plant’s maximum possible rate of generation. Generally expressed in Megawatts (“MW”), Equation 1’s product yields an instantaneous value which in most cases can be sustained only for a limited period of time.
Equation 2 yields a measure of total energy that a hydroelectric project can generate over a period of time. The product of Equation 2 is generally expressed as Megawatt hours ("MWh"). The “MWh” value yielded by Equation 2 was used to form the basis of benefits produced by Maynard Dam over its lifetime.

**Power Duration Curve**

The USACE National Hydropower Resource Assessment (2013) used the head and flow variables to compute potential capacity using a power exceedance curve. A power exceedance curve shows the percentage of the time power levels are exceeded using daily historical data. A rule of thumb is to develop a hydroelectric plant that captures 70 percent of the energy of the river, or equivalently, a 30 percent probability of exceedance. However, the rule of thumb does not consider the timing of the available power, and thus, this paper addresses that uncertainty in a sensitivity analysis reported in Appendix E.

![Power Duration Curves (Colonel Charles D. Maynard Lock and Dam)](image)

**Base Case**

The main body of this paper will report on a “base case” scenario which represents the combination of variables that possess the highest probability of occurrence. The particular variables that were utilized in the base case scenario will be addressed in their respective sections. A complete breakdown of all cost variables utilized in the base case scenario can be found in Appendix A. Furthermore, the base case scenario utilizes the projected average annual electricity prices and the projected average annual generation for the assumed 50 year life of the Maynard Dam hydroelectric proposal as provided by the USACE National Hydropower Resource Assessment (2013).

**Benefits Evaluation**

The benefits of the analyzed project consist solely of the revenues received from the potential generation by the proposed hydroelectric facility. Other benefits of the dam itself including flood control, irrigation, and recreation are already realized and adding hydroelectric capability does not add any additional benefits outside of monetary gains attributable to electricity sales. Therefore, in order to determine the benefits for this project, the potential generation and projected electricity prices for the state of Arkansas during the expected life of the hydroelectric facility were identified. Utilizing the data from the USACE
National Hydropower Resource Assessment (2013), this analysis identifies that the projected average annual generation at the 30% exceedance level is 249,829,813 MWh.

A second key element to valuing electrical output lies in its pricing. This analysis employs projected electricity prices in Arkansas for the life of the hydroelectric dam (50 years). The projected electricity prices were derived from the USACE National Hydropower Resource Assessment (2013). This study derived its prices from the U.S. Energy Information Administration’s (EIA) 2013 Annual Energy Outlook Early Release which provides projected annual end-use electricity costs to the year 2040 for twenty-two Electric Market Module (EMM) supply regions using the National Energy Modeling System (NEMS). The EIA’s projected annual end-use electricity costs are chronicled by major cost element, including generation, transmission, and distribution for each supply region. The USACE National Hydropower Resource Assessment (2013) utilized the projected generation category of the EIA’s end use price for their long term energy values. Additionally, the USACE National Hydropower Resource Assessment (2013) addressed the issue of seasonal demand fluctuations at the state level by applying a monthly shaping factor to the projected generation electricity prices previously mentioned. The methodology for the monthly shaping factor was intended to acknowledge that individual states face different energy values for additional generation above and beyond the assumed equal annual generating costs within EMM regions. For example, additional demand during the high temperature summer months would result in higher energy prices during the summer. Therefore, the USACE National Hydropower Resource Assessment (2013) utilized the shaping factor equation depicted below using historical monthly retail energy prices for the state of Arkansas.

\[
Shaping \_ Factor_{State}(Month) = \frac{\sum_{year=2008}^{2012} Retail\_Price_{state}(Month,Year)}{5 \cdot \text{Average\_Retail\_Price\_Year}}
\]

Source: USACE National Hydropower Resource Assessment (2013)

These historical values were derived from the EIA’s Applications Programming Interface that stores average monthly retail energy prices for each state. Lastly, once the monthly shaping factors were derived, they were applied to the EIA’s generation cost forecast for the specific EMM supply regions using the following calculation.

\[
Energy\_Value_{State}(Month,Year) = Shaping\_Factor_{State}(Month) \times Generation\_Cost_{EMM\_Region\_Year}
\]

Source: USACE National Hydropower Resource Assessment (2013)

Utilizing the average annual generation provided by the USACE National Hydropower Resource Assessment (2013) at the 30% exceedance level of 249,829,813 MWh and multiplying that by the projected average annual electricity price, the projected annual revenue received throughout the life of the asset (50 years) could be calculated. Furthermore, the notion of salvage value was addressed by realizing that one time cash inflow at the terminal year of the assets life (year 2065). This report assumes that the salvage value amount will be approximately identical to that of the initial total construction costs. This assumption was based on the rationale that economic depreciation would not be significant due to the Operating and Maintenance Costs that include a “Major Repairs Fund” and a “Variable O&M” cost component that would counteract the presence of economic depreciation. However, in response to the
uncertainty surrounding the Maynard Dam’s eventual salvage value, a sensitivity analysis was conducted and is reported in Appendix B. Depreciation in the accounting sense (allocating the cost of the asset over its 50 year useful life) was not included in this analysis due to the fact that taxes are irrelevant because the assumption is that a Federal agency will implement this project, and thus no tax liability is present. By utilizing the most recently provided Federal Discount Rate (corresponding to Fiscal Year 2013) of 3.75%, which will be discussed in a specific section towards the end of the report, the present value of benefits (revenue derived from generation multiplied by price plus salvage value in year 2065) received is $320,171,753.32.

**Cost Estimates**

The cost estimates included in this analysis are for construction costs, non-construction development costs, and annual operating and maintenance costs. This analysis utilizes equations developed by the Idaho National Engineering and Environmental Laboratory (INEEL) 2003 study and the Bureau of Reclamation (BOR) 2011 study. The cost estimates developed by INEEL were based on a historical survey of a wide range of cost components over a large number and sizes of projects at different existing facilities. INEEL acquired historical data on licensing, construction, and environmental mitigation from various sources including FERC environmental assessment and licensing documents, U.S. Energy Information Administration data, Electric Power Research Institute reports, and other reports on hydropower construction and environmental mitigation. Based on the historical data, cost estimating equations were derived through generalized least squares regression techniques, with capacity, generator speed, and head acting as independent variables. Those costs included powertrain components, licensing, construction, fish and wildlife mitigation, water quality monitoring, and O&M.

The costs associated with the INEEL report are in 2002 dollars and the BOR study costs are in 2010 dollars. Therefore, those costs were escalated to 2012 dollars using the Civil Works Construction Cost Index System (CWCCIS) and from the Engineering News-Record’s skilled labor index. In Appendix A, a table displays the cost equations, sources, and indices used to escalate the applicable costs.

**Turbine and Generator**

The selection of the turbine and generator is based on the results of the USACE National Hydropower Resource Assessment (2013), which were derived from experience and judgment of the Hydroelectric Design Center (HDC) at USACE. The USACE report outlines that the design head should be calculated from the head duration curve at the 30% probability of exceedance level. The generator rotational speed is estimated using the following equations derived from the BOR report Selecting Hydraulic Reaction Turbines (1976).

\[ n = \frac{n_h^{5/4}}{p^{1/2}} \]

Where,

- \( n \) = generator speed (rpm)
- \( h \) = design head (ft.)
p=installed capacity (hp)

$n_s$ (specific speed) is estimated as:

$$n_s = \frac{850}{\sqrt{h}} \text{ for } h \leq 80 \text{ ft} \quad \text{or} \quad n_s = \frac{632}{\sqrt{h}} \text{ for } h > 80 \text{ ft}.$$  

The turbine selection is based on the head values using the following categorization:

$$\text{Turbine Type} = \begin{cases} \text{Bulb} & \text{head} < 50 \text{ ft} \\ \text{Kaplan} & 50 < \text{Head} < 70 \\ \text{Francis} & \text{Head} > 70 \text{ ft} \end{cases}$$

The following are the limits of the turbine and generators based on the maximum capacity values:

- Bulb Turbine: < 40 MW
- Francis Turbine: < 40 MW
- Kaplan Turbine: No Constraint

**Development Costs**

Included in construction costs are those related to civil works, turbines, generators, mechanical balance of plants, electrical balance of plants, transformers, and contingencies. Furthermore, other construction costs include licensing costs, engineering and construction management costs, and an assumed contingency cost. Additional construction costs related to fish and wildlife mitigation, recreation mitigation, historical and archeological mitigation, water quality monitoring, and fish passage costs may be deemed applicable upon a specific analysis of the effects on wildlife due to the implementation of hydroelectric capabilities at Maynard Dam. It is not within the scope of this analysis to determine if these additional construction costs are applicable to Maynard Dam. However, due to the high probability that these construction costs will need to be implemented in order to obtain a FERC license, they were included in the base case scenario.
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Tax costs were not included in the development costs due to the fact that Federal agencies do not pay taxes. Also, total development costs were assumed to be evenly distributed over the first four years of the asset life. It was assumed that the project will begin construction in 2015 and be completed in 2018. Thus, the present value of the total development costs is calculated by utilizing the 2013 Federal Discount Rate of 3.75%, which results in an amount of $179,079,579. The choice of the discount rate will be discussed in detail in another section.

Operating and Maintenance Costs
The costs associated with O&M are those related to fixed O&M costs, variable O&M costs, FERC charges, insurance, management, and major repair costs. Identical to that of other costs, these estimates were escalated from INEEL’s 2003 study and the BOR’s 2011 study to reflect 2012 dollars. As alluded to in the “Benefits Evaluation” section of this report, it is assumed that the “Major Repairs Fund” and “Variable O&M” cost components counteract the effect of economic depreciation based on the formulation of these values. A table detailing the cost estimate equations and the appendices used to escalate the dollars is included in Appendix A.

<table>
<thead>
<tr>
<th>Total Development Costs - Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Works                         $ 26,800,758</td>
</tr>
<tr>
<td>Kaplan Turbine                      $ -</td>
</tr>
<tr>
<td>Francis Turbine                     $ -</td>
</tr>
<tr>
<td>Bulb Turbine                        $ 46,814,815</td>
</tr>
<tr>
<td>Generator                           $ 20,187,080</td>
</tr>
<tr>
<td>Mechanical Balance of Plant         $ 9,362,963</td>
</tr>
<tr>
<td>Electrical Balance of Plant         $ 7,065,478</td>
</tr>
<tr>
<td>Transformer                         $ 15,690</td>
</tr>
<tr>
<td>Contingency                         $ 22,049,357</td>
</tr>
<tr>
<td>Engineering and Construction Maintainance $ 16,537,017</td>
</tr>
<tr>
<td>Licensing Costs                     $ 7,020,856</td>
</tr>
<tr>
<td>Fish and Wildlife Mitigation        $ 12,602,716</td>
</tr>
<tr>
<td>Recreation Mitigation               $ 11,078,708</td>
</tr>
<tr>
<td>Historical and Archeological Mitigation $ 2,254,758</td>
</tr>
<tr>
<td>Water Quality Monitoring            $ 1,646,044</td>
</tr>
<tr>
<td>Fish Passage                        $ 17,114,334</td>
</tr>
<tr>
<td>Transmission Line                   $ 2,576,000</td>
</tr>
<tr>
<td>Transmission Line Right-of-Way      $ 407,273</td>
</tr>
<tr>
<td><strong>Total</strong>                           $ 203,533,845</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual O&amp;M Expense - Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed O&amp;M                       $ 648,198</td>
</tr>
<tr>
<td>Variable O&amp;M                    $ 788,334</td>
</tr>
<tr>
<td>Ferc Annual Charge              $ 28,013</td>
</tr>
<tr>
<td>Insurance                       $ 487,406</td>
</tr>
<tr>
<td>Transmission / Interconnection  $ 10,000</td>
</tr>
<tr>
<td>Management                      $ 812,344</td>
</tr>
<tr>
<td>Major Repairs Fund              $ 162,469</td>
</tr>
<tr>
<td><strong>Total</strong>                       $ 2,936,764</td>
</tr>
</tbody>
</table>
These Annual O&M Expenses begin in the first year after construction (year 2019) and remain constant throughout the life of the asset (until year 2065). Utilizing the 2013 Federal Discount Rate of 3.75%, the present value of the Annual O&M Expenses throughout the life of the asset is $53,600,770.72.

**Financial Criteria**

As previously mentioned, this analysis used an assumed life of a hydroelectric dam of 50 years. Moreover, this analysis assumes that construction of the hydroelectric capabilities will not be initiated until 2015 and will end in 2018. The total development costs are split evenly over the first four years of construction. Once construction is complete, the O&M costs and the revenues from the sale of electricity begin in 2019. All costs and benefits reported are in 2012 dollars.

In order to determine economic feasibility, six important financial calculations were reported; the benefit-cost ratio (BCR), the Internal Rate of Return (IRR), the Modified Internal Rate of Return (MIRR), the Payback Period, and the Discounted Payback Period. The BCR compares the relationship between the net present value (NPV) of the cost and benefits of the proposed project over the assumed 50 year life of the hydroelectric dam. Secondly, the IRR is the discount rate at which the net present value of all cash flows from the project is equal to zero. An IRR allows you to compare the proposed project’s rate to that of financial markets in order to gauge the desirability of the proposed project. However, the IRR has a few potential flaws, most notably the fact that it assumes that cash flows are reinvested at the IRR itself, and thus overstates the expected return. Therefore, the Modified Internal Rate of Return (MIRR) addresses this issue by assuming that cash flows are reinvested at the cost of capital (2013 Federal Discount Rate of 3.75%) instead. The Payback Period is simply the number of years that are required to recover the funds initially invested in a project from its cash flows. The Discounted Payback Period is exactly the same methodology as the Payback Period however it is based on the present value of the cash flows. All of these financial decision criteria result in the same accept/reject decisions when analyzing independent projects. Thus, all six financial criteria should conclude on the same accept/reject decision for the implementation of a hydroelectric facility at Maynard Dam. In general, the higher the NPV the more desirable the project is. Furthermore, if the IRR/MIRR results in a value greater than the cost of capital then the project is adding value and should be implemented. Moreover, the decision criterion for the BCR is anything over 1.0 and the project is adding value, and thus should be implemented. Lastly, the criterion for the Payback Period and the Discounted Payback Period is the shorter the better because that corresponds to a less risky project with more liquidity.

**Discount Rate**

The choice of the discount rate plays a substantial role in the decision of whether or not a proposed project is economically feasibility and should therefore be implemented. Moreover, the longer the life of the analyzed project, the greater the impact the discount rate has on future benefits and costs. The discount rate reflects the preferences of individuals. In general, consumers prefer to consume now rather than later, and thus, we attribute more weight to the costs and benefits that are realized in the near future. There are many different ways to obtain a discount rate, most of which are derived to reflect the preferences observed in the financial markets. This analysis utilizes the Federal discount rate that has been determined by the U.S Department of the Treasury and stated in Section 80 Public Law 93-251. The U.S. Department of the Treasury computes the discount rate as the average market yield on interest-bearing marketable securities of the United States that have 15 years or more remaining until maturity. The data utilized for the yield on the interest-bearing marketable securities is based on average yields during the
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previous year (Kitch, 2012). Thus, the base case scenario reported in this analysis utilizes the 2013 Federal discount rate of 3.75%. However, the uncertainty of the discount rate cannot be ignored and in order to address that uncertainty a sensitivity analysis is reported in Appendix F. That sensitivity analysis uses various discount rates derived primarily from financial markets, but also from the optimal growth rate approach to test the variability in the accept/reject decision.

Key Assumptions
Throughout this analysis a few key assumptions were made in order to derive an accept/reject decision for the implementation of hydroelectric capabilities at Maynard Dam. The following is a list of those key assumptions made throughout this report:

- The project will be implemented by a Federal agency, and thus taxes are irrelevant.
- For the purposes of constructing the cost-benefit analysis calculations, project construction will not begin until year 2015. However, the projected is under analysis in year 2013, thus year 2013 corresponds to year 0.
- Fish and Wildlife Mitigation, Recreation Mitigation, Historical and Archeological Mitigation, Water Quality Monitoring, and Fish Passage costs were included in the Maynard Dam’s base case construction scenario because it was assumed that the FERC would require these measures in its licensing process.
- For the Transmission Line and Transmission Line-Right-of-Way development costs an assumed length of 11.2 miles was used based on a rough geographical analysis.
- Real annual O&M costs remain constant throughout the life of the asset.
- Fixed costs are incurred evenly between the first four years of construction (2015-2018).
- The Major Repairs Fund and the Annual O&M expenses counteract the potential effect of the economic depreciation, and thus the salvage value is equal to the initial total cost of construction ($203,533,845.25).
- Renewable energy credits at the state or Federal level were not included in the base case scenario due to either the nonexistence or uncertainty surrounding them.
- This analysis relies on the accuracy of the cost equations originally reported in the Idaho National Engineering and Environmental Laboratory (INEEL) 2003 study and the Bureau of Reclamation (BOR) 2011 study.
- The Civil Works Construction Cost Index System (CWCCIS) and the Engineering News-Record’s skilled labor index were used to index cost equations.
- The project average annual generation of 249,829,813 MWh as determined by USACE National Hydropower Resource Assessment (2013) is assumed constant throughout the life of the asset.
- The rule of thumb stating that the most feasible option is often to capture 70% of the energy of a river (30% exceedance level) was assumed.
- The 2013 Federal Discount Rate of 3.75% was the most appropriate discount rate. This U.S Department of the Treasury provided discount rate does not include the impact of inflation. Therefore, for consistency sake, the impacts of inflation were not included when projecting future cash flows. That being said, inflation was utilized when indexing the cost equations to 2012 dollars.
Chapter 4  Results/Conclusions

The purpose of this paper was to provide a cost-benefit analysis of Maynard Dam located at Navigation Mile 86.3 of the MKARNS. This paper developed a base case scenario that included the most plausible estimates of the variables utilized. The following are the results derived utilizing the base case scenario.

<table>
<thead>
<tr>
<th>Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit-Cost Ratio</td>
</tr>
<tr>
<td>Net Present Value</td>
</tr>
<tr>
<td>Internal Rate of Return</td>
</tr>
<tr>
<td>Modified Internal Rate of Return</td>
</tr>
<tr>
<td>Discounted Payback (years)</td>
</tr>
<tr>
<td>Payback (years)</td>
</tr>
</tbody>
</table>

A BCR of above 1.0 suggests that the project is profitable, and therefore these results suggest that the project would be worth implementing. The $87.49 million NPV provides further evidence that this project is profitable. The IRR of 5.68% and the MIRR or 4.56% are both greater than the 3.75% cost of capital, and thus demonstrate that this project is profitable. Lastly, the payback and discounted payback period do not provide as concrete of a decision as the other financial criteria, and thus need to be evaluated in respect to the preferences of the Federal agency.

Based on the financial criteria outlined above, the proposed project for hydroelectric capabilities at Maynard Dam should be implemented. However, as mentioned throughout the analysis, there is inherent uncertainty surrounding the projected electricity prices, discount rate, development costs, annual O&M costs, and the salvage value used. Furthermore, specific analysis should be conducted in order to determine the most cost-effective exceedance level for use in developing the Maynard Dam’s engineering specifications. Appendix B and Appendix D report the analytical results of these sensitivity analyses.
References


An Assessment of Hydroelectric Feasibility at Colonel Charles D. Maynard Dam in Tucker, Arkansas


# Appendix A  Cost Index Table

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Type</th>
<th>Cost Equation</th>
<th>Source</th>
<th>Cost Index Used To Escalate to 2012 Dollars</th>
<th>Included in Base Case Analysis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Works</td>
<td>Direct Construction Costs</td>
<td>Cost = (0.40) x (Turbine Cost + Generator Cost)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
<td>BOR specified 40% based on experience and judgment.</td>
</tr>
<tr>
<td>Bulb Turbine</td>
<td>Direct Construction Costs</td>
<td>Cost = 8,773,016.4 x (Capacity, MW)^0.86 x Design Head^0.63</td>
<td>INEEL 2003 Study</td>
<td>CWCCIS Power Plant Index 2002-2012 = 46.21694%</td>
<td>✓</td>
<td>INEEL equation was used in collaboration with the USACE's HDC.</td>
</tr>
<tr>
<td>Generator</td>
<td>Direct Construction Costs</td>
<td>Cost = 4,386,508.2 x (Capacity, MW)^0.65 x (Generator Speed, RPM)^0.38</td>
<td>INEEL 2003 Study</td>
<td>CWCCIS Power Plant Index 2002-2012 = 46.21694%</td>
<td>✓</td>
<td>N/A</td>
</tr>
<tr>
<td>Mechanical Balance of Plant</td>
<td>Direct Construction Costs</td>
<td>Cost = (0.20) x (Turbine Cost)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
<td>BOR specified 20% based on experience and judgment.</td>
</tr>
<tr>
<td>Electrical Balance of Plant</td>
<td>Direct Construction Costs</td>
<td>Cost = (0.35) x (Generator Cost)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
<td>BOR specified 35% based on experience and judgment.</td>
</tr>
<tr>
<td>Transformer</td>
<td>Direct Construction Costs</td>
<td>Cost = 15,688.31294 – (0.0001 x (Capacity, kW/.9)^2) + (25.403 x (Capacity, kW/.9))</td>
<td>BOR 2011 Study</td>
<td>CWCCIS Power Plant Index 2010-2012 = 5.531501%</td>
<td>✓</td>
<td>BOR cost regression equation was developed based on experience, published recent bids, and kVA. Assumes 0.9 power factor.</td>
</tr>
</tbody>
</table>
# An Assessment of Hydroelectric Feasibility at Colonel Charles D. Maynard Dam in Tucker, Arkansas

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Direct Construction Costs</th>
<th>Cost Formula</th>
<th>BOR 2011 Study</th>
<th>INEEL Study</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Line</td>
<td></td>
<td>Cost = (Length, miles) x (230,000/mile if greater than 115kV)</td>
<td>N/A</td>
<td>N/A</td>
<td>BOR estimated costs per mile based on 2002 generic costs based on line capacity.</td>
</tr>
<tr>
<td>Contingency</td>
<td>Direct Construction Costs</td>
<td>Cost = (0.20) x Sum of other Direct Construction Costs</td>
<td>N/A</td>
<td>N/A</td>
<td>BOR specified 20% based on experience and judgment.</td>
</tr>
<tr>
<td>Engineering and Construction Management</td>
<td>Direct Construction Costs</td>
<td>Cost = (0.15) x (Sum of Other Direct Construction Costs)</td>
<td>N/A</td>
<td>N/A</td>
<td>BOR assumed 15% based on experience and judgment.</td>
</tr>
<tr>
<td>Licensing Costs</td>
<td>Additional Direct Construction</td>
<td>Cost = (453,272.514) x (Capacity, MW)(^{0.7})</td>
<td>N/A</td>
<td>CWCCIS Power Plant Index 2002-2012 = 46.21694%</td>
<td>Based on INEEL's licensing cost estimates for dams without power.</td>
</tr>
<tr>
<td>Transmission Line Right-of-Way</td>
<td>Additional Direct Construction</td>
<td>Cost = (Length, miles) x (5,280 x 150/43,560) x (2,000)</td>
<td>N/A</td>
<td>N/A</td>
<td>BOR assumed 150-foot right-of-way with land cost of $2,000 per acre.</td>
</tr>
<tr>
<td>Fish and Wildlife Mitigation</td>
<td>Additional Direct Construction</td>
<td>Cost = 294,050.62 x (Capacity, MW)(^{0.96})</td>
<td>N/A</td>
<td>CWCCIS Fish &amp; Wildlife Mitigation Index 2002-2012 = 47.02531%</td>
<td>Based on INEEL's fish and wildlife mitigation cost estimates for dams without power.</td>
</tr>
<tr>
<td>Recreation Mitigation</td>
<td>Additional Direct Construction</td>
<td>Cost = 248,568.798 x (Capacity, MW)(^{0.97})</td>
<td>N/A</td>
<td>CWCCIS Power Plant Index 2002-2012 = 46.21694%</td>
<td>Based on INEEL's recreation mitigation cost estimates for dams without power.</td>
</tr>
<tr>
<td>Historical and Archeological Mitigation</td>
<td>Additional Direct Construction</td>
<td>Cost = 134,607.224 x (Capacity, MW)(^{0.72})</td>
<td>N/A</td>
<td>CWCCIS Cultural Resource Preservation Index 2002-2012 = 58.36144%</td>
<td>Based on INEEL's historical &amp; archeological mitigation cost estimates for dams without power.</td>
</tr>
<tr>
<td>Water Quality Monitoring</td>
<td>Additional Direct Construction</td>
<td>Cost = 294,050.62x (Capacity, MW)^0.44</td>
<td>INEEL 2003 Study</td>
<td>CWCCIS Fish &amp; Wildlife Facilities Index 2002-2012 = 47.02531%</td>
<td>✓</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------------</td>
<td>------------------</td>
<td>-------------------------------------------------</td>
<td>----</td>
</tr>
<tr>
<td>Fish Passage</td>
<td>Additional Direct Construction</td>
<td>Cost = 19,113,290.3 x (Capacity, MW)^0.56</td>
<td>INEEL 2003 Study</td>
<td>CWCCIS Fish &amp; Wildlife Facilities Index 2002-2012 = 47.02531%</td>
<td>✓</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = 34,409.2368 x (Capacity, MW)^0.75</td>
<td>INEEL 2003 Study</td>
<td>ENR Skilled Labor Index 2002-2012 = 43.3718%</td>
<td>✓</td>
</tr>
<tr>
<td>Variable O&amp;M</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = 34,409.2368 x (Capacity, MW)^0.80</td>
<td>INEEL 2003 Study</td>
<td>ENR Skilled Labor Index 2002-2012 = 43.3718%</td>
<td>✓</td>
</tr>
<tr>
<td>FERC Charges</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = Installed Capacity (kW) + 112.5 x Annual Generation (GWh [gigawatt hours])</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Insurance</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = (Total Direct Construction Cost) x (0.003)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Transmission / Interconnection</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = 10,000</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Management</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = (Total Direct Construction Cost) x (0.005)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Major Repairs</td>
<td>Operation and Maintenance Costs</td>
<td>Cost = (Total Direct Construction Cost) x (0.001)</td>
<td>BOR 2011 Study</td>
<td>N/A</td>
<td>✓</td>
</tr>
</tbody>
</table>
Appendix B  
Sensitivity Analysis of Key Variables

There is a great deal of uncertainty involved when projecting cash flows for the life of a 50 year project. This analysis made many assumptions in order to obtain the base case results. Therefore, this sensitivity analysis tests the impact of key variable fluctuations on the NPV. The methodology for this sensitivity analysis is to test the range of NPV values when key variables are altered by the same range of percentages. Listed below are the results of this sensitivity analysis.

<table>
<thead>
<tr>
<th>% Deviation from Base Case</th>
<th>Discount Rate</th>
<th>Projected Electricity Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discount Rate</td>
<td>Average of Projected Electric Price</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Base Case</td>
</tr>
<tr>
<td>-30%</td>
<td>2.63% $176,273,597</td>
<td>-30% $46.48 $442,653</td>
</tr>
<tr>
<td>-15%</td>
<td>3.19% $127,093,649</td>
<td>-15% $56.44 $43,967,029</td>
</tr>
<tr>
<td>0%</td>
<td>3.75% $87,491,404</td>
<td>0% $66.40 $87,491,404</td>
</tr>
<tr>
<td>15%</td>
<td>4.31% $55,453,809</td>
<td>15% $76.36 $131,015,779</td>
</tr>
<tr>
<td>30%</td>
<td>4.88% $29,002,996</td>
<td>30% $86.32 $174,540,155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Deviation from Base Case</th>
<th>Annual O&amp;M Costs</th>
<th>Development Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual O&amp;M Costs</td>
<td>Average of Development Costs</td>
</tr>
<tr>
<td></td>
<td>Base Case</td>
<td>Base Case</td>
</tr>
<tr>
<td>-30%</td>
<td>$2,055,735 $103,571,635</td>
<td>-30% $142,473,692 $132,212,502</td>
</tr>
<tr>
<td>-15%</td>
<td>$2,496,250 $95,531,519</td>
<td>-15% $173,003,768 $109,851,953</td>
</tr>
<tr>
<td>0%</td>
<td>$2,936,764 $87,491,404</td>
<td>0% $203,533,845 $87,491,404</td>
</tr>
<tr>
<td>15%</td>
<td>$3,377,279 $79,451,288</td>
<td>15% $234,063,922 $65,130,855</td>
</tr>
<tr>
<td>30%</td>
<td>$3,817,793 $71,411,173</td>
<td>30% $264,593,999 $42,770,306</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Deviation from Base Case</th>
<th>Salvage Value</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salvage Value</td>
<td>87,491,404</td>
</tr>
<tr>
<td>-30%</td>
<td>$142,473,692 $78,488,629</td>
<td></td>
</tr>
<tr>
<td>-15%</td>
<td>$173,003,768 $82,990,016</td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>$203,533,845 $87,491,404</td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td>$234,063,922 $91,992,792</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>$264,593,999 $96,494,179</td>
<td></td>
</tr>
</tbody>
</table>
The table above is the range of the NPV’s taken from the respective individual tables. The data was then utilized to construct a sensitivity graph for those key variables. The sensitivity graph allows for a visual representation of the NPV range for the key variables. This graph can be used to interpret the sensitivities of each variable in relation to the NPV. Furthermore, this graph can be used to provide insight into the project’s overall risk. The key in interpreting the sensitivity graph is that the slopes of the lines in the graph and the ranges in the table above indicate the sensitivity of the project’s NPV to variations in each input. The greater the variables range, then the steeper the variables slope, and thus the more sensitive the project’s NPV is to that particular variable. Based on the sensitivity graph, the key variables with the most sensitivity are the discount rate, the projected electricity prices, the annual O&M costs, and the development costs. In general, the steeper the key variables are and the more uncertain the expected values of those key variables are, then the more risky the project is.
Appendix C Scenario Analysis

A shortcoming of sensitivity analysis is that it only allows for the fluctuation of one variable at a time while holding all others constant. However, it is entirely plausible that several key variables may turn out to better or worse than expected in the base case scenario. Thus, a scenario analysis is included in order to report the effect on the NPV when multiple key variables are altered. Furthermore, a scenario analysis allows for probabilities to be assigned to the base case scenario, the worst case scenario, and the best case scenario in order to derive a final expected value of the project’s NPV. Moreover, the standard deviation and the coefficient of variation are included to get a better sense of the project’s overall risk.

As previously mentioned, multiple scenarios need to be specified in order to conduct a scenario analysis. First, the base case scenario is utilized to represent the most probable outcome. Next, the best case scenario and worst case scenario must be specified. The key variables that fluctuate among these scenarios are those that were determined in the sensitivity analysis to have the most sensitivity (discount rate, projected electricity prices, annual O&M costs, and development costs). It is often defined that the best and worst cases have a probability of occurrence of 25% and the base case conditions to have a 50% probability of occurrence, and thus those percentages are utilized in this scenario analysis.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Probability</th>
<th>Electricity Prices (annual average)</th>
<th>Discount Rate</th>
<th>Annual O&amp;M Costs</th>
<th>Development Costs</th>
<th>NPV</th>
<th>Squared Deviation Times Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Case</td>
<td>25%</td>
<td>$86.32</td>
<td>2.63%</td>
<td>$2,055,735</td>
<td>$142,473,692</td>
<td>$350,528,121</td>
<td>14,852,917,379,652,500</td>
</tr>
<tr>
<td>Base Case</td>
<td>50%</td>
<td>$66.40</td>
<td>3.75%</td>
<td>$2,936,764</td>
<td>$203,533,845</td>
<td>$87,491,404</td>
<td>186,083,417,466,372</td>
</tr>
<tr>
<td>Worst Case</td>
<td>25%</td>
<td>$46.48</td>
<td>4.88%</td>
<td>$3,817,793</td>
<td>$264,593,999</td>
<td>$(98,378,809)</td>
<td>10,522,845,066,816,300</td>
</tr>
</tbody>
</table>

Expected NPV = sum, prob times NPV
Standard Deviation = Sq. Root of column I sum
Coefficient of Variation = Std Dev. / Expected NPV

25,561,845,863,935,200

The expected NPV given above is calculated by summing the products of multiplying each scenario’s probability of occurrence by their respective NPV’s. This calculation results in an expected NPV of $106,783,030. Furthermore, the standard deviation of the expected NPV is calculated at $159,880,724.

Next, the standard deviation is divided by the expected NPV to calculate the coefficient of variation of 1.50. The coefficient of variation can be interpreted as the project’s stand-alone risk and would ultimately be evaluated against other proposed projects in a mutually exclusive scenario. Overall, this scenario analysis suggests that this project has an expected NPV of $106,783,030 which is an approximate 22% increase from the base case scenario. The riskiness of this project is relative to the preferences of the agency adopting the project, however the standard deviation and the coefficient variation calculated above can be used to compare against that agency’s typical risk preference calculations.

Appendix D Inclusion of Renewable Energy Credits

Financial incentives for the development of hydroelectric facilities often come in the form of tax credits and/or various subsidies. An example of an available subsidy is Performance Based Incentives which can include a wide range of financial incentives from both the state and Federal level. Typically these incentives include a utility providing financial compensation to residential and commercial members who generate energy from approved renewable energy sources. The incentive payments are based on the amount of kilowatt hour (kWh) production and, generally, a price determined by state regulatory
authorities (often based on the market price of energy). Performance based incentives are often accompanied by strict limitations regarding which energy sources are accepted as well as which other incentives can be received in addition to the performance based incentives (DSIRE, 1995).

The two primary federal renewable energy incentives are the Production Tax Credit (PTC) and the Investment Tax Credit (ITC). The ITC and PTC are both per-kilowatt-hour tax credits for eligible energy sources. In general, the ITC and PTC equal 30 percent of eligible costs (DSIRE, 1995). While these two programs are uniquely different, The American Recovery and Reinvestment Act of 2009 allows facilities that qualify for the PTC to take the ITC instead. In addition, in January 2013 the American Taxpayer Relief Act of 2013 revised the language governing the eligibility of PTC-eligible facilities to claim the ITC. Originally, the law required PTC-eligible facilities to have a placed in service date by the end of 2013. The law now allows facilities to claim ITC if projects begin construction by the end of 2013 (DSIRE, 1995). Renewable energy facilities that qualify for the PTC also have the option to take an equivalent cash grant from the U.S Department of Treasury. However, in order to be eligible for the PTC or ITC, eligible facilities must begin construction by December 31, 2013.

The base case analytical scenario for Maynard Dam as reported here does not include any green incentives from the state or federal level. Furthermore, only Federal Performance Based Incentives are discussed in this Appendix due to the uncertainty in the ability to capture utility based incentives from a Federal agency. Moreover, tax based incentives were not discussed due to the fact that Federal agencies have no tax liability.

Currently the state of Arkansas does not offer any state level incentives for the development of hydroelectric facilities and, as mentioned above, the Federal incentives expire at the end of 2013. However, a sensitivity analysis was conducted to view the potential benefits of a subsidy on hydroelectric generation such as the Performance Based Incentives mentioned above. The Federal Performance Based Incentives amount to approximately $11.00/MWh (DSIRE, 1995).

<table>
<thead>
<tr>
<th>Base Case with Renewable Energy Credits</th>
<th>Base Case</th>
<th>Difference from Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCR</td>
<td>1.59</td>
<td>1.38</td>
</tr>
<tr>
<td>NPV</td>
<td>$137,483,111</td>
<td>$87,491,404</td>
</tr>
<tr>
<td>IRR</td>
<td>6.75%</td>
<td>5.68%</td>
</tr>
<tr>
<td>MIRR</td>
<td>4.92%</td>
<td>4.56%</td>
</tr>
<tr>
<td>Discounted Payback (years)</td>
<td>25.32</td>
<td>32.21</td>
</tr>
<tr>
<td>Payback (years)</td>
<td>18.08</td>
<td>21.08</td>
</tr>
</tbody>
</table>

The results suggest that inclusion of the Federal renewable energy credit of $11.00/MWh makes a substantial impact on the six financial criteria. An impact of this magnitude makes this particular site more desirable, but these results also suggest an overall importance of the Federal renewable energy credits for potential sites less desirable than that of Maynard Dam.

**Appendix E  Range of Exceedance Levels**

This analysis attempts to identify the optimal exceedance level based on the calculation of the NPV. As previously mentioned, this report utilized the 30% probability of exceedance based on the industry rule of
An Assessment of Hydroelectric Feasibility at Colonel Charles D. Maynard Dam in Tucker, Arkansas

thumb that supports capturing 70\% of the energy of the river. As the probability of exceedance levels increase and decrease, the total development costs, O&M costs, and the average annual generation fluctuates in response. More specifically, at low exceedance levels the generation output tends to be relatively high (increasing the present value of future project output and therefore its NPV) and construction costs tend to be high (increasing the present value of project development costs and therefore lowering project NPV). The following table displays the NPV at various probabilities of exceedance levels.

<table>
<thead>
<tr>
<th>Probability of Exceedance Level</th>
<th>Exceedance Level</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Exceedance Level</td>
<td>$64,747,808</td>
<td>$87,491,404</td>
</tr>
<tr>
<td>20% Exceedance Level</td>
<td>$79,787,969</td>
<td></td>
</tr>
<tr>
<td>30% Exceedance Level</td>
<td>$87,491,404</td>
<td></td>
</tr>
<tr>
<td>40% Exceedance Level</td>
<td>$86,596,747</td>
<td></td>
</tr>
<tr>
<td>50% Exceedance Level</td>
<td>$88,904,767</td>
<td></td>
</tr>
<tr>
<td>60% Exceedance Level</td>
<td>$71,198,650</td>
<td></td>
</tr>
<tr>
<td>70% Exceedance Level</td>
<td>$49,186,232</td>
<td></td>
</tr>
<tr>
<td>80% Exceedance Level</td>
<td>$29,775,421</td>
<td></td>
</tr>
</tbody>
</table>

Based on the results presented above, the optimal probability of exceedance level is at the 50\% exceedance level, or equivalently, capturing 50\% of the river’s energy. At the 50\% probability of exceedance level the average annual generation is only 182,571 MWh compared to the 249,002 MWh at the base case exceedance level of 30\%. However, the 50\% probability of exceedance level is more desirable to that of the 30\% because the costs are substantially lower. The table below displays the difference in costs between the 50\% probability of exceedance and the 30\% level.
Appendix F  Using Different Discount Rates

This sensitivity analysis addresses the uncertainty and substantial impact that the discount rate has on the six financial criteria. This sensitivity analysis uses different discount rates while holding all other variables in the base case scenario constant. In general, the discount rate represents the cost of capital to implement the proposed project. Since this analysis is a proposition for a Federal agency, the discount rate used should reflect some notion of the preferences of individuals in society.

The first method utilized is the technique of capturing the marginal rate of return on private investment. The argument for using the marginal rate of return on private investment for the discount rate is that before the government takes resources out of the private sector, it should be able to demonstrate that society will receive a greater return in the public sector than it would have received in the resources were
utilized in the private sector (Boardman, 2006). For the marginal rate of return on private investment the discount rate used was 4.5%. This value was derived from the Boardman (2006) Cost-Benefit Analysis text that reported on a study that analyzed historical values of Moody’s AAA-rated bonds and the real average monthly yield on all Moody’s rated corporate bonds to conclude that the value varies between 3-5% and, according to Boardman (2006), a reasonable estimate is 4.5%.

Another method is to approximate the social marginal rate of time preference, which contends that individuals in society are willing to postpone a small amount of current consumption in exchange for additional future consumption (Boardman, 2006). Boardman (2006) suggests a value of 1.5% based on historical analysis of real, after-tax returns to ten-year Treasury bonds. The idea is that Treasury bonds explicitly represent ten-year inflation forecasts.

Thirdly, the shadow price of capital technique was utilized. This technique is based on the idea that the rate at which individuals are willing to trade present for future consumption differs from the rate of return on private investment (Boardman, 2006). Therefore, Boardman (2006) contends that the flows of investment should be treated differently from flows of consumption. Moreover, Boardman (2006) gives a range of discount rate values of 1.21-1.47%, depending on the appropriate marginal rate of time preference included in the equation. Boardman (2006) reports that the shadow price of capital method requires that discounting should be done in four steps:

1. Costs and benefits in each period are divided into those that affect consumption and those that affect investment.
2. Flows into and out of investment are multiplied by the shadow price of capital (SPC) to convert them into consumption equivalents.
3. Changes in consumption are added to changes in consumption equivalents.
4. Resulting amounts are discounted at the social marginal rate of time preference ($p_z$).

The Boardman (2006) text gives the following equation for the shadow price of capital:

$$SPC = \frac{(r_z + \delta)(1-f)}{p_z - r_z f + \delta(1-f)}$$

Where $p_z =$ Social Marginal Rate of Time Preference, $r_z =$ Marginal Rate of Return on Private Investment, $f =$ the fraction of the gross return on capital that is reinvested, and $\delta$ is the depreciation rate of the capital invested.

Fourthly, in order to address the potential biases with using a market driven interest rate, the optimal growth rate approach was used. The optimal growth rate approach rejects the position that social choices should reflect individual preferences as inferred from market interest rates (Boardman, 2006). One reason to not use market interest rates is because markets are not perfect and individual consumers do not behave as assumed by the standard economic model of intertemporal choice (Boardman, 2006). Boardman (2006) displays the following equation to derive the discount rate based on the optimal growth rate approach:

$$p_x = d + ge,$$
Where \( d \) = the pure rate of time preference, \( g \) = the growth in per capita consumption, and \( e \) = the absolute value of the rate at which the marginal value of consumption declines as per capita consumption increases.

The value suggested by the Boardman (2006) is a central estimate of 3.5%. Boardman (2006) estimated the value of \( g = 2.3\% \), \( e = 1 \), and \( d = 1 \) for a discount rate of 3.3%, but with the value varying between 2.0% and 5.0%, and thus a central estimate of 3.5% was suggested.

Lastly, the Department of the Treasury has determined a 2013 Hydropower Interest Rate of 2.75%. This interest rate was established under Secretarial Order RA 6120.2 Paragraph 11 (c) of the Secretary of Energy and Departmental Manual 730 DM 3, superseding Secretarial Order 2929 of the Secretary of the Interior (Kitch, 2012). This interest rate is described as being applicable to interest during construction, investment cost repayment, and capitalized O&M costs. This interest rate is included in the event that this project is approved to utilize this 2.75% interest rate upon further Federal analysis.

The table below depicts the results utilizing the methods described above.

<table>
<thead>
<tr>
<th>Method</th>
<th>Discount Rate</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal Rate of Return on Private Investment</td>
<td>4.50%</td>
<td>$46,015,266</td>
</tr>
<tr>
<td>Social Marginal Rate of Time Preference</td>
<td>1.50%</td>
<td>$316,129,182</td>
</tr>
<tr>
<td>2013 Federal Discount Rate</td>
<td>3.75%</td>
<td>$87,491,404</td>
</tr>
<tr>
<td>Shadow Price of Capital</td>
<td>1.34%</td>
<td>$341,671,291</td>
</tr>
<tr>
<td>Optimal Growth Rate Approach</td>
<td>3.50%</td>
<td>$104,128,230</td>
</tr>
<tr>
<td>2013 Federal Hydropower Interest Rate</td>
<td>2.75%</td>
<td>$164,808,520</td>
</tr>
</tbody>
</table>

**Appendix G Supplemental Information**

The purpose of this Appendix is to outline the full range of benefits and costs of dams in general and the non-monetized benefits of hydroelectric dams in particular. Since these benefits and costs are non-monetized they were not included in the primary analysis of the proposed project. While the proposed project solely analyzes the feasibility of implementing hydroelectric capabilities at a pre-existing dam, the effects of the initial construction of a dam should not be ignored.

**Environmental**

Dams have significant effects on the physical, biological, and human environment in and near the site. Furthermore, the construction of a dam is typically not for one single purpose, as opposed to that of a coal power station which is built solely for the purpose of power generation.

**Physical**

The construction of a dam significantly effects the physical environment of the potential site. The river and ecosystem of the surrounding land is altered once construction begins. The free flow of water will stop and will begin to build up behind the dam in the new reservoir. The opportunity cost of using this land for a reservoir would vary by site and would need to be analyzed individually by project. The land
may have been previously used for agriculture, forestry, or housing. In addition, the loss of habitat would warrant analysis if this land hosted threatened or endangered species.

The potential risk of sediment accumulation in the new rapidly filling reservoir could eventually cause less water to be stored when sediments continue to fill the bottom of the reservoir. This could potentially create an issue because less stored water in a reservoir would lead to less power generation as the reservoir's capacity shrinks (Castaldi, Chastain, Windram & Ziatyk, 2003).

Furthermore, dams are typically constructed in undeveloped areas which would require new roads to be built for ease of the construction process. This would warrant the removal of vegetation and topsoil. In addition, recent research has suggested that dam construction can have an impact on the microclimate level and the possibility of inducing earthquakes. The theory is that the dam creates added forces along inactive faults that may potentially free stronger orogenic tensions (Castaldi, Chastain, Windram & Ziatyk, 2003). These physical environmental concerns would warrant analysis if analyzing the feasibility of building a new dam.

**Biological**

The primary biological concern is that of animal and plant life. As previously mentioned, the construction of the dam would require the flooding of a large area that most likely was inhabited by animals and plants. If the reservoir is expected to be used for recreational purposes in the future, the land would need to be completely cleared of trees. Moreover, the process of tree removal amplifies the impacts to the environment by adding pollutants into the region and may require an increase in roads.

Another potential biological impact that would warrant analysis is the growth of aquatic weeds. The impact of weeds can play a significant role in water loss. Consequently, more weeds growing in the reservoir would result in a higher rate of evapotranspiration, which is simply the sum of evaporation and plant transpiration from the Earth’s land surface to the atmosphere (Burba, 2010). Furthermore, the weeds would compete with the fish for space and nutrients causing more harm to the survival of the fish. Mitigation would entail manual clearing, and chemical, or biological means to remove the weeds. Each of these options contains unique flaws and risks that would need to be evaluated based on the local conditions of the site (Castaldi, Chastain, Windram & Ziatyk, 2003).

In the Northwest, the impacts on fish migration and habitat may be the most well-known consequences of dam construction. While the new dam would create a new larger habitat for some species of fish, potential issues still may arise. For some fish, the building of the dam would make completing their life cycle nearly impossible. Migrating fish, such as salmon, rely on streams and rivers to get to and from different environments. Thus, the existence of the dam could create a large roadblock for these fish. Fish issues can be mitigated through the implementation of fish safety technology. Current fish safety technologies utilized to overcome migration impacts include fish lifts, fish ladders, and “fish-friendly” turbines.

**Fish Lifts**

Fish lifts are designed and constructed like an elevator for fish. Essentially, migratory fish swim into a hopper located on the downstream side of the dam and are lifted to an exit channel where they continue their upstream journey. The fish are attracted to the hopper by currents created by a strategic release of water (Safe Harbor Water Power Corporation, 2013). The image below provided by the Safe Harbor Water Power Corporation (2013) gives an illustration of this process.
Fish Ladders
A fish ladder is defined as a structure designed to allow fish the ability to migrate upstream, by means of movement through or over a barrier. Fish ladders may be necessary because dams are an obstruction in the river and have the potential to fragment aquatic ecosystems and affect fish populations. The fragmentation of rivers can result in a decrease in fish population, and thus the fish ladders are implemented to decrease the adverse effects of the dam’s obstruction to the fish. Fish ladders are often recommended when the barrier is as low as 1 to 2 feet in height. A few key factors that need to be considered in an analysis of necessity for fish ladders include the water depth below the blockage, the height of the barrier, the water velocity over/through the barrier, the quantity and quality of fish habitat upstream of the barrier, fish movement patterns, and the species composition of the fish community (State of Michigan, 2001).

Fish-Friendly Turbines
This type of fish safety technology is a relatively recent technology that reduces passage mortality during the downstream migration of fingerlings. This type of turbine is referred to as the Alden Fish-Friendly Turbine. Scientists and engineers at the Electric Power Research Institute (EPRI), Alden Laboratories, and their partners have designed a turbine that reduces fish passage injury and mortality (Dham, 2011). The innovative aspect of the Alden Fish-Friendly Turbine is that it only has three blades (opposed to traditional turbines which contain 5-18 blades), no gaps between the blades, and the blades rotate much more slowly than a traditional turbine (Dham, 2011). These key features allow for a decrease in the risk of mortality for fish passing through the turbine while maintaining the efficiency and energy production of a traditional turbine.

Environmental Effects Conclusion
Specific analysis would be conducted for each site to determine feasibility for implementation of these fish safety technologies. Furthermore, other techniques to lessen dam impacts on animals, plants and surrounding lands include: reservoir sediment and river erosion management, modifying dam operations to restore river flows, building fish hatcheries, controlling the temperature and oxygen levels of water released from dams, and conserving and remediating land surrounding reservoirs, rivers and dams.

Humans
Despite the obvious positive benefits to the human-environment such as flood control, the dam may also negatively impact the residents. The implementation of the dam may require the relocation of the locals,
which could be very costly, both monetarily and emotionally. This issue would undoubtedly be included on the initial cost-benefit analysis.

**Non-Monetized Economic Benefits of Non-Powered Dams**
The implementation of non-powered dams serves a variety of useful benefits to society. Most notably is the ability to store surplus river water during wet periods in order to supplement for dry seasons. The use of dams contribute to fulfilling basic human needs such as; water for drinking and industrial use, irrigation, flood control, inland navigation, and recreation.

**Water for Drinking and Industrial Use**
Water is not evenly distributed throughout the world and its availability is generally inconsistent throughout the year. As mentioned above, the use of dams permits the storage of surplus water in order to combat scarcity for domestic, agricultural and industrial uses (Kapoor, 2011).

**Irrigation**
The water that is stored can also be used for irrigation purposes. Large quantities of water are required in order to meet the needs of agricultural irrigation. According to the Federal Emergency Management Agency (2013), ten percent of American cropland is irrigated using water stored behind dams. Furthermore, the Federal Emergency Management Agency (2013) contends that thousands of jobs are tied to producing crops grown with irrigated water.

**Flood Control**
Dams can be used to effectively control floods by regulating river water flows downstream of the dam, helping prevent massive economic costs that can result from flooding. Dams can be designed, constructed and operated for routing floods through the basin without any damage to life and property of the community by storing the excess precipitation in the reservoir and releasing the water later when desired (Kapoor, 2011).

**Inland Navigation**
An additional benefit is the enhancement of inland navigation which can be made difficult due to the existence of currents, various natural river levels, and snowfall. Dams can effectively be used to control the level of water in a river where inland navigation is utilized (Kapoor, 2011).

**Recreation**
The reservoir created by dam construction results in recreational beauty in the lake that is formed. Moreover, the lake supports recreational benefits such as boating, swimming, and fishing. These activities create economic benefits to those recreational markets in addition to the increased utility received from the recreationists. Furthermore, the notion of use and nonuse value would be prevalent in the sense that people value the mere existence of the dam/reservoir as well as their direct recreational use of the reservoir.

**Non-Monetized Economic Benefits of Hydroelectric Dams**
The economic benefits of hydroelectricity can be summarized by the terms reliable, affordable, available, and sustainable. Furthermore, the expansion of hydroelectric plants supports job creation. A study by Navigant Consulting found that America’s hydropower industry has the potential to create more than 1.4 million cumulative jobs by 2025 (National Hydropower Association, 2013).
Reliable

Hydroelectric plants play a key role in providing fast reliable energy to the power grid. Hydroelectric plants are the only major generators that can provide dispatch power to grid immediately when all other energy sources are inaccessible. Thus, hydroelectric plants provide essential back-up power during electricity disruptions. These facilities have the ability to quickly go from zero power generation to maximum output, which allows the facility to meet the changing demands for electricity throughout the day. Furthermore, hydroelectric facilities are reliable in the sense that they have the ability to operate in isolation without drawing on an outside power source (National Hydropower Association, 2013).

Affordable

The use of hydroelectric plants leads to lower electricity costs to consumers through low average total costs. By utilizing the power of moving water, hydro electricity prices do not depend on unpredictable changes in fuel costs. The benefit to consumers can be seen by states that get the majority of their electricity from hydropower. States such as Idaho, Washington, and Oregon on average have energy bills that are lower than the rest of the country (National Hydropower Association, 2013). According to a study from Navigant Consulting and the American Council on Renewable Energy (ACORE), hydropower offers the lowest levelized cost of electricity across all major fossil fuel and renewable energy sources. The levelized costs below reflect the low maintenance, operations and fuel costs of hydro when compared with other electricity sources and across a full project lifetime. Hydroelectric facilities are assumed to have a lifespan of 50 years (which traditionally has corresponded to the default period for which the Federal Energy Regulatory Commission issues operating licenses), which allows the costs to be spread across a longer timeframe.

Available

As previously mentioned, hydro is generating power in every region of the country and is America’s largest source of clean, renewable electricity. Furthermore, hydropower is purely a domestic source and requires only the power of America’s moving waters, rivers, streams and ocean tides to generate electricity. Therefore, much of the money invested in hydropower stays in America, creating a multiplier effect that further assists the U.S. economy.

The opportunity for hydroelectric expansion via converting non-powered dams in the U.S. can immensely benefit the economy as a whole. According to the National Hydropower Association (2013), only 3
percent of the nation’s 80,000 dams currently generate electricity. Developing these sites can drastically expand our supply of domestic renewable energy and maximize the benefits of our existing infrastructure. Furthermore, developing these sites would lead to the creation of hundreds of thousands of good paying jobs that cannot be outsourced. As previously mentioned, the 2009 study by Navigant indicates that installing 60,000 MW would result in 1.4 million cumulative jobs by 2025. The conversion of non-powered dams would account for 10,000 MW of the previously mentioned 60,000 MW and would create jobs in every region across the country (National Hydropower Association, 2013).

Sustainable
The use of hydroelectric facilities results in power generation without producing air pollution or toxic by-products. According to the National Hydropower Association (2013), using hydropower avoids nearly 200 million metric tons of carbon pollution in the U.S. each year. Therefore, society as a whole benefits by the use of hydroelectric plants through cleaner air and water (National Hydropower Association, 2013).