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Feasibility Study of Economics and Performance of a Hydroelectric Installation at the Jeddo Mine Drainage Tunnel

A Study Prepared in Partnership with the Environmental Protection Agency for the RE-Powering America's Land Initiative: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites

Joseph Owen Roberts and Gail Mosey

Produced under direction of the U.S. Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-09-1719 and Task No WFD3.1000.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-7A30-51321
February 2013
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Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Jeddo Tunnel discharge site for a feasibility study of renewable energy potential.[1] The Jeddo Tunnel is a manmade water level drainage tunnel used to drain deep mines in the Eastern Middle Anthracite Field near Hazleton, Pennsylvania. Citizens of the area, city planners, and site managers are interested in redevelopment uses for this resource as remediation costs are estimated at $15 million over the next 20 years[2] for a passive treatment system. The purpose of this report is to assess technical and economic viability of the site for hydroelectric and geothermal energy production. In addition, the report outlines financing options that could assist in the implementation of such a system.

The site was found to be constructible, and no major construction or maintenance issues were raised from the turbine manufacturer or dam designer. There may be environmental issues associated with the construction of a small water retention dam just below the tunnel outlet, but considering the environmental impacts already affecting the immediate and larger Jeddo basin drainage, it appears the overall relative environmental benefits of this project outweigh the negative environmental impacts.

The economics of the potential systems were analyzed using an electric rate of $0.10/kWh, assuming the power could be utilized by local off-takers a short distance away, such as the local elementary school and wastewater treatment plant, or be net metered to either facility. Table ES-1 summarizes the system performance, economics, and job potential of modeled systems at the Jeddo discharge. Calculations for this analysis assume the 30% cash grant in lieu of the federal tax credit incentive, per Treasury Bill Section 1603,[3] would be captured for the system. This is an important point that merits further investigation, preferably by a legal representative, due to the fact that "new" hydroelectric facilities do not qualify for this cash grant. However, the project appears to meet the intent of Section 1603 under the definition of a "hydrokinetic facility." At the time of publication of this report, the 1603 incentive had expired but had the possibility of being reinstated.

The results in Table ES-1 show the impacts on the simple payback with and without the Treasury bill cash grant. As shown, the upfront savings afforded by the cash grant positively impact simple payback of the project.

Next steps should include the clarification of whether or not this facility can meet the definition of "hydrokinetic facility"[4] as well as the exploration of a virtual net-metering policy in the area.

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[1] EPA. "RE Powering America's Land: Evaluating the Feasibility of Siting Renewable Energy Production on Potentially Contaminated Land." http://www.epa.gov/renewableenergyland/docs/develop_potential/drums.pdf. Accessed April 14, 2011.
[2] Hewitt, M. "Jeddo Tunnel Abandoned Mine Drainage Passive vs. Active Treatment Cost Estimates." Ashley, PA: Eastern Pennsylvania Coalition of for Abandoned Mine Reclamation (EPCAMR), October 2006.
[3] U.S. Treasury Department. "Payments for Specified Energy Property in Lieu of Tax Credits Under the American Recovery and Reinvestment Act of 2009." http://www.treasury.gov/initiatives/recovery/Documents/guidance.pdf. Accessed April 14, 2011.
[4] U.S. Treasury Department. "Payments for Specified Energy Property in Lieu of Tax Credits Under the American Recovery and Reinvestment Act of 2009," pp. 13–14. http://www.treasury.gov/initiatives/recovery/Documents/guidance.pdf. Accessed April 14, 2011.

Given the nature of the project and its benefits to both the community and the environment, efforts could be made to pursue other grants and low interest loans that could increase the financial viability of the project. Also, further investigation of the height optimization of the dam and verification of the annual flow characteristics (which are contingent upon planned remediation within the drainage basin) should be undertaken.

Table ES-1. Hydro System Performance and Job Estimates[5]

System Size (kW)	Turbine Type	Annual Output (kWh/yr)	System Cost	Energy Production Cost ($/kWh)	Simple Payback Period (years)	Construction Jobs	Long-Term Jobs
247	Kaplan	1,162,453	$2,014,233	0.0796	17.3	22.4	19.4
405	Crossflow	1,029,433	$2,063,516	0.0913	21.3	22.9	19.4

[5] Estimates assume an inflation rate of 1.2%, discount rate of 3%, utilization of the 30% cash grant in lieu of the tax credit, 80% debt ratio, 50-year project life, 6% interest rate and 30-year note term, 1.2% energy escalation rate, and an O&M cost of $35,000/year. Long-term job-years are total jobs for the 50-year design life of the project at the aforementioned O&M cost, which averages 0.39 jobs per year.

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1 Introduction

The U.S. Environmental Protection Agency (EPA) launched the RE-Powering America's Land initiative in September 2008. EPA and the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) are collaborating on a number of projects to evaluate the feasibility of siting renewable energy projects on these potentially contaminated sites.

The EPA selected the Jeddo Tunnel discharge site for a feasibility study of renewable energy potential. Citizens of the area, city planners, and site managers are interested in redevelopment uses for this site as remediation costs are estimated at $15 million over the next 20 years for a passive treatment system. The purpose of this report is to assess technical and economic viability of the site for hydroelectric and geothermal energy production. In addition, the report outlines financing options that could assist in the implementation of a system.

1.1 Study Location and Background

The Jeddo Tunnel is a manmade water level drainage tunnel used to drain deep mines in the Eastern Middle Anthracite Field near Hazleton, Pennsylvania. Jeddo Tunnel A was completed in 1895, and this tunnel discharges into the Little Nescopeck Creek and drains four major coal basins: Big Black Creek, Little Black Creek, Cross Creek, and Hazleton. The tunnel was abandoned in 1955 following the collapse of the deep mining industry in the United States. The Jeddo Tunnel drains 32.24 mi^2 of hilly/mountainous terrain consisting of both active and abandoned mining sites, farmland, grazing land, forest land, rural residential homesteads, and the City of Hazleton. Historical records[6] indicate discharges of an average of 134 cubic meters per minute (cmm) into Little Nescopeck Creek, a high-quality cold water fishery.

As precipitation filters through the active and abandoned mining sites, it picks up large quantities of aluminum, manganese, and iron. The combination of the high levels of metals with the low pH of the water eliminates all animal life downstream of the confluence of the Jeddo discharge and the Little Nescopeck Creek and severely impairs the water quality in the Nescopeck River.[7] The levels of aluminum, manganese, and iron are 9.9, 1.7, and 3.4 times higher than allowable levels of these metals in streams affected by acid mine drainage (AMD) in the State of Pennsylvania.[8] The Little Nescopeck Creek receives all the flow from the Jeddo Tunnel discharge, and the discharge from the tunnel is the primary source of pollution in the Little Nescopeck Creek watershed. The tunnel discharge and Little Nescopeck Creek then join the Nescopeck Creek, which subsequently flows into the Susquehanna River around Berwick, Pennsylvania.

There have been many studies aimed at mitigating the AMD pollution from the Jeddo discharge, but the least expensive proposed measures cost more than $15 million for 20 years of treatment.[9] The aim of this study is to explore the potential not to treat the AMD but to utilize the potential

[6] Ballaron, P. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* August 1999.
[7] Pennsylvania Department of Environmental Protection. "Black Creek, Little Nescopeck Creek, and UNT Little Nescopeck Creek Watershed TMDL," p. 28. http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/LittleNescopeck/LittleNescopeckReport.pdf. Accessed April 14, 2011.
[8] Dempsey, B.; Mendinsky, J. *DEP GG EMARR (10/1/03 to 6/30/04);* August 2004, p. 6.
[9] Hewitt, M. "Jeddo Tunnel Abandoned Mine Drainage Passive vs. Active Treatment Cost Estimates." Ashley, PA: Eastern Pennsylvania Coalition of for Abandoned Mine Reclamation (EPCAMR), October 2006.

energy in the water flow to generate electricity. This project does not have the revenue generation capacity to pay for a complete AMD treatment measure, but the revenue generated could be used to offset mitigation costs

1.2 Proposed Location

The Jeddo Tunnel discharge is located near Drums, Pennsylvania. All of the precipitation in this area is either transpired, evaporated, or exits at the Jeddo Tunnel A discharge. There are still active surface anthracite mining operations in several of the smaller areas, and much of the area has been remediated to different extents. The basin contains many infiltration points created from mining operations and cave-ins, which proportionally increase the fraction of precipitation that directly infiltrates the ground as opposed to being collected in streams, natural ponds, and basins. Remediation measures have been proposed that would reduce this fraction of direct infiltration, and some of these measures are expected to be carried out in the near future. This will have some impact on the amount of water that will be transpired by plants or that will evaporate, but the current estimates from the Pennsylvania Department of Environmental Protection (PADEP) show that this may possibly decrease the average tunnel discharge by several percent.[10] Peter Haentjens of the Eastern Middle Anthracite Region for Recovery (EMARR) later clarified this point and gathered the following information from PADEP:

> Hawbaker has an application to mine coal and aggregate out of the Monmouth Vane Mine east of the Hazleton Shaft that would involve about 150 acres. The reclamation plan would include catch basins and wetlands that would capture water that will percolate into the ground and the tunnel drainage. This would have little impact on tunnel discharge except for evaporation. There are other plans to restore surface flow to Black Creek and Hazel Creek after mining activities cease. There are significant problems associated with restoration of both of these creeks especially with blocking off existing sink holes. It will be our intention to convince DEP that using those sink holes to raise alkalinity makes more sense than plugging them. Even if DEP does proceed with current plans, the impact on Jeddo discharge would be fairly small. To reduce the discharge by 20% to 30% would require plugging all of the 22 sinks….[11]

The land surrounding the tunnel discharge is currently owned by Pagnotti Enterprises, Inc. Pagnotti currently mines anthracite in the Jeddo basin. The land use lease terms or long-term land ownership have not been determined. It is recommended that land ownership and use issues be resolved before committing financial resources to a large project.

[10] Menghini, M. Telephone conversation. PADEP, Harrisburg, PA, 22 October 2010.
[11] Haentjens, P. Email. EMARR, Hazleton, PA, 18 February 2011.

2 Hydroelectric Systems

Hydroelectric turbines convert the potential and kinetic energy from water to electrical energy through a generator. The power potential of a turbine can be computed from Equation 1 where *P* is the power in watts, η is the turbine efficiency (unit less ratio), ρ is the density of water (kg/m^3), *g* is the acceleration of gravity (9.81 m/s^2), *h* is head (m), and $\dot{q}$ is flow rate (m^3/s).

Equation 1: Power Potential from a Hydroelectric Turbine

$$P = \eta \cdot \rho \cdot g \cdot h \cdot \dot{q}$$

Selection of a hydroelectric turbine should take into account applicable head pressures and flow rates. For the Jeddo site, which has a head of approximately 6.4 m and a design flow of 5.1m^3/s, Kaplan and Crossflow turbines are applicable technologies. The Crossflow turbine offers a simple design with lower peak efficiency than a Kaplan turbine but a much broader efficiency curve due to the sequential deployment of high velocity water onto varying areas of the turbine.

Kaplan turbines considered for this application change the pitch or angle of the turbine blades to vary the amount of power extracted. Other Kaplan turbines have movable wicket gates surrounding the turbine, which further increase the efficiency but add more cost and complexity and are typically not used for small hydro projects as the added cost cannot be recouped from increased output. These turbines can have a fairly wide range of flows that produce power, but the efficiency drops at low flows.

While the lifetime of this project was modeled at 50 years, which is a typical design life for a hydroelectric project of this scale, historically hydroelectric projects have usable lives up to twice the design life.

Crossflow and single-regulated Kaplan turbines were considered for this application. Crossflow turbines require a gearbox and other moving parts to regulate the flow of the water through the turbine, whereas the Kaplan designs do not require a gearbox and have only limited moving parts in the turbine. Crossflow turbines also require much finer trash filtering systems as their runners are spaced much closer together and require more frequent cleanings of the intake and turbine runners. Kaplan turbines are also more efficient at their peak but have a slightly higher capital cost. Since project size and economics speak to the facility being unmanned on a daily basis, a higher reliability, lower maintenance turbine, such as the Kaplan, is recommended.

The economic models assume that a cash grant in lieu of the investment tax credit (ITC) will be utilized to put some capital down to secure lower loan rates. The model assumes a 30-year loan at a 6% interest rate with the full amount of the remainder of the cost of the project after the cash grant to be financed. Appendix C details the various costs for both a Kaplan and Crossflow turbine utilizing the proposed dam design.

3 Hydroelectric Resource Definition

Several long-term stream gauges and precipitation gauges were used to extrapolate the long-term tunnel discharge flow. Figure 1 shows the Jeddo basin as well as the United States Geological Services (USGS) precipitation and stream gauges used to determine the average annual tunnel discharge.

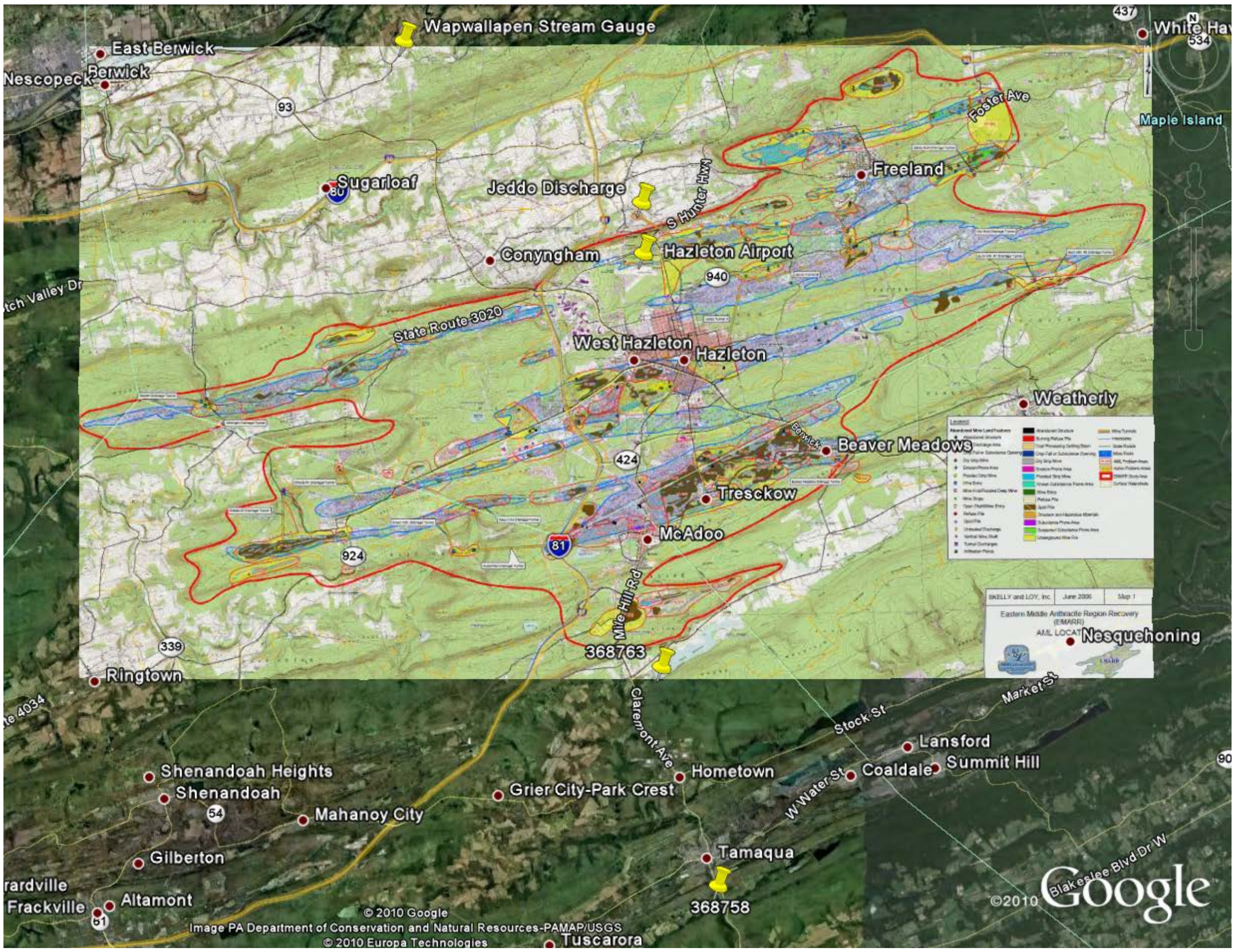

Figure 1. Locations of data collection points[12]

In water year 1999, the Susquehanna River Basin Commission (SRBC) studied the water balance in the Jeddo basin to evaluate possible remediation measures to reduce the tunnel discharge. A water year is defined as the period of October 1 to September 30, with the year being defined by the year that September 30 falls in. Thus, if the period ends September 30, 1998, then this would be referred to as water year 1998. This section of the paper reports dates in water years.

The SRBC study found the base flow is 30–33 ft^3/s for natural groundwater drainage during drought and summer months.[13]

[12] Google Earth. http://www.google.com/earth/index.html. Accessed October 12, 2011.
[13] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* p. 19, August 1999.

> Precipitation averaged about 49 inches per year in the area (based on data from Tamaqua reservoir) for the 66-year period from 1932 to 1998. A comparison of this average with precipitation in 1996, 1997, and 1998 indicates that, in 1996, precipitation in Hazleton exceeded the average by 11 percent. Precipitation was about average in 1997. For 1998, precipitation was 13 percent below average in the Jeddo Tunnel Basin.[14]

Selection of a hydroelectric turbine that still produces electrical energy at this low flow is critical as flows during the summer months can typically reach these levels and there seems to be no cost-effective advantage to using a significantly larger turbine to capture more energy from the high flow periods.

Based on the historical data available to Ballaron, it appears that 1997 was an average precipitation year for the Jeddo basin area. Thus, stream flow data from 1997 was assumed to be approximately average. There is some uncertainty in this assumption due to the frequency distribution of rain events, and further investigation into quantifying this uncertainty is recommended.

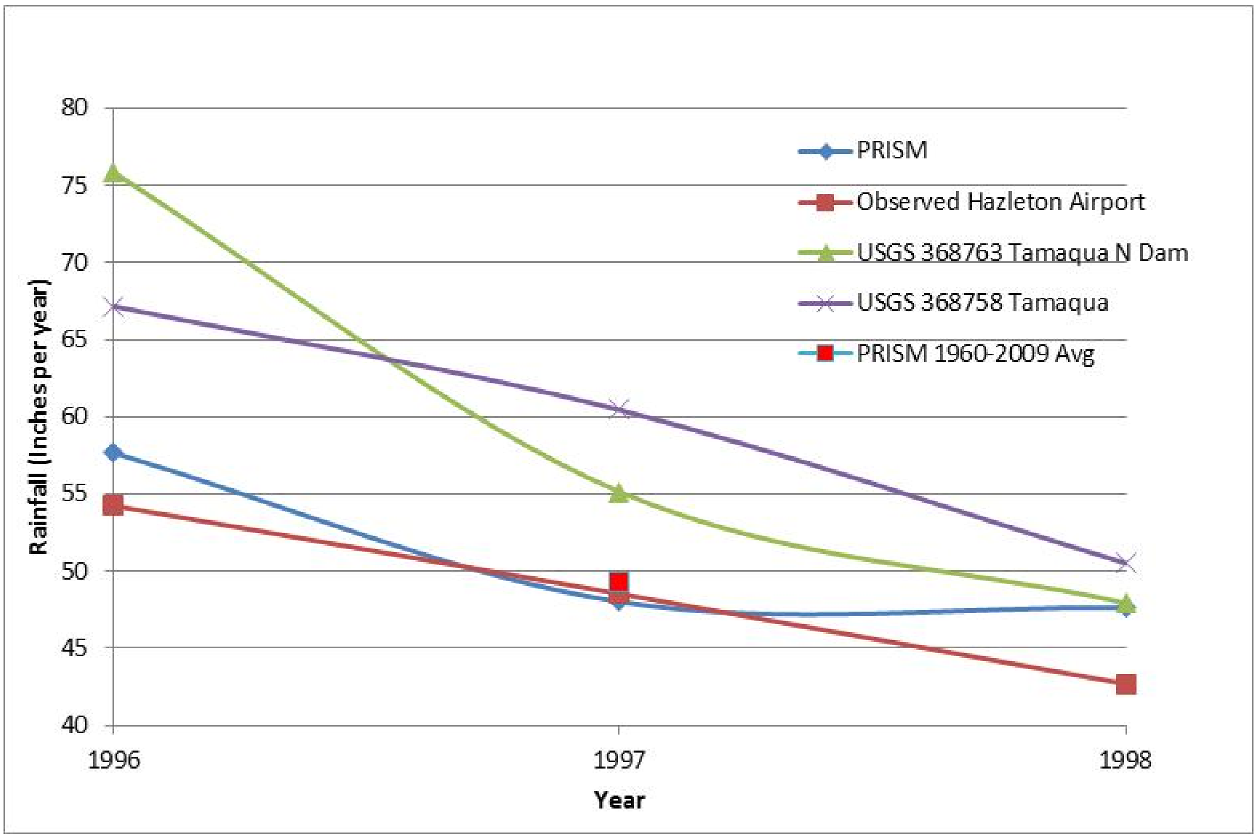

Figure 2. Area precipitation data comparison

[14] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* p. 11, August 1999.

Figure 2 shows the four main precipitation data sources for the Jeddo area. The observed data comes from the 1999 Ballaron report, and all years are water years.[15] Ballaron used USGS site 368758 Tamaqua for long-term precipitation estimation, but this dataset contains records from 1932 to 1998.

These assumptions were then validated using the PRISM dataset, which is the most extensive compilation of precipitation data in the United States.

> PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. Continuously updated, this unique analytical tool incorporates point data, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows, coastal effects, and temperature inversions. PRISM data sets are recognized world-wide as the highest-quality spatial climate datasets currently available. PRISM is the USDA's official climatological data.[16]

The PRISM dataset estimates the annual average rainfall within the Jeddo basin to be 49.28 in/yr between 1960 and 2009.[17] This estimate is consistent with Ballaron's suggestion that 1997 was approximately an average precipitation year.

Figure 3 shows the flow duration curve for the Jeddo Tunnel discharge for the 1997 water year (October 1, 1996–September 30, 1997). This illustrates the base flow with no records in 1997 being lower than 37 m^3/min and a 5% exceeded flow of 45 m^3/min. Appendix B has this data in a tabular format for future use.

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[15] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* August 1999.
[16] Prism Climate Group. http://www.prism.oregonstate.edu/. Accessed April 14, 2011.
[17] Prism Climate Group. "Prism Data Explorer." http://prismmap.nacse.org/nn/index.phtml?vartype=ppt&month=14&year0=1971_2000&year1=1971_2000. Accessed April 14, 2011.

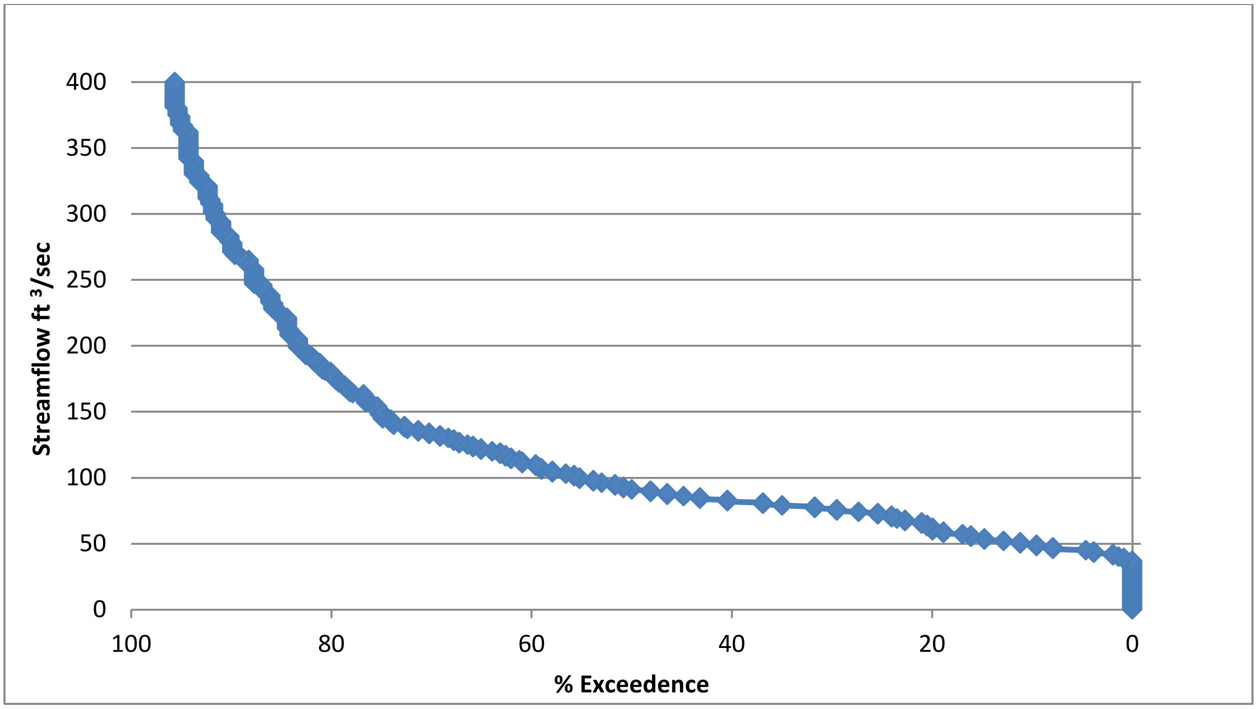

Figure 3. Flow duration curve for water year 1997

Ballaron and others at PADEP recommended using USGS 01538000 Wapwallopen Creek stream gauge to attempt to correlate the historical stream flow data with tunnel outflow. Reportedly this is one of the most consistent and longest stream flow datasets available within the immediate Jeddo area.[18] Figure 4 shows that the annual average flow for the 1997 hydrological year was 4.3% above the annual average from 1970 through 2009. This is fairly consistent with Ballaron's findings that 1997 was an average precipitation year for the Jeddo basin, but this data is not within the Jeddo basin so there is some uncertainty in the degree of correlation.

[18] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* August 1999.

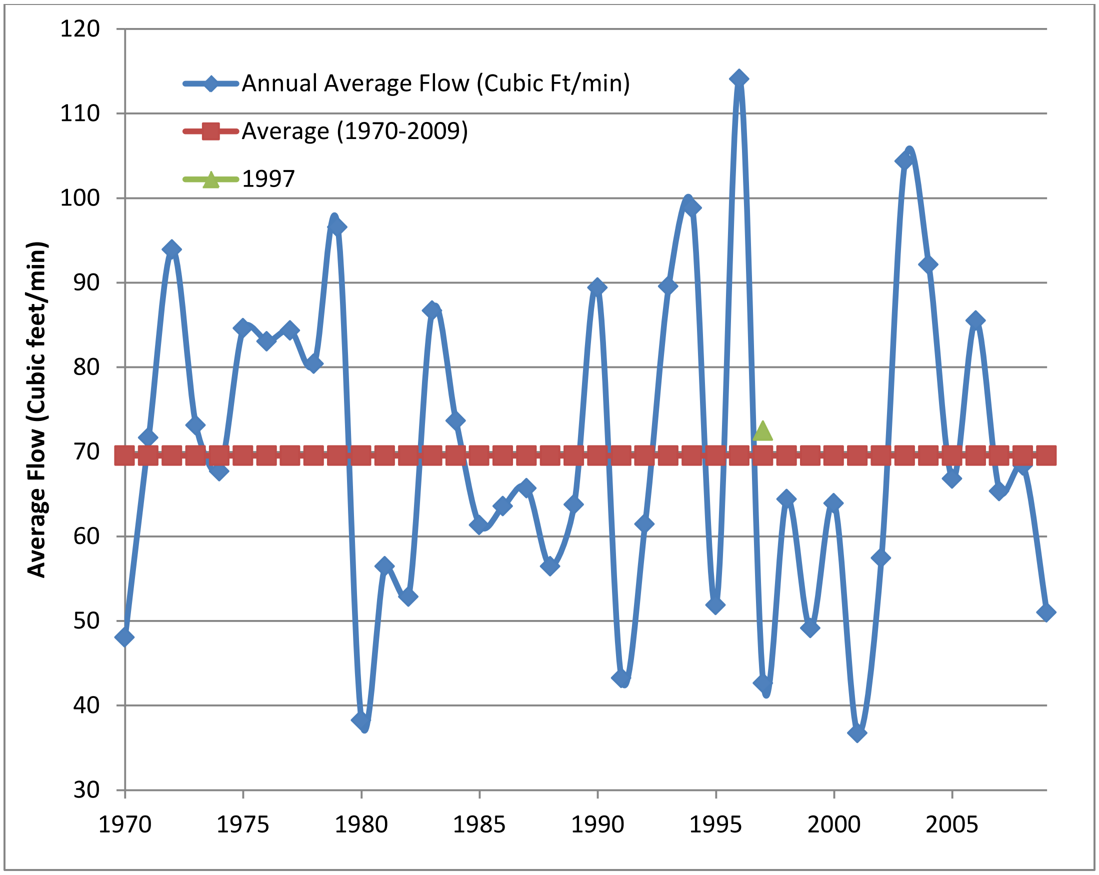

Figure 4. Wapwallopen historical stream flow annual averages

Linear scaling of the resource with correlated precipitation data is not possible because some groundwater base flow exists, surface runoff fraction changes, and evapotranspiration changes. Surface runoff data taken for the 1999 Jeddo water balance showed 5%–11% of total annual precipitation was recorded as direct runoff.[19] Thus, the fraction of precipitation that passes through the basin is not constant and the 3-year study of the water balance in the Jeddo basin averages 66.3% of the long-term annual average.

Surface remediation in the Jeddo basin is planned. The PADEP currently plans to reshape most of the basin and install shallow catchment basins, but this work will not change the basin drainage area. The shallow catchment basins will have two effects: they will increase evaporation, and they will act as a storage medium that will help regulate tunnel discharge. This storage of water on the surface should be minimal, which minimizes evapotranspiration; however, there are plans to vegetate these basins, which will increase evapotranspiration. Thus, if the effective storage of the basin increases, the overall output from the hydroelectric facility could be significantly increased as the current modeling approach for the Jeddo drainage system ignores the storage that is present in mine pools. Further plans have been discussed to place a low-permeability material just below the surface, which would reduce infiltration and tunnel

[19] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* August 1999.

output by 10%–25%.[20] This decrease in tunnel output flow would be highly dependent on which drainage area the material is placed in and how extensive the material placement is.

3.1 Hydro Resource Verification Through Correlation

The stream flow data from the Wapwallopen Creek and Jeddo discharge were compared via scatterplot, as shown in Figure 5, to determine the extent of their correlation given that they are in different watershed basins. An analysis technique known as measure–correlate–predict (MCP) was undertaken with three different statistical approaches. Both linear and exponential regression analysis techniques were applied to the scatterplot with the resultant equations and correlation factors (R^2) shown in Table 1.

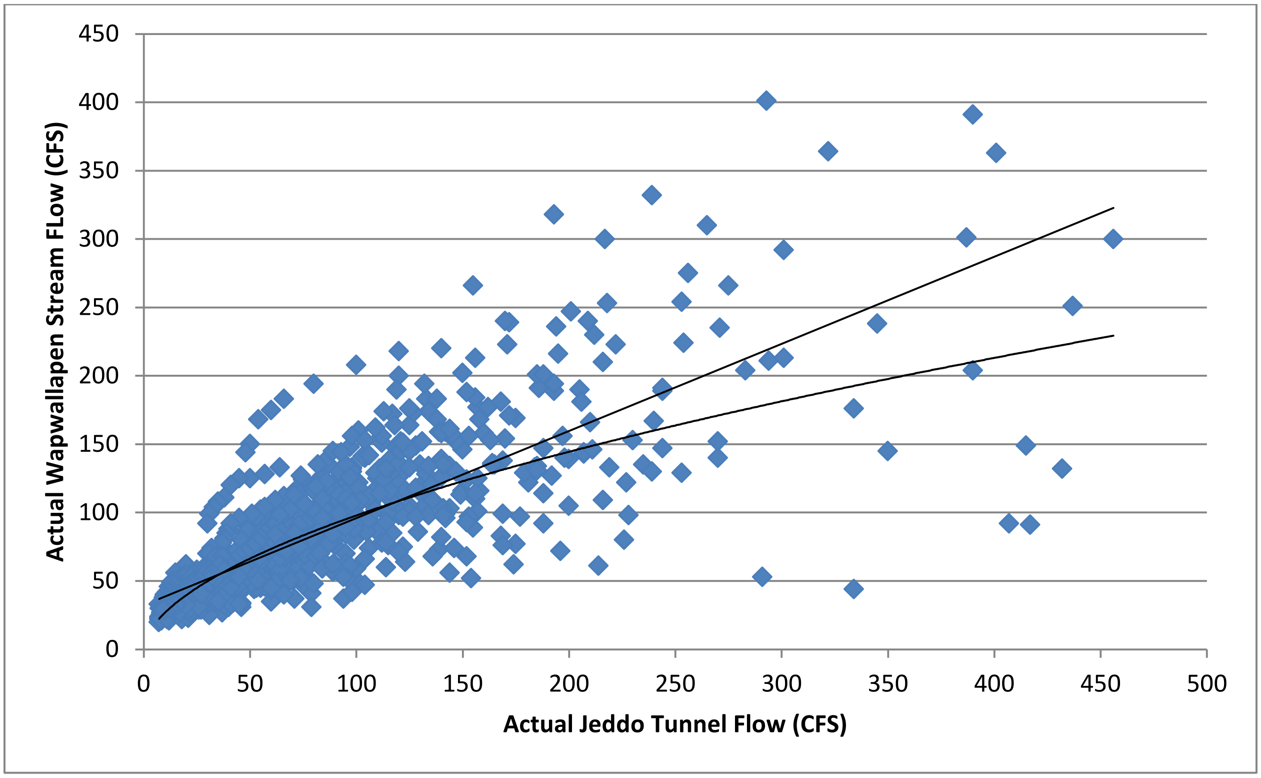

Figure 5. Scatterplot and trend line analysis of Jeddo Tunnel versus Wapwallopen stream flow

A third MCP technique, known as variance ratio analysis was also investigated. The results of all three methods are shown in Table 1.

[20] Ballaron. "Water Balance for the Jeddo Tunnel Basin." *Publication No. 208,* August 1999.

Table 1. MCP Methods and Results

Method	Prediction Equation	Correlation Equation	R^2
Linear	(0.637 * Wap flow) + 32.35	y = 0.637x + 32.35	$R^2 = 0.6505$
Exponential	$(2.9757 * \text{Wap flow})^{0.7371}$	$y = 7.3975x^{0.5609}$	$R^2 = 0.7649$
Variance Ratio	[(Jeddo avg - (Jeddo stdev/Wap stdev)] * (Wap avg) + [(Jeddo stdev/Wap stdev) * Wap flow)]	y = 0.8065x + 15.098	$R^2 = 0.6505$

Table 1 shows the prediction equations and R^2 values for these three MCP methods. The R^2 correlation factor provides an indication of the relative "goodness of fit" of the regression line to the data. The exponential regression equation results in the highest R^2 value and is used as the basis for Jeddo Tunnel flow predictions in subsequent economic modeling. This data was filtered for all values greater than 500 ft^3/sec because the turbine outputs are constant above this flow rate.

All datasets within the site-specific study period of 1996–1998 show the same trend with differing magnitudes of change. These methods do not accurately predict the tunnel outflow that occurs during and after significant precipitation events, and their use for daily stream flow estimates is not recommended. However, the models perform reasonably well for longer time frames, such as annual stream flow quantities, and this is the basis of the economic modeling. If a hydroelectric project is deemed feasible, it is advised that further study into the number of rain events per year and the magnitude of these events be undertaken to ensure optimization of the equipment to be used in the hydroelectric system. A true hydrologic study comparing these two drainage basins may improve the prediction reliability for the Jeddo Tunnel, though the current analysis may be sufficient for the type of hydroelectric project proposed.

4 Hydroelectric Design Parameters

The Jeddo basin was and continues to be mined for coal. The original coal mines were deep vertical shafts that followed seams of coal rich ore. The vertical orientation of these shafts required that precipitation and ground water to be removed or drained from the mine shafts in order for mining work to take place. Many mines of this configuration used electric or mechanical pumps to raise water at the bottom of the mine to the surface in order to facilitate mining work at the deepest part of the mines. In the case of the Jeddo basin, the mining companies determined that the cost of digging near horizontal shafts from the sides of the plateau that would intersect the vertical mine shafts would reduce or eliminate the cost of pumping water to the surface. Now that the horizontal drainage shafts are in place and the vertical shafts allow groundwater and precipitation to be concentrated in the vertical shafts; nearly the entire 32-mi^2 Jeddo basin is drained by the Jeddo Tunnel. The potential energy stored in the water of this drainage could be utilized for hydroelectric energy production. The following sections of this report will examine the potential for hydroelectricity in the Jeddo Tunnel area.

The horizontal tunnel on the northern side of the plateau drains the majority of the Jeddo Basin. This tunnel could potentially be harnessed for hydroelectric power production. To achieve usable kinetic energy from this unique arrangement, a small dam would need to be constructed to increase the vertical distance between the upstream and downstream bodies of water, which is referred to as 'head.' Figure 6 shows the location of the proposed dam, topography near the Jeddo basin discharge, and relative sizes of the dam and streambed. Further detail is in Appendix A.

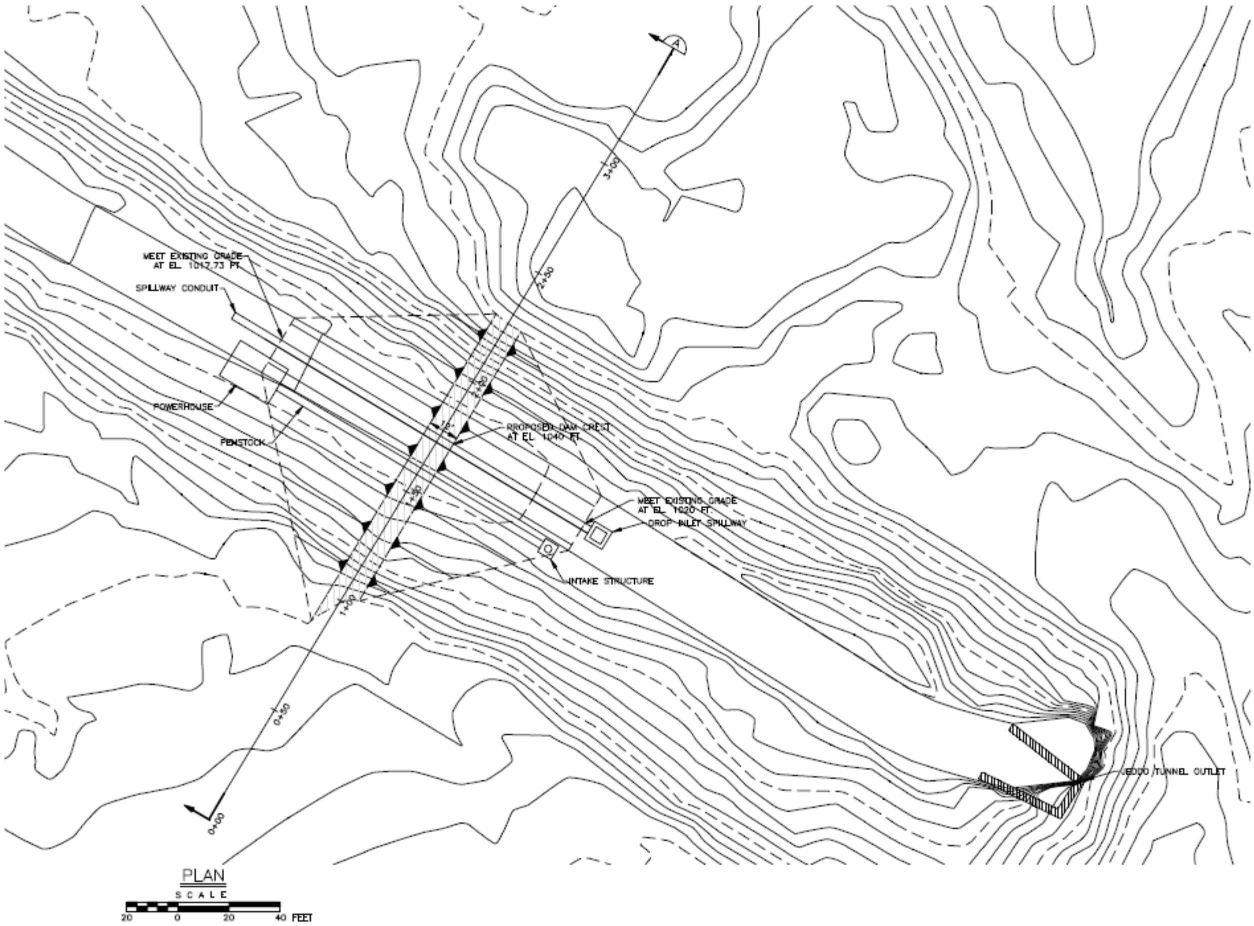

Figure 6. Proposed dam plan view

There were several proposed solutions to generate electricity at the Jeddo discharge. The proposed dam design is an earthen dam, and the largest contingencies are based on the geology and geography of the dam. Appendix A details the approximate costs and technical feasibility of construction at the Jeddo discharge. These cost estimates were used to model the life cycle cost of the project.

The intake structure for the dam was recommended to be changed to one more easily cleaned by workers; the structure is approximately 1 m below the surface of the water and closer to the peak of the dam.[21]

The dam design suggests that the top of the dam will be at an elevation of 1,040 ft, and the lower existing grade is at an elevation of 1,017.7 ft. This gives a total potential of 22 ft of head. For turbine power output calculations, an assumed head of 21 ft was used due to water control level requirements. This is still a somewhat conservative number as an additional foot of head would result in approximately 4.6% more average energy output. To achieve this increase in annual energy production, much higher precision control (at an additional cost) is necessary. The topographic features suggest that moving the dam closer to the tunnel or simply increasing the

[21] Dupuis, M. Email. Canadian Hydro Components, Almonte, ON, Canada, October 2010.

height of the dam would allow an additional 2 ft of head with minimal cost increases. It is possible to increase the net head up to an additional 10 ft with additional earth movement and additional cost. This may need to be investigated further because the capital costs of the turbine, site access, and electrical components will not change. This 2–10 ft increase in head would produce a 9%–45% increase in annual energy production; however, due to the geography of the site, the increase in cost will not be linear.

Other options include eliminating the dam and capping the tunnel to increase head pressure. However, this approach has a number of unknowns, such as the stability of the geotechnical conditions upstream of the tunnel, which make it a much riskier approach. For instance, capping the tunnel may result in leaching accumulated contaminated water into the ground and spreading the flow of contaminants that had only been in the tunnel. Significant amounts of "standing water" in the tunnel for long periods of time may actually strengthen tunnel walls, but considerable pressure on the walls may cause structural or water seepage issues. At this stage, capping the tunnel is not recommended.

5 Economics and Performance of a Hydroelectric System

5.1 Electricity Generation

The losses for all hydroelectric systems were modeled as they appear in Table 2. Each turbine efficiency was accounted for in the power curve calculation; losses for annual scheduled maintenance as well as turbine degradation, hydraulic losses, and electrical distribution were modeled as per Table 2.

Table 2. Hydroelectric Losses

Turbine Hydraulic Losses (Included in power curves)	NA
Regular Maintenance (1.5 weeks a year)	3%
Electrical and Distribution	3%
Turbine Degradation and Other Hydraulic Losses	4%

Table 3 shows the energy production and associated economic results. Further details can be seen in Appendix D.

Table 3. Hydroelectric Turbine Performance Comparison[22]

System Size (kW)	Turbine Type	Turbine Design Flow (m^3/sec)	Annual Output (kWh/yr)	System Cost	Energy Production Cost ($/kWh)	Simple Payback Period (years)	Potential Jobs (construction)	Cash Grant Utilization
247	Kaplan	4.7	1,162,453	$2,014,233	$0.0796	21.5	22.4	No
247	Kaplan	4.7	1,162,453	$2,014,233	$0.0796	17.4	22.4	Yes
405	Crossflow	5.8	1,029,433	$2,063,516	$0.0913	21.3	22.9	Yes

5.2 Applicable Policy

As of this writing, Pennsylvania policy[23] allows virtual meter aggregation, which enables a single account holder to essentially sum the meters within 2 miles of a generation source. This is a product of agricultural applications where farmers may have had multiple plots of land but wished to use a single source of generation for electricity or other form of energy for irrigation or other purposes. Depending on how one reads the policy for net metering, it is unclear if the account holder must lease or own the land that the generation source is installed upon, but the electrical account holder name must be the same. There have been examples of third parties installing PV systems at little or no cost to owners who have qualified for net metering because the contract with the PV equipment supplier requires the land owner to "operate" or "maintain"

[22] Estimates assume an inflation rate of 1.2%, discount rate of 3%, utilization of the 30% cash grant in lieu of the tax credit, 80% debt ratio, 50-year project life, 6% interest rate and 30-year note term, 1.2% energy escalation rate, and an O&M cost of $35,000/year. Long-term job-years are total jobs for the 50-year design life of the project at the aforementioned O&M cost, which averages 0.39 jobs per year.

[23] DSIRE. "Pennsylvania." http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA03R&re=1&ee=1. Accessed April 14, 2011.

the PV system by cleaning the PV panels with some frequency. Thus, this suggests that the equipment owner does not need to be the land owner, but the account holder must be the entity that has a load and generates the electricity as well as operates or maintains the system, which could be as simple as writing an operations and maintenance (O&M) contract with a third party. There would be excess generation with the current scenario because the school load average is approximately 90 kW and the average hydro generation is 150 kW.

More conventional options for developing a project include having a third party lease the land, own and maintain the equipment, and sell the power and renewable energy certificates (RECs). This would allow that third party to take advantage of the production tax credit (PTC) or ITC. The PTC is currently $0.011/kWh for the first 10 years of a qualified hydroelectric project, which would amount to $152,264 total over the first 10 years of the project, whereas the cash grant in lieu of the tax credits[24] would provide an upfront cash grant of 30% of the installed cost of the project, amounting to slightly more than $600,000.

While this project would not qualify as a hydroelectric facility for this cash grant (only incremental hydropower production projects to existing hydroelectric facilities are allowed), the the Jeddo Tunnel would possibly qualify as a hydrokinetic facility due to the fact that it was manmade.[25] However, there is specific language within this document explicitly prohibiting a dam or any impoundment for electrical production purposes. There is language that allows electrical production from diversionary structures with the specific exception of manmade structures. It seems that the intent of the bill is to discourage the further damming of streams and rivers but to encourage energy capture from irrigation and other manmade sources of water flow. Project advocates should seek legal guidance and EPA feedback as to whether the Jeddo Tunnel project appropriately aligns with the intent and letter of the law.

The local REC prices on average are at $0.00365/kWh for Tier 1 RECs,[26] but this value may increase in the near future due to the aforementioned increase in Pennsylvania state REC requirements. The price of energy that this third party would be able to sell at would be significantly less than the assumed $0.10/kWh used in the modeling.

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[24] U.S. Treasury Department. "Payments for Specified Energy Property in Lieu of Tax Credits Under the American Recovery and Reinvestment Act of 2009." http://www.treasury.gov/initiatives/recovery/Documents/guidance.pdf. Accessed April 14, 2011.

[25] U.S. Treasury Department. "Payments for Specified Energy Property in Lieu of Tax Credits Under the American Recovery and Reinvestment Act of 2009," pp. 13–14. http://www.treasury.gov/initiatives/recovery/Documents/guidance.pdf. Accessed April 14, 2011.

[26] Tier 1 includes low impact hydroelectric generation, wind, and biomass. The prices for Tier 1 RECs from 2008–2009 ranged from $0.50/MWh to $23.00/MWh. The demand for Tier 1 RECs is unknown with more energy suppliers joining the Pennsylvania-New Jersey-Maryland (PJM) interconnection [any supplier in the PJM interconnection can sell RECs towards the Pennsylvania State renewable portfolio standard (RPS)]. The Pennsylvania State RPS requirements for Tier 1 generation increase at a rate of 0.5% per year for the next 10 years, which represents a tripling of demand for Tier1 RECs in 10 years. Historical averages for REC costs have been higher than the most recent data, but due to the short history of the Pennsylvania RPS and the fact that generators have 3 years to retain or sell their RECs, it is very hard to judge the future prices of RECS based on historical data. The compliance charge is currently $45/MWh, but this does not seem to be a large driver currently for REC prices. The hydro installation must also qualify as "low impact" (http://www.lowimpacthydro.org/) due to the current environmental damage.
Pennsylvania Public Utility Commission. "2008 and 2009 Annual Reports." http://www.puc.state.pa.us/electric/pdf/AEPS/AEPS_Ann_Rpt_2008-09.pdf. Accessed April 14, 2011.

5.3 Model Assumptions

The project was modeled assuming that the electricity produced by the Jeddo Tunnel project could be delivered at competitive rates to local high-use consumers, such as schools and the wastewater treatment plant. This would need to be a negotiated arrangement between these customers and local utilities, and the utility may want to charge a fee for "wheeling" the electricity from the point of interconnection to the respective loads. The project owner would need to register as a qualifying facility, per the Public Utility Regulatory Policies Act of 1978 (PURPA),[27] to be an electricity generator with the Pennsylvania Public Utility Commission. The average output from the turbine is modeled at 158 kW, which exceeds the school's annual average usage by approximately 89 kW. The wastewater treatment plant's load has been quoted at 100 kW or greater, but no documentation has been available to support this.

The project will require the upgrade or new installation of distribution-level voltage lines (possibly between 10 kV and 14 kV depending on the local utility voltage) for approximately 1,850 ft where it could interconnect with existing three-phase distribution lines. The power would then need to be wheeled 2,200 ft to the wastewater treatment plant or 2,500 feet to the elementary school. Figure 7 shows the relative locations of the possible off-takers to the Jeddo discharge.

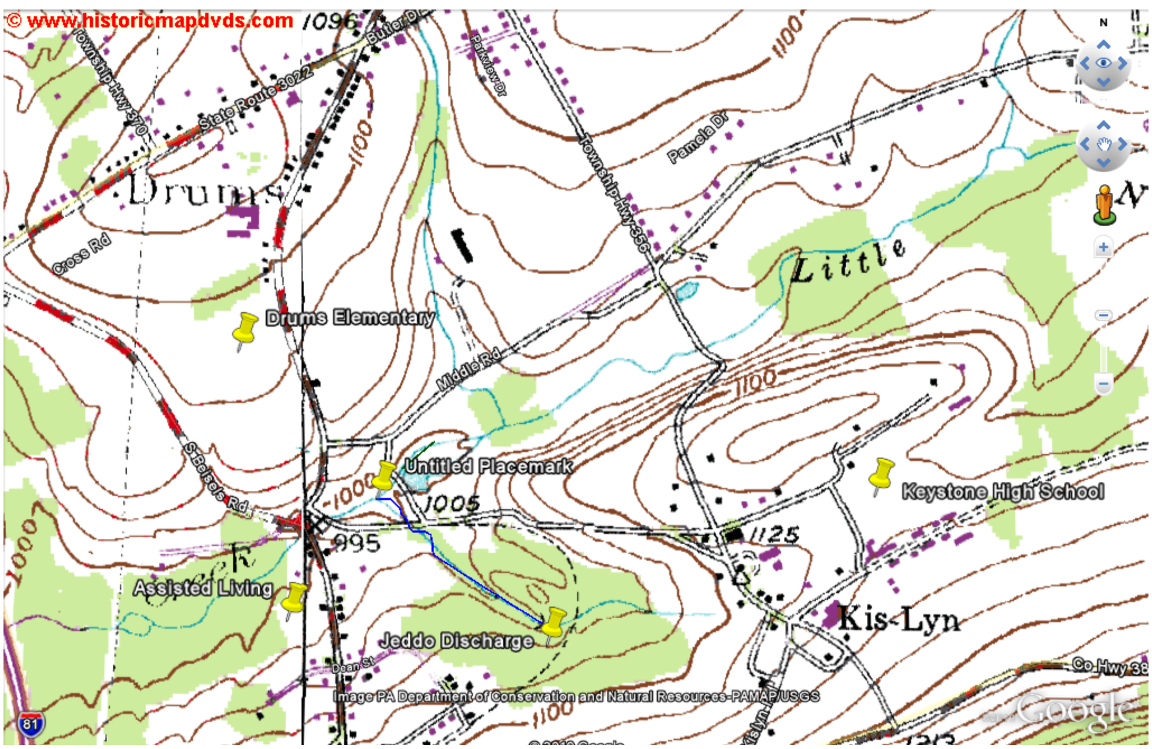

Figure 7. Possible off-taker locations[28]

[27] Warwick, W.M. "A Primer on Electric Utilities, Deregulation, and Restructuring of U.S. Electricity Markets." U.S. Department of Energy, May 2002. http://www1.eere.energy.gov/femp/pdfs/primer.pdf. Accessed April 14, 2011.

[28] Google Earth. http://www.google.com/earth/index.html. Accessed October 15, 2011.

Electrical energy costs are projected to increase at a rate of 1.19% annually, averaged from 2010 to 2039 by EIA,[29] and this assumption was used in the economic modeling of the project. The discount rate and inflation were taken to be 3.0% and 0.9%, respectively, which are specified by the National Institute for Standards and Technology (NIST).[30]

The estimated cost from Rizzo and Associates[31] was used to model the construction and engineering cost of the dam and installation of the turbine and powerhouse. The turbine cost and choice is still a major variable since the resource is not well defined in the Rizzo study.

O&M costs were estimated at $35,000 annually, which includes a service contract for annual maintenance from the turbine supplier and remote monitoring of the system. This cost estimate also includes a portion of revenue, approximately $10,000 annually, to be set aside in an escrow account to cover possible major repairs needed in the future. An annual land fee of $10,000 was included in the $35,000 total. Spare parts were also included at an upfront cost of $50,000 to have an inventory of maintenance-related parts to be retained to minimize downtime in the instance of a mechanical failure. Though it is expected that the Kaplan turbine will have lower O&M costs due to turbine design advantages for this site, both turbines were modeled with the same O&M costs.

5.4 Applicable State and Local Grants and Incentives

Many state and local grants and incentives could provide some capital or rebates that increase the financial viability of this project. The Database of State Incentives for Renewables and Efficiency (DSIRE) for the State of Pennsylvania[32] provides a listing of grants, incentives, and rebate programs available through local utilities and the state. The State of Pennsylvania has a revolving loan program that has the potential to fully fund this project[33] and might offer a lower interest rate than was modeled. The State of Pennsylvania also offers a small grant program that could pay for some of the site investigation[34] if a local school was willing to apply to achieve a LEED Silver rating for its building. The Sustainable Energy Fund Loan Program[35] applies to the PPL territory and may be utilized if a real educational aspect of the project could be realized.

[29] EIA. http://www.eia.doe.gov/. Accessed April 14, 2011.
[30] U.S. Department of Energy. "NIST Updates Discounts Rates for Federal Life-Cycle Cost Analyses." Federal Energy Management Program. http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=15859. Accessed April 14, 2011.
[31] See Appendix A.
[32] DSIRE. "Pennsylvania Green Energy Loan Fund." Pennsylvania. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA73F&re=1&ee=1. Accessed April 14, 2011.
[33] DSIRE. "Pennsylvania Green Energy Loan Fund." Pennsylvania. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA73F&re=1&ee=1. Accessed April 14, 2011.
[34] DSIRE. "High Performance Green Schools Planning Grants." Pennsylvania. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA25F&re=1&ee=1. Accessed April 14, 2011.
[35] DSIRE. "Sustainable Energy Fund (SEF) Loan Program (PPL Territory)." Pennsylvania. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA08F&re=1&ee=1. Accessed April 14, 2011.

6 Ground and Water Source Heat Pump System Design Considerations

Per EPA's request, NREL investigated the potential for water and ground source energy production at this site. Appendix H of the *Renewable Energy Optimization Report for Naval Station Newport*[36] serves as an introduction to how water source heat pumps operate and the factors that affect their performance and economic viability. Most ground or water source heat pump systems become economically viable at larger scales and where more expensive fuel sources for heating are used (such as electricity through air source heat pumps or direct radiation, as opposed to natural gas direct heating). Because the Jeddo discharge has a component of its flow that is not affected by drought, this resource could be suitable for use as a heat sink and heat source for building space heating and cooling. The largest unknown for these possible systems is that the stream temperatures through the seasons are unknown. Discussions with SRBC indicated that the aggregate water temperature would reflect the makeup of the flow. The base component of flow that is made up of groundwater, which constitutes approximately 0.9 m^3/s, should have a temperature approaching deep ground temperature. However, the shallow depth of the stream will be conducive to solar gain as the water exits the tunnel and makes its way to the point where the heat exchangers would be placed.

The federal government offers incentives for high efficiency furnaces, heat pumps, and other HVAC components.[37] The State of Pennsylvania also offers loans for geothermal heat pump installations at \$3/ft^2 up to \$5 million. The fund was allocated with \$25 million in January 2009, and it is unclear as to how much funding remains.[38] The PPL utility area also may have some applicable loan services that would reduce the cost of a geothermal heat pump installation.[39]

The most feasible geothermal heat pump system for buildings near the Jeddo discharge would be a closed loop system that uses flat plate heat exchangers. The flow rate of the stream is such that heat added from any of the possible buildings will be insignificant relative to the large quantities of cool water continuously flowing by. The heat discharged from the heat exchangers is mixed rapidly with the moving river water so heat build-up in the water stream is relatively minor. Assuming a minimum flow of 0.9 m^3/s, a 130-ton air-conditioning unit will only raise the temperature of the stream several tenths of one degree Celsius while operating continuously at full cooling output. This temperature increase should be further studied to ensure it will not affect stream life at the confluence of the Little Nescopeck and the Jeddo discharge or downstream of this point.

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[36] Robichaud, R.; Mosey, G.; Olis, D. (February 2012). *Renewable Energy Optimization Report for Naval Station Newport.* NREL/TP-6A20-48852. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy12osti/48852.pdf. Accessed October 17, 2012.
[37] ENERGY STAR. "2011 Federal Tax Credits for Consumer Energy Efficiency." http://www.energystar.gov/index.cfm?c=tax_credits.tx_index. Accessed April 14, 2011.
[38] DSIRE. "DCED – Wind and Geothermal Incentives Program." http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA40F&re=1&ee=1. Accessed April 14, 2011.
[39] DSIRE. "Sustainable Energy Fun (SEF) Loan Program (PPL Territory)." http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA08F&re=1&ee=1. Accessed April 14, 2011.

7 Geothermal Heat Pump System Economics

There are several potential off-takers of this energy, namely an assisted living home, the local elementary school, and Keystone Job Corporation High School.

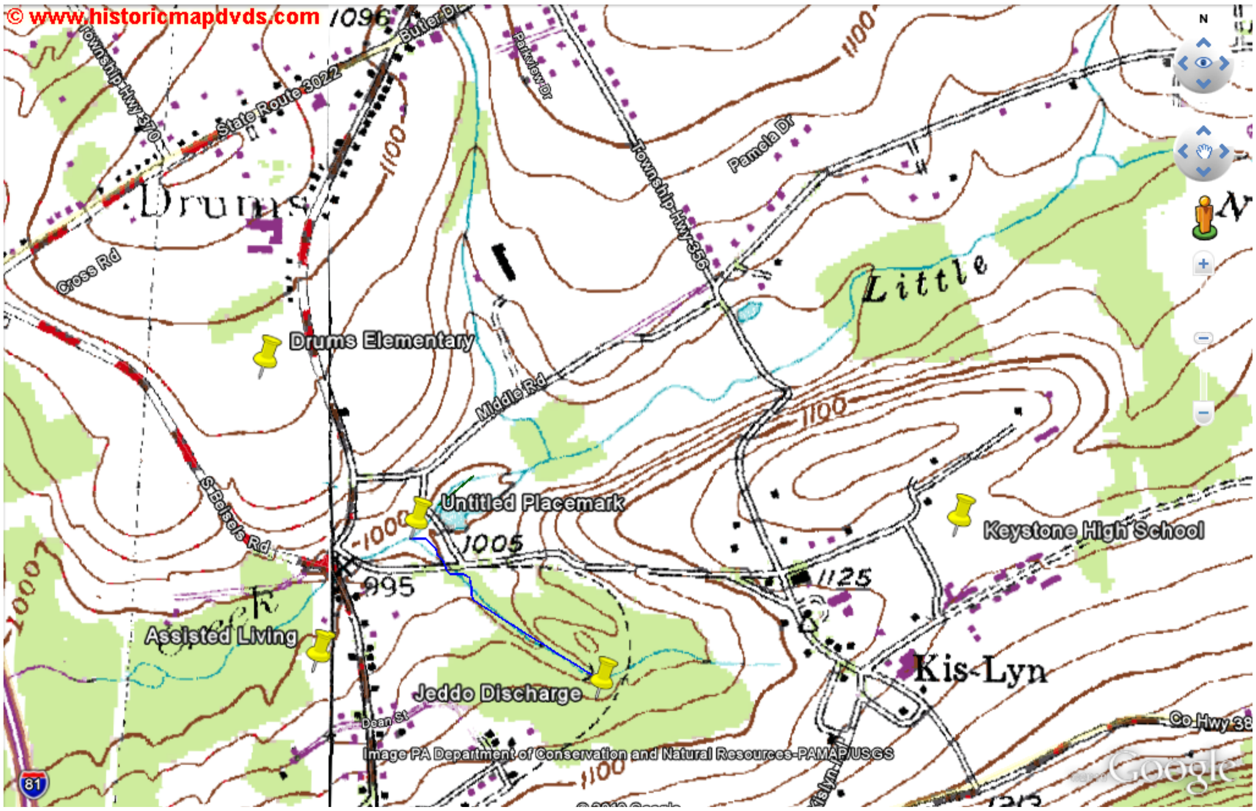

Figure 8. Potential ground source energy off-takers[40]

Figure 8 shows the physical relationship of the Jeddo discharge and each off-taker. Table 4 shows the linear distances and elevation differences from each site to the shortest point to the stream flow. Some systems will be more cost effective than those modeled here if they are allowed to place their heat exchanges in the Little Nescopeck Creek, but these environmental impacts and concerns will need to be specifically reviewed.

[40] Google Earth. http://www.google.com/earth/index.html. Accessed October 12, 2011.

Table 4. Potential Ground Source Off-Takers[41]

	Linear Distance (ft)	Elevation Difference (ft)
Keystone High School	2,400	115
Drums Elementary School	1,500	87
Assisted Living Facility	1,100	15

Some market research showed that installed costs average approximately $11,000/ton for larger systems in the 100–150 ton range.[42] These costs were for a full turnkey system with approximately 70 individual (room-specific) heat exchangers, which would be appropriate for a retrofit application such as the three potential off-takers mentioned above. Obviously the final pricing will depend on many other variables, but this cost should be indicative of a current cost for comparable systems in similar climates. Further study of the number of degree heating and cooling days for this area along with the heat loads for each building should be conducted to determine the feasibility of such a ground source heat pump arrangement.

A RETScreen economic model was created assuming a 15,000 ft^2 building with a heating and cooling load of 40 W/m^2, which represents an average of the three potential aforementioned buildings. Other assumptions included Energy Information Administration average Pennsylvania pricing for natural gas heat and electricity, assuming a 90% efficient natural gas furnace and a seasonal coefficient of performance of 3.5 for the baseline system. The new system assumed a 17-ton heating and cooling system and closed loop water source heat pumps with water temperatures assumed to follow ground temperatures from the included historical data as well as all assumptions are available in Appendix E. The cost of the system was modeled at $13,900/ton capacity to reflect the economies of scale of the modeled 17-ton system compared with the 100–150-ton system example.

This system provides a 23.9-year simple payback. As with the hydroelectric project, other grant and loan programs are available that may be used to enhance the financing and overall viability of this project. The DSIRE website[43] has the most comprehensive listing of these programs and grants.

[41] These distances are calculated from the closest point of access to the Jeddo discharge stream; some systems may be able to achieve a shorter interconnection with the Little Nescopeck Creek.
[42] Verbal quoted costs from recommended installers from AWEB Supply http://www.awebgeo.com/, November 2010.
[43] DSIRE. "Financial Incentives." Pennsylvania. http://dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=PA. Accessed April 14, 2011.

8 Summary and Conclusions

This report has assessed the technical and economic viability of the site for hydroelectric and geothermal energy production. In addition, the report outlines financing options that could assist in the implementation of such a system.

Economically, the hydroelectric project appears feasible under the stated assumptions. Table 5 outlines the basic economic performance of the system.

Table 5. Hydro System Performance Including Job Estimates

System Size (kW)	Turbine Type	Turbine Design Flow (m^3/sec)	Annual Output (kWh/yr)	System Cost	Energy Production Cost ($/kWh)	Simple Payback Period (years)	Construction Jobs	Cash Grant
247	Kaplan	4.7	1,162,453	$2,014,233	0.0796	21.5	22.4	No
247	Kaplan	4.7	1,162,453	$2,014,233	0.0796	17.4	22.4	Yes
405	Cross-flow	5.8	1,029,433	$2,063,516	0.0913	21.3	22.9	Yes

Next steps should include the clarification of whether or not this facility can meet the definition of "hydrokinetic facility"[44] as well as the exploration of virtual net-metering policy in the area. Efforts should be made to pursue other grants and low-interest loans that could increase the financial viability of the project. Also, further investigation of the optimal height of the dam and verification of the annual flow characteristics, which are contingent upon planned remediation within the drainage basin, should be undertaken.

The assumption of wheeling the power at current electricity costs is contingent upon the utility agreeing to this proposition. If this proves impossible, selling the electricity to an off-taker would result in a substantially lower sale price of energy. Wheeling charges imposed by the utility would also drive the effective sale price of electricity down. The possibility of virtually net metering this facility is quite realistic, as it may be as simple as placing an off-taker's name on the electricity bill for the production facility.

The possibility of increasing the height of the dam an additional 2–10 ft for additional head pressure could improve the life cycle cost of the project and should be investigated further. The hydroelectric turbine was modeled as a single-regulated Kaplan-type machine because of the low head of the site and because there are many commercially available units for this design flow. Crossflow turbines are also a good option as they are cost competitive and may offer benefits in reduced civil scopes and reduced maintenance. Selection of a hydroelectric turbine that still produces electrical energy at low flows (approximately 0.85–1.00 m^3/s) is critical as flows during the summer months and drought can typically reach these levels and there seems to be no cost advantage to using a significantly larger turbine to capture more energy from the high-flow periods.

[44] U.S. Treasury Department. "Payments for Specified Energy Property in Lieu of Tax Credits Under the American Recovery and Reinvestment Act of 2009," pp.13–14. http://www.treasury.gov/initiatives/recovery/Documents/guidance.pdf. Accessed April 14, 2011.

Geothermal heat pumps may be able to provide paybacks of 25 years or even less when combined with state and federal loans and incentives. Further study into the environmental impacts as well as seasonal water temperatures and land use issues are needed.

Overall the hydroelectric project looks viable economically and technically. The project would offset approximately 63,497 metric tons of carbon dioxide, 316 metric tons of sulfur dioxide, and 138 metric tons of nitrous oxide emissions and generate 69 TWh of electricity in its design life. Additionally, it would create approximately 28 jobs in construction and 19 job-years, or 0.39 jobs/year for O&M, over the life of the project.

Appendix A. Conceptual Dam Design

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August 27, 2010
Project No. 10-4414

Mr. Joseph Owen Roberts
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

TRANSMITTAL
DRAFT CONCEPTUAL DESIGN
JEDDO TUNNEL DAM & HYDROELECTRIC FACILITY

Dear Mr. Roberts:

This letter presents Paul C. Rizzo Associates' (RIZZO) conceptual design for the construction of an embankment Dam and hydroelectric facility at the outflow of the Jeddo Mine Drainage Tunnel. It has been prepared for the National Renewable Energy Laboratory (NREL) in accordance with our June 25, 2010 Proposal.

INTRODUCTION

The Jeddo Tunnel is a man-made water level drainage tunnel constructed approximately 100 years ago to dewater deep mined coal measures in the Eastern Middle Anthracite Field. The tunnel drainage system drains water from four major coal basins: Big Black Creek, Little Black Creek, Cross Creek, and Hazelton. The tunnel has continued to drain the abandoned mine workings after the collapse of the deep industry in the 1950s. The tunnel currently drains over 30 square mi miles (mi^2) with an average discharge of 80 cubic feet per second (cfs) into the Little Nescopeck Creek.

The Little Nescopeck Creek, a tributary to Nescopeck Creek, is severely impacted by the poor quality of the water discharged from the tunnel. The water discharged through the tunnel is characterized as Acid Mine Drainage (AMD).

PROJECT DESCRIPTION

The conceptual design for the construction of a low head hydroelectric facility at the Site will consist of an earth embankment dam approximately 22 feet (ft) high and a small powerhouse that will house the hydroelectric equipment. The geography and geology around the Tunnel Outlet play a significant role in the siting of the proposed Dam. They determine the optimum location for the Dam, what materials are available for construction, and the foundation conditions for the Dam.

SITE LOCATION AND DESCRIPTION

The Site for the proposed Jeddo Tunnel Dam system is located approximately 1.0 mi south of Drums and 3.4 mi northeast of Conyngham, Luzerne County. From Conyngham, take County Highway 38 3.0 mi east, turn left onto South Old Turnpike Road, and make a right onto Dean Street. At the end of Dean Street, stop and walk southeast to the old service road that runs behind several private residences. Approximately 600 ft after passing under the tree line, turn left and the Jeddo Tunnel Outlet is located approximately 150 ft northwest of the service road. There is an elevation drop of roughly 42 ft from the service road at Elevation (El.) 1062 ft to the outlet of the Jeddo Tunnel at approximately El. 1020 ft. A Site Location Plan is provided on ***Figure 1***.

The location is heavily wooded with a mixture of deciduous and evergreen trees (average 12 to18 inch in diameter). The undergrowth varies from light (dead leaves and ferns) to heavy (bushes, thorns, and small trees). From the site visit, the ground surface appears to be made of a thin layer of heavily organic soil overlaying much harder glacial till and alluvial soil. The run of the creek from the Tunnel Outlet (El. 1020 ft) to the confluence with Little Nescopeck Creek (El. 995 ft) is approximately 1,600 to 1,700 ft. The stream bank slopes are generally less than 1H:1V at the tunnel outlet. The left (looking downstream) stream bank slope begins to top off at approximately El. 1052 ft and the right stream bank slope begins to top off at approximately El. 1045 ft. The stream bank slopes gradually fall off in height further downstream of the Tunnel Outlet. The stream bank slopes are generally 2H:1V to 1.5H:1V. At approximately 600 ft downstream, the bank is only 7 to 10 ft above the streambed elevation. The ground surface above the left stream bank slopes downward towards the northwest with a difference in elevation of 22 ft over a horizontal distance of 320 ft. The ground surface above the right stream bank slopes upwards from the Jeddo Tunnel for a total difference in elevation of 6 ft over a horizontal distance of 220 ft, then downwards for difference in elevation of 16 ft over a horizontal distance of 160 ft.

The existing Tunnel Outlet is of masonry construction, some concrete repair work has been performed on the structure in the past. The only other structure in the vicinity is an old abandoned United States Geological Survey (USGS) Stream Gage. There were no above ground utilities observed during the site visit, nor were there any signs of the presence of underground utilities. The area immediately around the tunnel outlet may have been built up with mine cuttings and spoil, but has since been overgrown with vegetation.

Based on field observations and topographical data, a site well suited for the Dam is located approximately 250 ft downstream of the Jeddo Tunnel Outlet. At this location, the stream bed is estimated to be at El. 1018 ft. The tops of the side slopes at this location downstream of the Tunnel Outlet are between El. 1040 and El. 1045 ft. The streambed at this location is approximately 25 ft wide and the span across the valley from the top of the one side slope to the other is approximately 130 ft. Further information on the Site location and sketches are included in the field log provided in ***Attachment A***. Photographs of the Site are provided in ***Attachment B***.

SITE GEOLOGIC CONDITIONS

The Jeddo Tunnel Site lies in a stable geologic region that has experienced only minor earthquake activity, with no measured historical epicenter located within 50 mi of the Site.

The Site lies within the Appalachian Mountain Section of the Ridge and Valley Province that consists of long, narrow ridges and broad to narrow valleys exhibiting moderate to very high relief. These ridges and valleys are a direct result of lithologic disparities in erosional resistance and the folded and faulted structures developed in the geologic past, when the mountains were built, during the Alleghanian Orogeny.

This Province is primarily a zone containing Cambrian to Pennsylvanian rocks that were folded and faulted during the Alleghanian Orogeny that occurred during late Pennsylvanian through Permian times, nearly 300 million years ago. In addition to the geologic events that affected the entire Ridge and Valley Physiographic Province, three glacial advances affected the site-vicinity during the Pleistocene Epoch.

The Jeddo Tunnel Site region is located in a stable continental region (SCR) characterized by low rates of crustal deformation with no active plate boundary conditions. There is no evidence for late Cenozoic seismogenic activity of any tectonic feature or structure within the Site region (within 200 mi, 322 kilometer (km)).

The Site is within 10 mi of the Susquehanna River near the southern edge of glaciation in Pennsylvania. The Jeddo Tunnel Site area is located within the Anthracite Upland Section of the Ridge and Valley Physiographic Province, and is bordered by the Susquehanna Lowland Section to the north and the Blue Mountain Section to the south. The Site area is underlain by the Lower Mississippian formations, with the Mauch Chunk Formation bedrock directly beneath the Site. The Mauch Chunk Formation generally consists of a lower unit of interbedded grayish-red shale, siltstone, sandstone, and some conglomerate, and an upper unit consisting of light-gray calcareous quartz sandstone. Some non-red zones exist including Loyalhanna Member, which along the Allegheny Front (Blair County to Sullivan County) is greenish-gray, calcareous crossbedded sandstone. Also includes Greenbrier Limestone Member, and Wymps Gap and Deer Valley Limestone, which are tongues of the Greenbrier.

The most recent geologic influence on the Site was the Late Illinoian and Pre-Illinoian glaciations that deposited glacial materials (thin, clayey to sandy till covering 10 to 25 percent of the ground) on the bedrock surface. The topography within 5 mi (8 km) of the Site consists of low to moderately high, linear ridges and valleys that primarily follow structural trends of the local geologic formations.

The local geologic formations have been subjected to a series of mountain-building episodes, including the Grenville, Taconic, and Alleghanian orogenies . The local structure of the Ridge and Valley Province was imparted to the area during the Alleghanian Orogeny at the end of the Permian Period, nearly 250 million years ago. The Site geologic history has been quiet since the end of the Permian; at that time, the local portion of the crust became more stable and tensional stresses predominated through the Cretaceous Period. The only disturbance of this quiet state was the advance of several ice sheets in the Pleistocene; however, since the Site is located at the extreme southern limit of the glaciated area, the ice sheets were at their thinnest and any crustal depression or subsequent rebound from the ice load has been minimal.

PROBABLE SUBSURFACE CONDITIONS

Based on the regional geology of the Site, RIZZO is assuming the following subsurface conditions to provide a basis for our conceptual design of the facility. The thin organic topsoil layer is underlain with glacial till of an unknown depth, and the glacial till is likely comprised of silty sand and coarse grained material with little or no cohesive properties. Beneath the glacial till overburden layer lays the bedrock. The bedrock is likely comprised primarily of interbedded shale and sandstone. The foundation of the proposed embankment Dam will be located within the overburden layer, so excavation down to bedrock is unlikely.

ENGINEERING CHARACTERISTICS OF LOCAL SOILS

Based on our experience with a nearby power plant site located approximately 10 miles to the northwest of the Site, probable values for index properties for the subsurface materials are summarized in ***Table 1*** below.

TABLE 1
MATERIAL PROPERTIES

MATERIAL	UNIT WEIGHT (PCF)			FRICTION ANGLE (DEG)	COHESION (PSF)	WATER CONTENT (%)
	DRY	MOIST	SAT.			
Glacial Overburden	109	121	144	32	0	11.0
Mauch Chunk Formation	169	170	170	40	7300	0.5

The glacial till material, according to the regional geology, is primarily classified as silty sand and coarse grained material. The overburden layer is assumed to have zero cohesion, but a friction angle on the order of 32 degrees. The unit weight of the material at time of excavation will be lower than that of a well-graded engineered fill of the same material.

DAM CONCEPTUAL DESIGN AND BUDGETARY COST ESTIMATE

The conceptual design is to construct a new Earth Fill Dam approximately 250 ft downstream of the Tunnel Outlet. The cost estimate for the dam construction assumes that a source of engineered fill material is locally available at the time of construction. In developing the conceptual design, modern safety standards were considered, as set forth by the U.S. Army

Corps of Engineers, the Pennsylvania Department of Environmental Protection Dam Safety & Encroachments Act (Act 325 of 1978), and Pennsylvania Code Title 25, Chapter 105, Dam Safety and Waterway Management.

Earth Fill Dam

The proposed Dam will be 22 ft high and 150 ft long, with a crest width of 12 ft. The upstream and downstream shells will be comprised of on-site borrow sources. A 3 horizontal to 1 vertical 3H:1V slope will be used for both the upstream and downstream slopes of the embankment dam. The design crest will be at El. 1040 with a slight over-build to account for potential settlement. A minimum 3-foot excavation of the existing surface material is anticipated for the Dam to be founded on glacial till and to reduce the abutment side slopes for safety. The total storage volume of the impoundment area is on the order of 2.7 million gallons of water. Conceptual drawings, including a plan view, cross sections, and details of the proposed Earth Fill Dam, are shown on ***Figures 2 and 3*** provided in ***Attachment C***.

A typical earth fill Dam would be constructed with a clay core for seepage protection. However, the existence of a local source of clay fill material is unknown at this time, and given the regional geology, unlikely to exist. In addition, the local soil is most likely comprised of a sandy glacial till, which is fairly free draining. Therefore, RIZZO's conceptual design for the embankment Dam includes a vertical chimney filter attached to a horizontal drain blanket extending to the toe of the Dam to provide seepage control and prevent piping within the Dam. The drainage blanket will extend to fully cover the abutment contacts to reduce the possibility of piping of materials through the abutments. All material for both fill and filter will be placed and compacted in 1 foot lifts.

Upon completion, riprap will be placed on the upstream face, and the downstream face will be mulched and seeded to prevent erosion, which is beneficial from both Dam safety and environmental perspectives. A drainage swale along the downstream toe of the Dam will divert surface water from the Dam.

Spillway

The design of the Dam is subject to guidelines set forth by the Federal Energy Regulatory Commission (FERC). Based on the lack of developed areas downstream from the proposed Dam, we have assumed that the structure will be classified as a low hazard dam. The Dam is located within a rural area, and has a relatively small storage capacity, the release of which would most likely be confined to the river channel in the event of a failure, and therefore would represent no danger to human life.

The drainage area upstream of the Dam is approximately 0.5 mi^2. To pass the inflow design flood (IDF) storm event over this drainage area, as well as the mine drainage from the tunnel outlet, a spillway is required. The proposed spillway is a drop inlet structure located upstream of the Dam. The spillway inlet structure will be a concrete box culvert located at the upstream base of Dam, and rise to the normal operating level of the impoundment.

Powerhouse

The ultimate purpose of the proposed Dam is to impound the mine drainage water for the generation of electricity. The powerhouse structure will be constructed at the downstream toe of the Dam, offset from the centerline to the left (looking downstream). The penstock will run underneath the embankment to an intake structure on the upstream side. The cost of the powerhouse is based on the estimated cost of the turbine unit, the penstock, and the estimated amount of cast-in-place and pre-cast concrete required for the construction of the powerhouse, penstock, and intake structure.

The conceptual design details a general layout for the powerhouse and intake structures. The powerhouse, penstock and intake structure will need to be sized based off of the turbine selected for the Project. RIZZO performed some preliminary calculations, Concluded that a net head of 18 ft and a design flow of 80 cfs, the estimated theoretical power output from the hydro system is 122 kilowatts. The actual power output will be less due to efficiency losses from the hydroelectric system.

Budgetary Cost Estimate

The associated costs for the construction of the Jeddo Tunnel Dam and main supporting structures are summarized in the table provided in ***Attachment D***. Cost estimates were developed based on quantity take-offs and RIZZO' experience with similar projects.

The cost to construct the Earth Fill Dam is estimated to be $2.0 Million. This includes a construction contingency of 20 percent, which is consistent with typical industry practice for construction cost estimation at this stage of design. As the design progresses, this contingency will reduce.

The costs provided assume that the appropriate permits and authorizations are readily obtainable from state and federal regulatory agencies. Costs associated with wetland mitigation are not regarded as applicable, and thus have not been considered.

Consideration was given to the feasibility of a mass concrete dam in place of an Earth Fill Dam. After review of the quantities and constructability issues, it was determined that a concrete dam would be significantly more expensive (i.e., twice the cost) than the Earth Fill Dam. The additional cost is primarily due to the high cost per unit for the concrete, the increased excavation depth to obtain a suitable foundation, and the necessary foundation improvements required of such a structure.

REPORT LIMITATIONS

The conceptual design presented in this letter has been formulated on the basis of the information provided by NREL and the assumptions stated herein. Any significant changes in this information should be brought to RIZZO's attention for review.

This letter has been prepared for the exclusive use of the NREL for the feasibility evaluation of the construction of a hydroelectric facility at the Jeddo Tunnel Project. Our recommendations are based on the assumed subsurface conditions at the Site based on the regional geology and our experience with other sites in northeastern Pennsylvania. RIZZO is not responsible for the conclusions, opinions, or recommendations of others based on these preliminary data.

SUMMARY

Paul C. Rizzo Associates, Inc. has prepared this conceptual design report based on field observation of the Site and modern engineering practices to assess the feasibility of the design of a Jeddo Tunnel Dam and hydroelectric facility. We have prepared preliminary sketches (***Figures 2 and 3 in Attachment C***) and estimated costs for Dam design and construction. Our evaluation indicates that an Earth Fill Dam can be installed for approximately $2.0 million.

If you have any questions or concerns please contact me at (412) 825-2008, or by email at john.osterle@rizzoassoc.com.

Respectfully submitted,
Paul C. Rizzo Associates, Inc.

John P. Osterle, P.E.
Vice President – Dams & Water Resources Projects

Kevin R. Cass, P.E.
Project Engineer

JPO/KRC/sjr/crb

Attachments

ATTACHMENT A
FIELD LOG

DCR

ENGINEERS & CONSULTANTS

FIELD ACTIVITY DAILY LOG

TUE	DATE	8 3 10	
	NO.	—	
	SHEET	1	OF 4

PROJECT NAME JEDDO TUNNEL

PROJECT NO. 10-4414

FIELD ACTIVITY SUBJECT: SITE VISIT - FEASIBILITY OF LOW HEAD DAM

DESCRIPTION ON DAILY ACTIVITIES AND EVENTS:

0900 KEVIN CASS (KRC) MET WITH JOSEPH OWEN ROBERT (JOR) OF THE NATIONAL RENEWABLE ENERGY LABORATORY (NREL) AND PETER HAENTJENS (PH) OF EASTERN MIDDLE ANTHRACITE REGION RECOVERY, INC. (EMARR), AND DROVE TO THE SITE OF THE PROPOSED DAM.

0910 KRC ARRIVED AT WALK-IN POINT ALONG DEAN ST., AT A CORNER BEND IN THE ROAD, WITH TWO GRAVEL DIRT ROADS RUNNING EAST AND SOUTH. KRC WALKED UP THE HILL ALONG THE SOUTH ROAD AND TURNED LEFT. THE DIRT ROAD RUNS BEHIND 3 OR 4 PRIVATE RESIDENCES, THEN INTO THE WOODS.

0917 AFTER WALKING ABOUT 500-600 FT INTO THE WOOD, KRC TURNED LEFT TO WALK DOWN TO THE JEDDO TUNNEL OUTLET. KRC PROCEEDED TO TAKE NOTES PICTURES, GPS READINGS, AND LASER RANGE FINDER READINGS OF THE AREA AROUND THE TUNNEL OUTLET. (SEE ATTACHED CHECKLIST FOR FURTHER DETAIL INTO FINDINGS).

0955 KRC CONTINUED TO WALK DOWNSTREAM ALONG THE RIGHT BANK. CREEK RETAINS A RELATIVELY CONSTANT WIDTH OF 20-25 ft. STEEP SIDE SLOPES GRADUALLY DROP OFF FROM ABOUT 40 FT ABOVE CREEK BED AT THE OUTLET TO 5-6 FEET ABOUT 600 FT DOWNSTREAM.

1005 AT ABOUT 750 FT DOWN STREAM KRC OBSERVED THE REMNANTS OF AN OLD DAM. THE STREAM BED WIDENS TO ABOUT 50 ft. THE OLD DAM EXTENDS FROM THE RIGHT BANK OUT ABOUT 30 ft. THE REMAINING IS BLOCKED UP WITH DOWNED TREES PILED UP. THE WOODS OPEN UP TO A FIELD ACROSS ON THE LEFT BANK.

1015 KRC CONTINUED DOWNSTREAM AND CROSSED OVER AT AN OLD BRIDGE (ABOUT 1/4 MILE DOWNSTREAM OF THE TUNNEL OUTLET). KRC WALKED BACK UP THE LEFT BANK TOWARDS THE TUNNEL.

1030 KRC AND OTHERS STOPPED ABOUT 250 ft DOWNSTREAM OF TUNNEL OUTLET,

[OVER] →

VISITORS ON SITE:

CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS.

WEATHER CONDITIONS
75°F HAZY AND HUMID. OVERCAST.

IMPORTANT TELEPHONE CALLS

PERSONNEL ON SITE: KEVIN CASS, JOSEPH OWEN ROBERTS, PETER HAENTJENS

FIELD ENGINEER KEVIN CASS [signature] DATE 8/3/10

F-133

DCR
ENGINEERS & CONSULTANTS

FIELD ACTIVITY DAILY LOG

TUE	DATE	8	3	10
	NO.	—		
	SHEET	2	OF	4

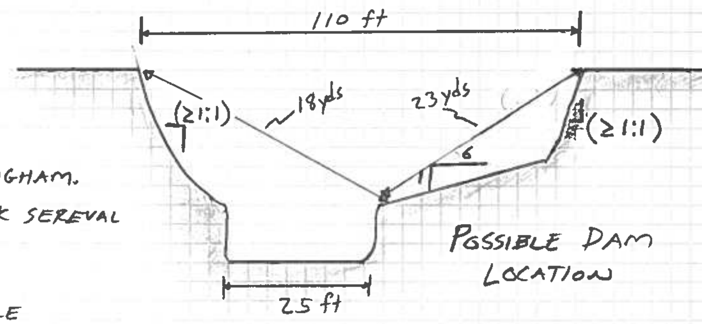
PROJECT NAME: JEDDO TUNNEL	PROJECT NO. 10-4414

FIELD ACTIVITY SUBJECT: SITE VISIT...

DESCRIPTION ON DAILY ACTIVITIES AND EVENTS:

THIS AREA IS A LIKELY SPOT FOR THE PROPOSED DAM. KRC SPENT SOMETIME DOCUMENTING THIS AREA. TOP OF RIDGE TO CREEK BED HAVE AN ELEVATION DIFFERENCE OF ABOUT 25-30 ft. THE LEFT AND RIGHT RIDGES ARE ABOUT 110-120 FT APART. AS WITH NEAR OUTLET, THE RIGHT BANK IS RATHER STEEP WHILE THE LEFT SLOPE VARIES.

1050 KRC RETURNED TO TUNNEL OUTLET AND DISCUSSED FINDINGS WITH JOR & PH.



1055 LEFT SITE AND RETURNED TO CAR. DROVE AROUND AREA, DOWN TO CONYNGHAM. CROSSED OVER LITTLE NESCOPECK CREEK SEREVAL TIMES TO LOOK AT IT.

1120 ARRIVED NEAR CONFLUENCE OF LITTLE NESCOPECK CREEK WITH NESCOPECK CREEK. WALKED OUT TO NESCOPECK CREEK TO OBSERVE.

1135 WALKED TRROUGH WOODS ABOUT 1/4 MILE TO CONFLUENCE. OBSERVED CLEAR WATER MEETING WITH ACID MINE DRAINAGE.

1155 RETURNED TO CARS. DISCUSSED PROJECT MORE. SITE VISIT OVER.

NOTES:

- PH SAID CREEK LEVEL CHANGES ONLY ≈30 FT FROM TUNNEL OUTLET DOWN TO LITTLE NESCOPECK CREEK.
- JEDDO TUNNEL SHAFT IS 9'x7' FOR MAJORITY, BUT LARGER AT OUTLET.
- TUNNEL WOULD BE FLOODED IF DAM WERE BUILT. POSSIBLE INPROVEMENT TO WATER CONDITIONS DUE TO LACK OF OXIDATION.

VISITORS ON SITE:	CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS.
WEATHER CONDITIONS	IMPORTANT TELEPHONE CALLS

PERSONNEL ON SITE: ———

FIELD ENGINEER KEVIN CASS [signature] DATE 8/3/10

F-133

DCR ENGINEERS & CONSULTANTS

FIELD ACTIVITY DAILY LOG

TUE	DATE	8	3	10
	NO.	—		
	SHEET	3	OF	4

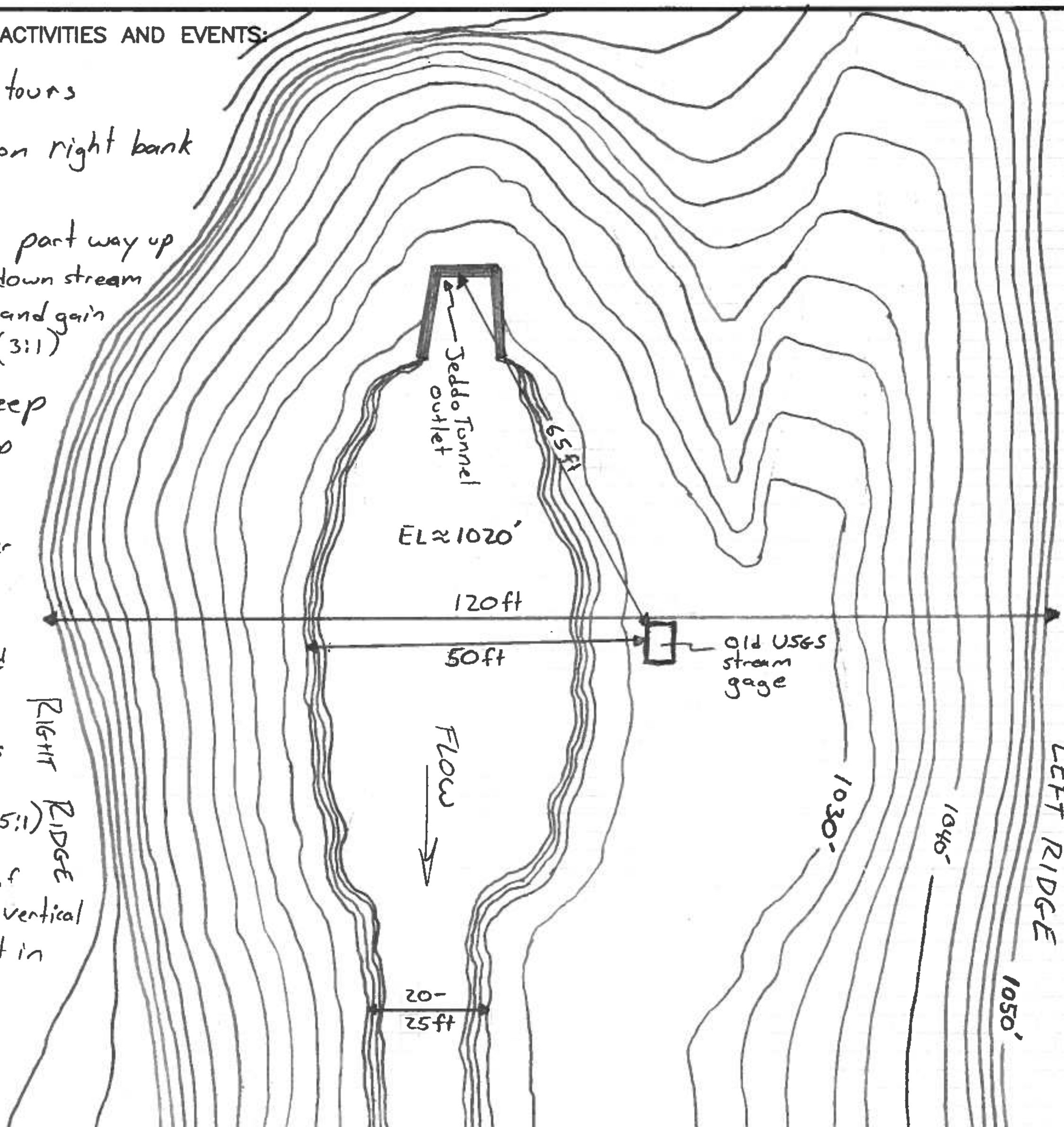
PROJECT NAME: JEDDO TUNNEL

PROJECT NO.: 10-4414

FIELD ACTIVITY SUBJECT: SITE VISIT...

DESCRIPTION ON DAILY ACTIVITIES AND EVENTS:

* Roughly 2 ft contours
* steep side slope on right bank (≥ 1:1)
* left bank plateaus part way up slope. Continues down stream but area shrinks and gain a slight slope. (3:1)
* left slope only steep (≥ 1:1) at the top 10 ft.
* area outside of river channel is relatively flat with a slight slope down words and away from creek.
* area behind continues uphill but at a much shallower slope (3:1-5:1)
* an initial 4-6 ft feet of creek channel is near vertical and slightly under cut in areas.



VISITORS ON SITE: —

CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS. —

WEATHER CONDITIONS: —

IMPORTANT TELEPHONE CALLS: —

PERSONNEL ON SITE: —

FIELD ENGINEER: KEVIN CASS [signature] DATE: 8/3/10

F-133

Surface Vegetation (grass, brush, heavily wooded, lightly wooded):

Area is heavily wooded. A mix of deciduous and evergreen with an Average tree diameter of 12-18 inches. Undergrowth varies from light (clear, ferns) to heavy (bushes, thorns, small trees)

Topography (level, sloping, river or stream, drainage ditches or swales, ponds):

Sloping downward towards the NW, with an estimated 25-30 foot difference over 1600 foot distance, from Tunnel outlet (El 1020 ft) to Little Nescopeck Creek (El 995 ft). The creek bed is approximately 30 feet below top of ridge with steap side slopes at the tunnel outlet (≈ El 1050 ft). The steap side slopes gradually fall off. At approximately 600 ft downstream of the Tunnel outlet, the bank is only 7-10 ft above the creekbed.

Surface Conditions (soft, firm, hard, wet, ponded water, topsoil, fill, disked):

relatively soft undergrowth in vicinity of tunnel outlet. Area Immediately surrounding outlet made up of old mine cuttings and spoil (overgrowth over 100yr period). Dark reddish brown clay w/ high degree of gravel. 1st 8" of ground is soft and moist is some areas. Further D/S near proposed dam site, soil is dryer. It is made up of a thin layer of organic soil overtopping what appears to be glacial or alluvial soil, and rock. several rock outcroppings were observed. Very hard soil after initial 6-8" of organic soil.

Condition of existing Structures (utilities, buildings, walls, foundations:

Existing tunnel outlet is constructed of masonry with some concrete repair work visible on the right side. Heavy spalding of concrete for first 2 feet above water surface (4"-5" back). An abandoned USGS stream gage exist just downstream of the tunnel along the left bank. No other structures in vicinity of outlet. Remnant of an old wooded dam block up part of the creek about 750 ft D/S of the outlet.

Utilities (aboveground and/or below ground):

No above ground utilities observed in the vicinity of the site. No known underground utilities apear to exist.

ATTACHMENT B
PHOTOGRAPHS OF THE SITE

PHOTO 1: ACCESS ROAD TO SITE

PHOTO 2: PATH TO TUNNEL OUTLET OFF ACCESS ROAD

PHOTO 3: TUNNEL OUTLET FROM TOP OF RIGHT STREAM BANK

PHOTO 4: LOOK DOWN ON JEDDO TUNNEL OUTLE FORM BEHIND

PHOTO 5: JEDDO TUNNEL OUTLET FROM LEFT BANK

PHOTO 6: JEDDO TUNNEL OUTLET

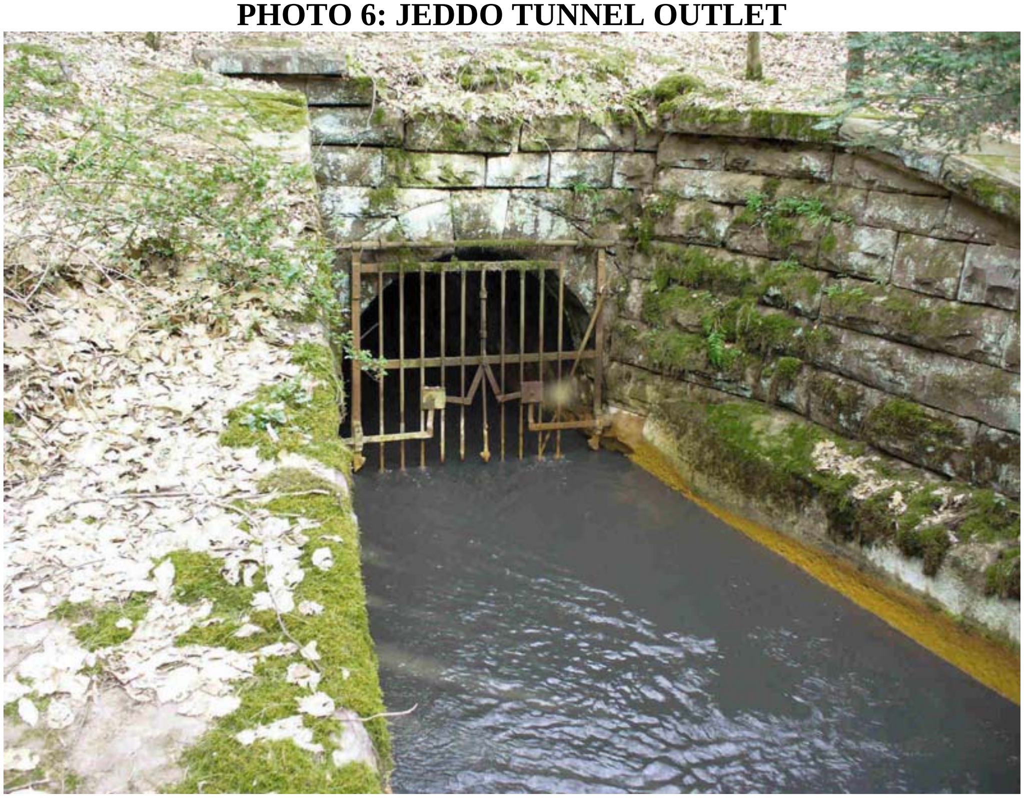


PHOTO 7: TUNNEL OUTLET FROM RIGHT BANK

PHOTO 8: LOOKING DOWNSTREAM FROM TUNNEL OUTLET

PHOTO 9: LOOKING AT RIGHT STREAM BANK FROM TUNNEL OUTLET

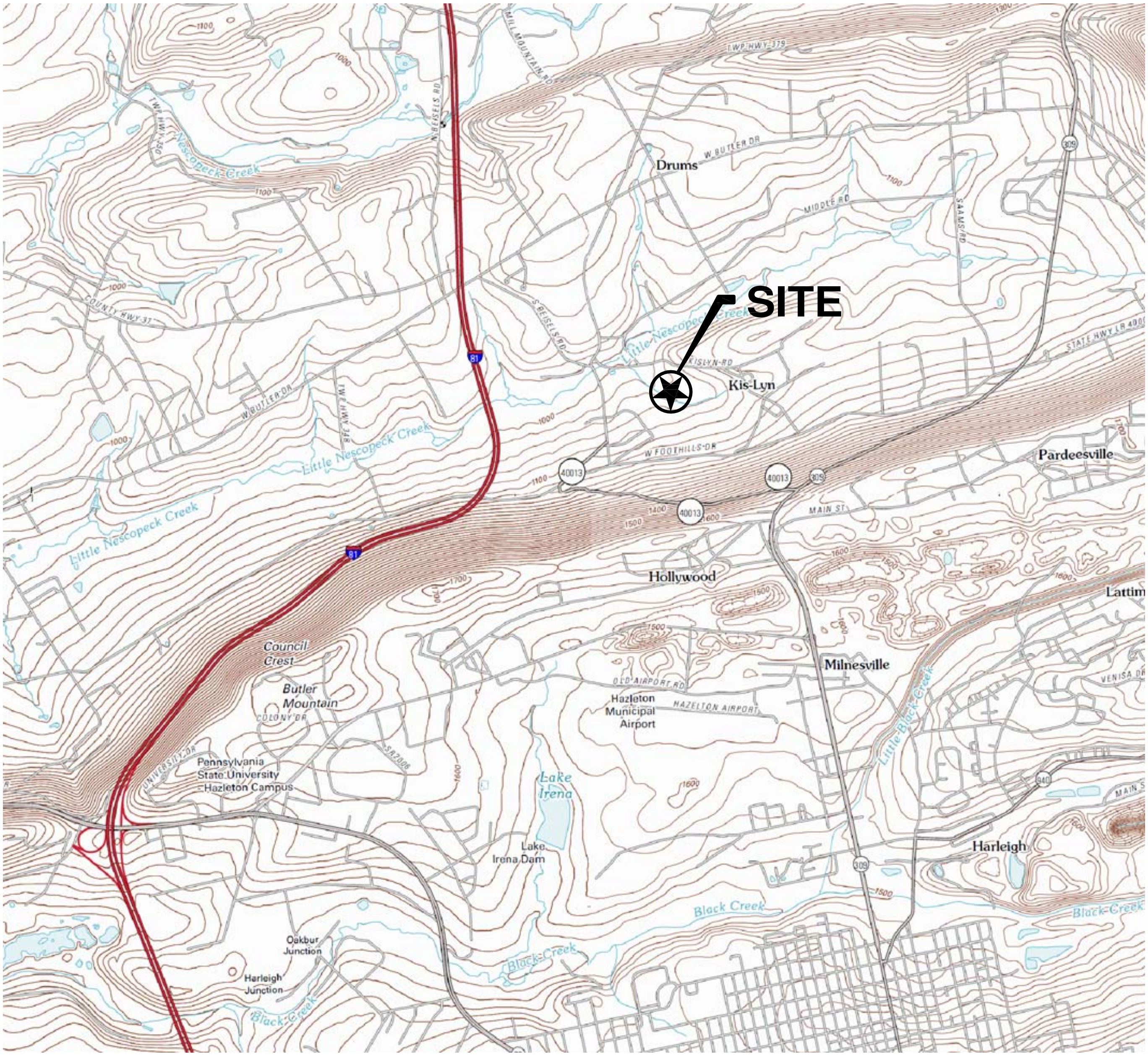
PHOTO 10: USGS STREAM GAGE WITH OUTLET IN BACKGROUND

PHOTO 11: LOOKING AT LEFT BANK AT TUNNEL OUTLET

PHOTO 12: PROPOSED DAM LOCATION FROM RIGHT BANK

PHOTO 13: PROPOSED DAM LOCATION FROM LEFT BANK

ATTACHMENT C
CONCEPTUAL DRAWINGS



CAD FILE NUMBER 10–4414–A1

CHECKED BY

APPROVED BY

JMJ 08/25/10

DRAWN BY

PLOT 1=1

DRAFT

FIGURE 1

SITE LOCATION MAP

JEDDO TUNNEL DAM
AND HYDROELECTRIC FACILITY

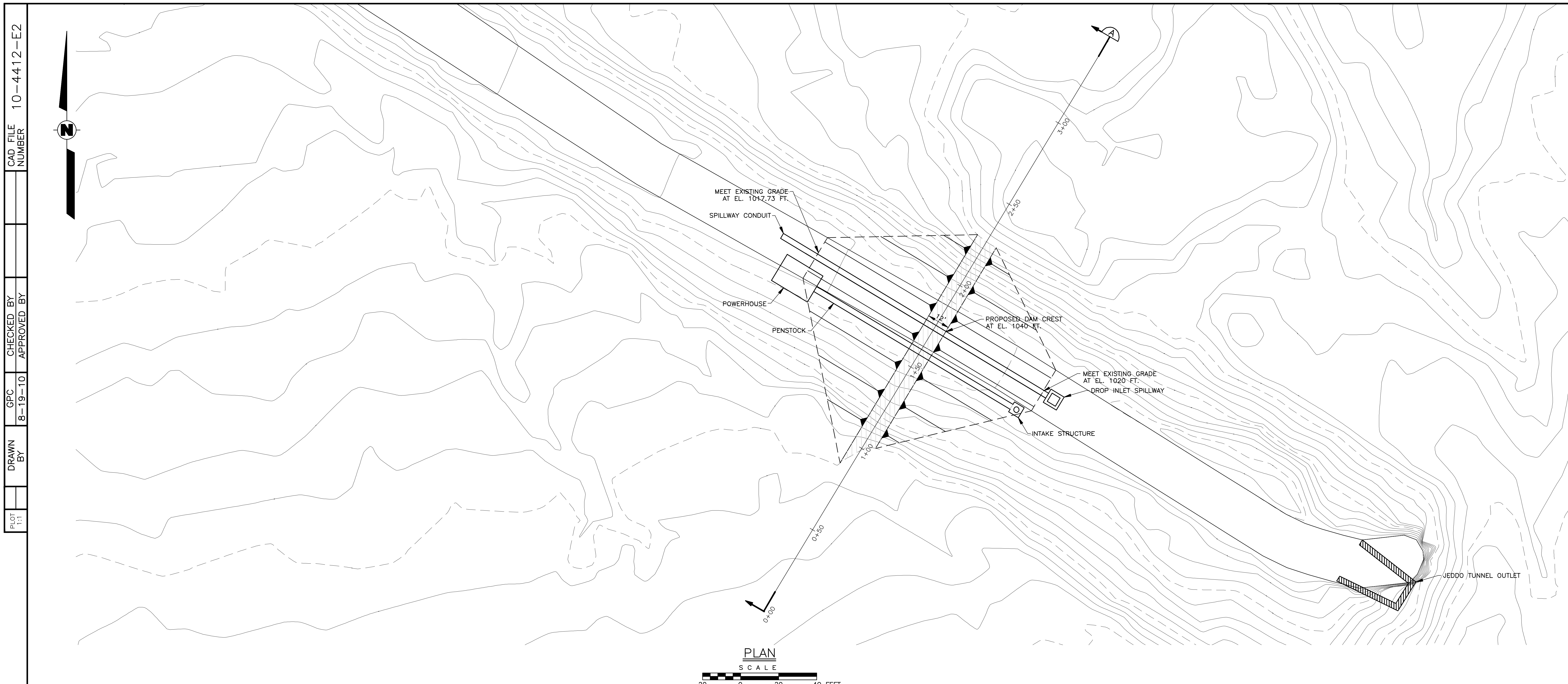
PREPARED FOR

NATIONAL RENEWABLE
ENERGY LABORATORY
GOLDEN, COLORADO

REFERENCES:

U.S.G.S. 7.5 MIN. TOPOGRAPHY MAPS, PENNSYLVANIA–FREELAND, CONYNGHAM, HAZELTON, AND SYBERTSVILLE QUADRANGLES, DATED 2010.

Paul C. Rizzo Associates, Inc.
ENGINEERS & CONSULTANTS



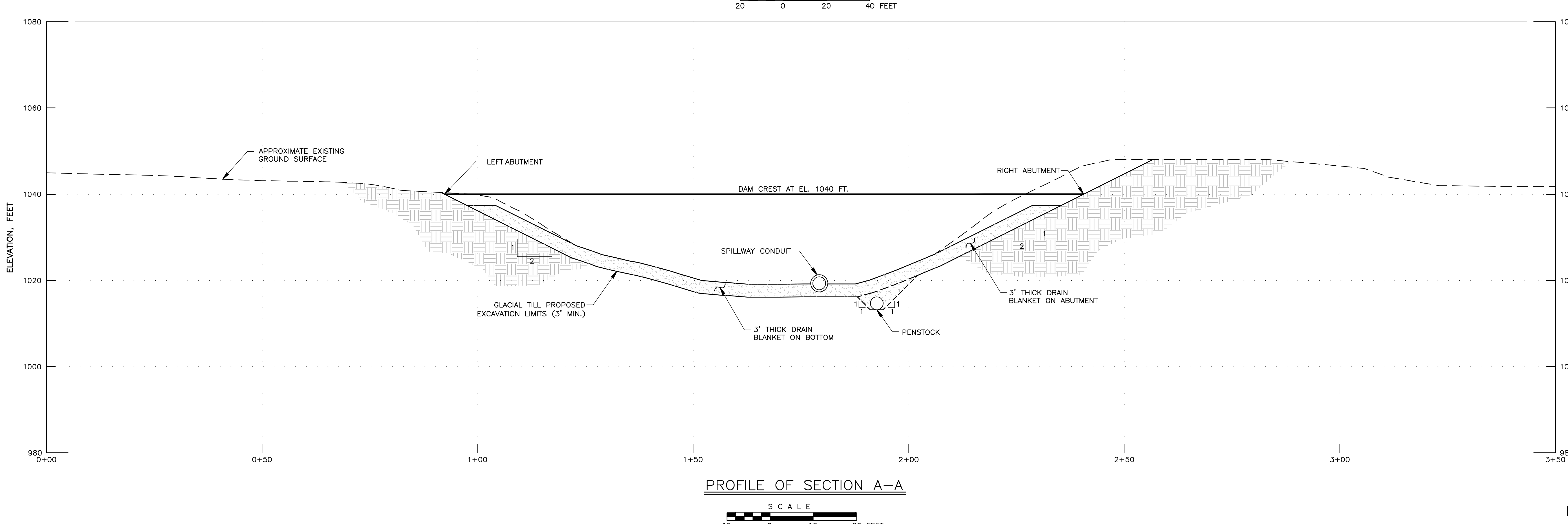


FIGURE 2

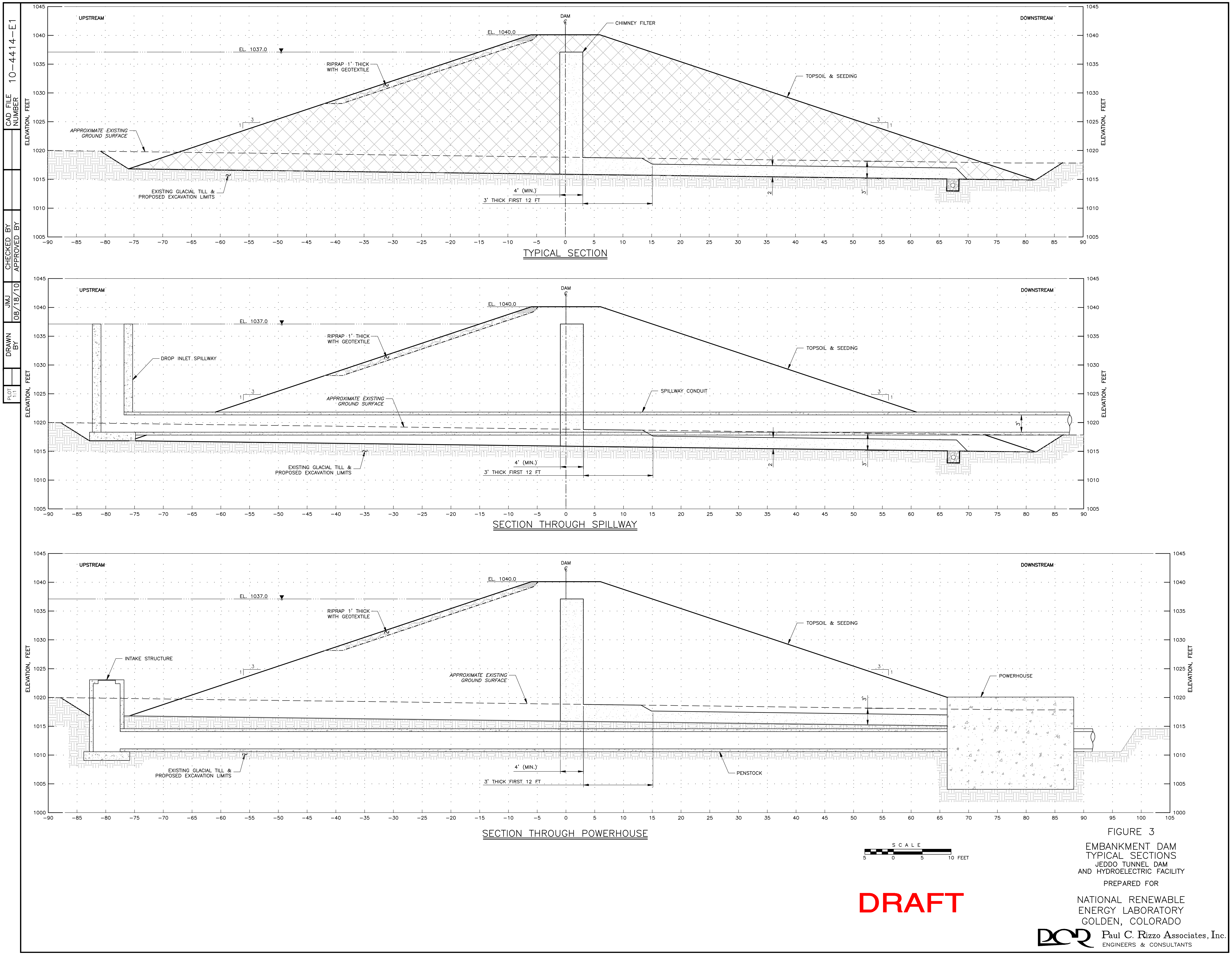
EMBANKMENT DAM
PLAN AND PROFILE
JEDDO TUNNEL DAM
AND HYDROELECTRIC FACILITY

PREPARED FOR

NATIONAL RENEWABLE
ENERGY LABORATORY
GOLDEN, COLORADO

Paul C. Rizzo Associates, Inc.
ENGINEERS & CONSULTANTS

DRAFT



CAD FILE NUMBER 10-4414-E1
DRAWN BY JMJ 08/18/10
CHECKED BY
APPROVED BY
PLOT 1:1
UPSTREAM
DOWNSTREAM
DAM ℄
EL. 1040.0
EL. 1037.0
CHIMNEY FILTER
RIPRAP 1' THICK WITH GEOTEXTILE
TOPSOIL & SEEDING
APPROXIMATE EXISTING GROUND SURFACE
EXISTING GLACIAL TILL & PROPOSED EXCAVATION LIMITS
4' (MIN.)
3' THICK FIRST 12 FT
ELEVATION, FEET
TYPICAL SECTION
DROP INLET SPILLWAY
SPILLWAY CONDUIT
SECTION THROUGH SPILLWAY
INTAKE STRUCTURE
POWERHOUSE
PENSTOCK
SECTION THROUGH POWERHOUSE
SCALE
5 0 5 10 FEET
FIGURE 3
EMBANKMENT DAM TYPICAL SECTIONS
JEDDO TUNNEL DAM AND HYDROELECTRIC FACILITY
PREPARED FOR
NATIONAL RENEWABLE ENERGY LABORATORY GOLDEN, COLORADO
DRAFT
Paul C. Rizzo Associates, Inc.
ENGINEERS & CONSULTANTS

ATTACHMENT D
COST ESTIMATE

JEDDO TUNNEL DAM AND HYDROELECTRIC FACILITY

Item	Description	Estimated Quantity & Cost: Estimated Quantity	Unit of Measure	Unit Cost	Total Cost Value
1	Mobilization & Demobilization	1	Lump Sum	$ 75,000	$ 75,000
2	Site Access and Site Work	1	Lump Sum	$ 25,000	$ 25,000
3	Erosion & Sedimentation Controls	1	Lump Sum	$ 8,000	$ 8,000
4	Clear and Grub	1.5	acre	$ 12,500	$ 18,750
5	Foundation Excavation	2,200	CY	$ 10	$ 22,000
6	Engineered Fill Construction	5,200	CY	$ 19	$ 98,800
7	Chimney Drain Filter Material	280	CY	$ 37	$ 10,360
8	Drainage Blanket Filter Materials	465	CY	$ 37	$ 17,205
9	Riprap	175	CY	$ 35	$ 6,125
10	Turbine	1	Lump Sum	$ 750,000	$ 750,000
11	Concrete (Spillway, Intake, & Powerhouse)	160	CY	$ 750	$ 120,000
12	Conduit (for Spillway Outlet and Penstock)	285	LF	$ 1,000	$ 285,000
				SUBTOTAL	$ 1,436,240
13	20% Contingency				$ 287,248
				SUBTOTAL	$ 1,723,488
14	Engineering Design and PADEP Permitting*	1	Lump Sum	$ 172,349	$ 172,349
15	Engineering and Construction Supervision	1	Lump Sum	$ 120,644	$ 120,644
	Total Cost				**$ 2,016,481**

* FERC Licensing effort not included in cost estimate.

Appendix B. Tabular Flow Duration Curve

Table B-1. Tabular Flow Duration Curve

Jeddo Discharge 1997 Measured Data	
Flow (m^3/min)	Probability of Exceedance
15	99.999
30	99.999
45	99.999
60	95.354
75	80.053
90	70.49
105	51.911
120	42.075
135	36.064
150	28.687
165	24.862
180	21.857
195	19.944
210	17.485
225	15.846
240	14.753
255	13.387
270	12.294
285	10.381
300	9.561
315	8.468
330	7.648
345	6.282
360	5.736
375	5.736
390	4.643
405	4.37
420	4.097
435	3.277
450	2.731
465	2.731
480	2.458
495	2.185
510	2.185
525	1.912
540	1.092
555	1.092
570	1.092
585	1.092
600	1.092
615	1.092
630	1.092
645	1.092
660	1.092
675	0.819
690	0.546
705	0.273
720	0.273
735	0.273
750	0.273
765	0
780	0
795	0
810	0

Appendix C. Project Cost Sheet

Table C-1. Kaplan Hydroelectric Project Costs

Feasibility study		
	Site investigation and survey	$10,000
	Environmental assessment	$50,000
	Preliminary design	$30,000
	Detailed cost estimate	$20,000
	Project management	$20,000
Development		
	Contract negotiations	$5,000
	Permits and approvals	$5,000
	Land rights	inc O&M
	Legal and accounting	$10,000
Engineering		
	Site and building design	inc
	Mechanical design	inc
	Electrical design	$50,000
	Civil design	$292,993
	Construction supervision	inc
Power system		
	Hydro turbine	$680,000
	Road construction	inc
	Transmission line	$40,000
	PMT and recloser	$30,000
Balance of system and miscellaneous		
	Clearing	inc
	Earth excavation	inc
	Rock excavation	inc
	Earthfill dam	inc
	Dewatering	inc
	Spillway	inc
	Intake	inc
	Tunnel	inc
	Penstock	inc
	Powerhouse civil	inc
	BOP dam proposal	$686,240
	Building and yard construction	inc
	Spare parts	$50,000
	Transportation turbine, payment, etc.	$25,000
	Training and turbine commissioning	$10,000
	Total	**$2,014,233**

Table C-2. Crossflow Hydroelectric Project Costs

Feasibility study		
	Site investigation and survey	$10,000
	Environmental assessment	$50,000
	Preliminary design	$30,000
	Detailed cost estimate	$20,000
	Project management	$20,000
Development		
	Contract negotiations	$5,000
	Permits and approvals	$5,000
	Land rights	inc O&M
	Legal and accounting	$10,000
Engineering		
	Site and building design	inc
	Mechanical design	inc
	Electrical design	$50,000
	Civil design	$292,993
	Construction supervision	inc
Power system		
	Hydro turbine	$ 729,283
	Road construction	inc
	Transmission line	$40,000
	PMT and recloser	$30,000
Balance of system and miscellaneous		
	Clearing	inc
	Earth excavation	inc
	Rock excavation	inc
	Earthfill dam	inc
	Dewatering	inc
	Spillway	inc
	Intake	inc
	Tunnel	inc
	Penstock	inc
	Powerhouse civil	inc
	BOP dam proposal	$686,240
	Building and yard construction	inc
	Spare parts	$50,000
	Transportation turbine, payment, etc.	$25,000
	Training and turbine commissioning	$10,000
	Total	**$2,063,516**

Appendix D. RETScreen Results

Figure D-1 shows the results for the Kaplan turbine cost data and energy production estimates assuming the 30% cash grant can be achieved.

RETScreen Financial Analysis - Power project

Financial parameters		
General		
Fuel cost escalation rate	%	
Inflation rate	%	1.2%
Discount rate	%	3.0%
Project life	yr	50
Finance		
Incentives and grants	$	0
Debt ratio	%	80.0%
Debt	$	1,127,840
Equity	$	281,960
Debt interest rate	%	6.00%
Debt term	yr	30
Debt payments	$/yr	81,936
Income tax analysis		☐

Annual income		
Electricity export income		
Electricity exported to grid	MWh	1,162
Electricity export rate	$/MWh	100.00
Electricity export income	$	116,180
Electricity export escalation rate	%	1.2%
GHG reduction income		☐
Net GHG reduction	tCO2/yr	228
Net GHG reduction - 50 yrs	tCO2	11,403
Customer premium income (rebate)		☐
Other income (cost)		☐
Clean Energy (CE) production income		☐

Project costs and savings/income summary			
Initial costs			
Power system	100.0%	$	1,409,800
Balance of system & misc.	0.0%	$	0
Total initial costs	**100.0%**	**$**	**1,409,800**
Annual costs and debt payments			
O&M		$	35,000
Fuel cost - proposed case		$	0
Debt payments - 30 yrs		$	81,936
Total annual costs		**$**	**116,936**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	116,180
Total annual savings and income		**$**	**116,180**

Financial viability		
Pre-tax IRR - equity	%	7.3%
Pre-tax IRR - assets	%	2.2%
After-tax IRR - equity	%	7.3%
After-tax IRR - assets	%	2.2%
Simple payback	yr	17.4
Equity payback	yr	23.4
Net Present Value (NPV)	$	777,636
Annual life cycle savings	$/yr	30,223
Benefit-Cost (B-C) ratio		3.76
Debt service coverage		1.00
Energy production cost	$/MWh	79.63
GHG reduction cost	$/tCO2	(133)

Yearly cash flows Year #	Pre-tax $	After-tax $	Cumulative $
0	-281,960	-281,960	-281,960
1	206	206	-281,754
2	1,180	1,180	-280,575
3	2,165	2,165	-278,410
4	3,162	3,162	-275,247
5	4,171	4,171	-271,076
6	5,192	5,192	-265,884
7	6,225	6,225	-259,658
8	7,271	7,271	-252,388
9	8,328	8,328	-244,059
10	9,399	9,399	-234,661
11	10,482	10,482	-224,179
12	11,577	11,577	-212,602
13	12,686	12,686	-199,916
14	13,808	13,808	-186,107
15	14,943	14,943	-171,164
16	16,092	16,092	-155,072
17	17,254	17,254	-137,818
18	18,430	18,430	-119,388
19	19,620	19,620	-99,767
20	20,825	20,825	-78,943
21	22,043	22,043	-56,900
22	23,276	23,276	-33,624
23	24,523	24,523	-9,101
24	25,786	25,786	16,685
25	27,063	27,063	43,747
26	28,355	28,355	72,103
27	29,663	29,663	101,765
28	30,986	30,986	132,751
29	32,325	32,325	165,076
30	33,680	33,680	198,756
31	116,987	116,987	315,743
32	118,374	118,374	434,117
33	119,777	119,777	553,894
34	121,198	121,198	675,092
35	122,635	122,635	797,726
36	124,089	124,089	921,815
37	125,560	125,560	1,047,375
38	127,049	127,049	1,174,424
39	128,555	128,555	1,302,979
40	130,079	130,079	1,433,058
41	131,622	131,622	1,564,679
42	133,182	133,182	1,697,861
43	134,761	134,761	1,832,623
44	136,359	136,359	1,968,982
45	137,976	137,976	2,106,957
46	139,612	139,612	2,246,569
47	141,267	141,267	2,387,836
48	142,942	142,942	2,530,778
49	144,637	144,637	2,675,415
50	146,352	146,352	2,821,767

Cumulative cash flows graph

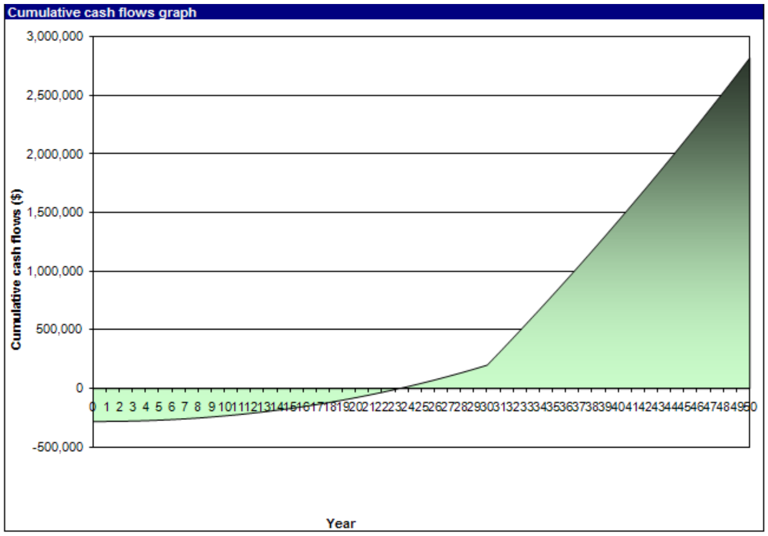


Figure D-1. RETScreen results Kaplan turbine

Figure D-2 shows the results for the Kaplan turbine cost data and energy production estimates assuming the 30% cash grand cannot be utilized.

RETScreen Financial Analysis - Power project

Financial parameters

General		
Fuel cost escalation rate	%	
Inflation rate	%	1.2%
Discount rate	%	3.0%
Project life	yr	50
Finance		
Incentives and grants	$	0
Debt ratio	%	80.0%
Debt	$	1,611,386
Equity	$	402,847
Debt interest rate	%	6.00%
Debt term	yr	30
Debt payments	$/yr	117,065
Income tax analysis		☐

Annual income

Electricity export income		
Electricity exported to grid	MWh	1,289
Electricity export rate	$/MWh	100.00
Electricity export income	$	128,882
Electricity export escalation rate	%	1.2%
GHG reduction income		☐
Net GHG reduction	tCO2/yr	253
Net GHG reduction - 50 yrs	tCO2	12,650
Customer premium income (rebate)		☐
Other income (cost)		☐
Clean Energy (CE) production income		☐

Project costs and savings/income summary

Initial costs			
Power system	100.0%	$	2,014,233
Balance of system & misc.	0.0%	$	0
Total initial costs	**100.0%**	**$**	**2,014,233**
Annual costs and debt payments			
O&M		$	35,000
Fuel cost - proposed case		$	0
Debt payments - 30 yrs		$	117,065
Total annual costs		**$**	**152,065**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	128,882
Total annual savings and income		**$**	**128,882**

Financial viability

Pre-tax IRR - equity	%	4.4%
Pre-tax IRR - assets	%	0.9%
After-tax IRR - equity	%	4.4%
After-tax IRR - assets	%	0.9%
Simple payback	yr	21.5
Equity payback	yr	33.7
Net Present Value (NPV)	$	385,671
Annual life cycle savings	$/yr	14,989
Benefit-Cost (B-C) ratio		1.96
Debt service coverage		0.81
Energy production cost	$/MWh	90.90
GHG reduction cost	$/tCO2	(59)

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-402,847	-402,847	-402,847
1	-22,070	-22,070	-424,917
2	-20,943	-20,943	-445,860
3	-19,803	-19,803	-465,663
4	-18,649	-18,649	-484,313
5	-17,482	-17,482	-501,795
6	-16,301	-16,301	-518,095
7	-15,105	-15,105	-533,200
8	-13,896	-13,896	-547,096
9	-12,672	-12,672	-559,768
10	-11,433	-11,433	-571,201
11	-10,180	-10,180	-581,381
12	-8,912	-8,912	-590,294
13	-7,629	-7,629	-597,923
14	-6,331	-6,331	-604,254
15	-5,018	-5,018	-609,272
16	-3,688	-3,688	-612,960
17	-2,343	-2,343	-615,304
18	-983	-983	-616,286
19	395	395	-615,892
20	1,788	1,788	-614,104
21	3,198	3,198	-610,906
22	4,624	4,624	-606,281
23	6,068	6,068	-600,213
24	7,529	7,529	-592,685
25	9,007	9,007	-583,678
26	10,502	10,502	-573,176
27	12,016	12,016	-561,160
28	13,547	13,547	-547,613
29	15,096	15,096	-532,517
30	16,664	16,664	-515,853
31	135,316	135,316	-380,538
32	136,921	136,921	-243,617
33	138,545	138,545	-105,071
34	140,189	140,189	35,117
35	141,852	141,852	176,969
36	143,534	143,534	320,503
37	145,237	145,237	465,741
38	146,960	146,960	612,701
39	148,703	148,703	761,404
40	150,467	150,467	911,871
41	152,252	152,252	1,064,123
42	154,058	154,058	1,218,182
43	155,886	155,886	1,374,068
44	157,735	157,735	1,531,803
45	159,606	159,606	1,691,409
46	161,499	161,499	1,852,908
47	163,415	163,415	2,016,323
48	165,354	165,354	2,181,677
49	167,315	167,315	2,348,993
50	169,300	169,300	2,518,293

Cumulative cash flows graph

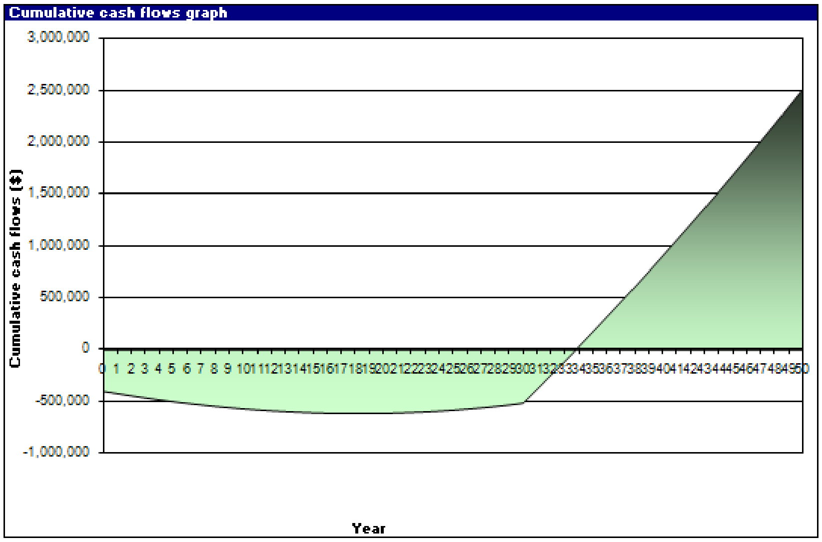


Figure D-2. Hydroelectric cash flow plots

Appendix E. Geothermal Heat Pump RETScreen Model Results

	Unit	Climate data location	Project location
Latitude	°N	41.3	41.3
Longitude	°E	-75.7	-75.7
Elevation	m	293	293
Heating design temperature	°C	-13.2	
Cooling design temperature	°C	30.0	
Earth temperature amplitude	°C	20.9	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		-2.9	68.3%	1.76	98.3	3.7	-5.5	648	0
February		-1.3	63.4%	2.54	98.3	3.7	-3.6	540	0
March		2.9	61.6%	3.56	98.2	4.0	1.3	468	0
April		9.3	60.4%	4.61	98.1	3.8	8.4	261	0
May		15.1	65.9%	5.39	98.2	3.4	14.9	90	158
June		19.7	71.0%	5.96	98.2	3.1	20.1	0	291
July		22.1	71.5%	5.88	98.3	2.9	22.3	0	375
August		21.1	73.3%	5.18	98.4	2.7	21.1	0	344
September		16.9	75.6%	4.07	98.5	2.9	16.7	33	207
October		10.7	72.3%	2.92	98.5	3.1	9.8	226	22
November		5.6	69.6%	1.77	98.3	3.5	3.7	372	0
December		-0.2	68.8%	1.43	98.3	3.6	-2.4	564	0
Annual		10.0	68.5%	3.76	98.3	3.4	9.0	3,203	1,397
Measured at	m					10.0	0.0		

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
United States of America	All types	0.544	0.0%	0.544

GHG emission					
Base case	tCO2	43.3			
Proposed case	tCO2	96.6			
Gross annual GHG emission reduction	tCO2	-53.3			
GHG credits transaction fee	%	0.0%			
Net annual GHG emission reduction	tCO2	-53.3	is equivalent to	-9.8	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	$/tCO2	0.00			

Financial Analysis

Financial parameters			
Inflation rate	%	1.2%	
Project life	yr	50	
Debt ratio	%	0%	
Initial costs			
Heating system	$	0	0.0%
Cooling system	$	0	0.0%
Other	$	250,000	100.0%
Total initial costs	$	250,000	100.0%
Incentives and grants	$	0	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	2,000	
Fuel cost - proposed case	$	18	
	$		
Total annual costs	$	2,018	
Annual savings and income			
Fuel cost - base case	$	12,476	
	$		
Total annual savings and income	$	12,476	
Financial viability			
Pre-tax IRR - assets	%	4.6%	
Simple payback	yr	23.9	
Equity payback	yr	20.9	

Cumulative cash flows graph

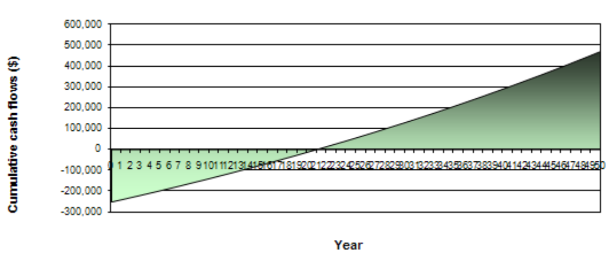


Figure E-1. Geothermal heat pump cash flow plots