Hydro-Electric Feasibility Study

At Upper Pony Creek Reservoir

Prepared for:

Coos Bay North Bend Water Board

By:

Sol Coast Consulting & Design, LLC

&

Parsons Brinckerhoff

Under Grant Funding: Renewable Energy Feasibility Fund

November, 2009

Executive Summary

A technical, fiscal, and permitting feasibility study has been conducted for the Coos Bay North Bend Water Board pertaining to the development of hydro-electric facilities at the Upper Pony Creek Reservoir. A net-metering design for onsite use of the generated power model was selected based on projected power generation rates. The pro-forma for the project developed to reflect the preliminary build-out design, historical electricity inflation rates, and currently available tax credits and utility incentives projects a return on investment of greater than 15 years. An alternate operational scenario based on moderate industrial growth flow rates was also investigated.

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Introduction

The Coos Bay North Bend Water Board is jointly held by the cities of North Bend and Coos Bay. In December of 2008, each of the two cities was awarded a Renewable Energy Feasibility Fund grant from the Oregon Economic and Community Development Department for a "Net Zero Filter Plant Study". While the application for the grant encompassed both hydro and solar electric resources for the Water Board campus, the award specified the restriction of grant dollars for funding of the hydro-electric resource.

As administrator of the grant, Coos Bay North Bend Water Board contracted with Sol Coast Consulting and Design and Parsons Brinckerhoff to conduct the study and publish a document of findings. The scope of the study includes:

- Evaluation of historical flow rates and head at existing conduit
- Preliminary technical designs and build-out budget
- Projected operations and maintenance costs
- Anticipated power generation
- Identification of likely public and private funding mechanisms
- Assessment of permitting requirements
- Cash flow (pro-forma)
- Project Build-Out Milestones

Findings for each of the above study components are documented in the sections and appendices to follow.

Project Setting

The Upper Pony Creek Reservoir, UPCR, is a municipal water supply reservoir located in Coos Bay Oregon. In 2000, UPCR was expanded to its present capacity through the construction of a new dam. At that time, per Water Resource Department requirements, vault space and flanging was provided for potential future installation of a hydro-electric generator. UPCR receives rainwater run-off from the Upper Pony Creek basin. Additionally, the 2000 water supply expansion project included the development of a pump station and conveyance piping for seasonal water transfers from the Joe Ney reservoir located in the adjacent drainage basin. The UPCR resides upstream of Lower Pony Creek Reservoir, LPCR. Lower Pony Creek Reservoir in turn provides feed water to the Pony Creek Treatment Plant which serves municipal and commercial customers in the Coos Bay North Bend area. (Figure 1)

Operating Conditions: Historical Flows and Head

Bracketed pool elevation, rainfall and flow conditions were selected to represent historical low and high flows from the months of January, March, June and October in 2005 (low precipitation conditions) and 2006 (high precipitation conditions). Days for which comprehensive data points were not available were discarded from the data set.

Direct flow monitoring through the outlet works on the UPCR is not available. Flows were quantified through volumetric modeling of the hydraulic systems. Releases from UPCR and precipitation in the Lower Pony Creek Drainage constitute the feed waters of LPCR. Depletion of waters from LPCR is accomplished through releases to the filter plant for municipal use, releases to Pony Creek for satisfaction of minimal fish flows, and evapo-transpiration. Theoretical daily flow rates for UPCR releases to LPCR were calculated using a volumetric balance equation:

$$R_{UPCR} = \Delta V_{LPCR} + TR_{LPCR} + E_{LPCR} + FR_{LPCR} + P_{LPCR}$$

Where

R_{UPCR} = *Releases, Upper Pony Creek Reservoir*

TR_{LPCR}= *Releases to Treatment Plant, Lower Pony Creek Reservoir*

FR_{LPCR}= *Releases for Fish Flow, Lower Pony Creek Reservoir*

ΔV_{LPCR}= *Change in Volume, Lower Pony Creek Reservoir*

E_{LPCR}= *Evapo-transpiration, Lower Pony Creek Reservoir*

P_{LPCR}= *Precipitation, Lower Pony Creek Reservoir*

Table 1: Summary of Daily Volumetric Flow and Available Head at UPCR Control House

Year	Month	Theoretical Flow (cfs)	Elevation (ft msl)	Head (ft)
2005	January	0.9 – 14.2	96.0 – 97.8	49.0 – 50.8
2005	March	1.2 – 16.6	96.5 – 97.5	49.5 – 50.5
2005	June	1.6 – 28.4	98.8 – 99.6	51.8 – 52.6
2005	October	1.0 – 8.9	90.7 – 91.9	43.7 – 44.9
2006	January	1.4 – 23.5	96.7 – 93.5	49.7 – 46.5
2006	March	1.2 – 37.7	106.4 – 106.7	59.4 – 59.7
2006	June	0.5 – 11.1	104.5 – 105.7	57.5 – 58.7
2006	October	2.9 – 12.8	89.6 – 92.4	42.6 – 45.4

Conceptual Electricity Production

Of the data points presented; low, high, average and frequency analyses were completed to define typical and extreme operational conditions experienced by a hydro-electric turbine. The results and conceptual turbine specification are included in Appendix A of this report as prepared by Parsons Brinckerhoff.

A 30 kW turbine has been used for preliminary specifications which is modeled to yield approximately 140,000 kWh/year under the historically based operating conditions presented above.

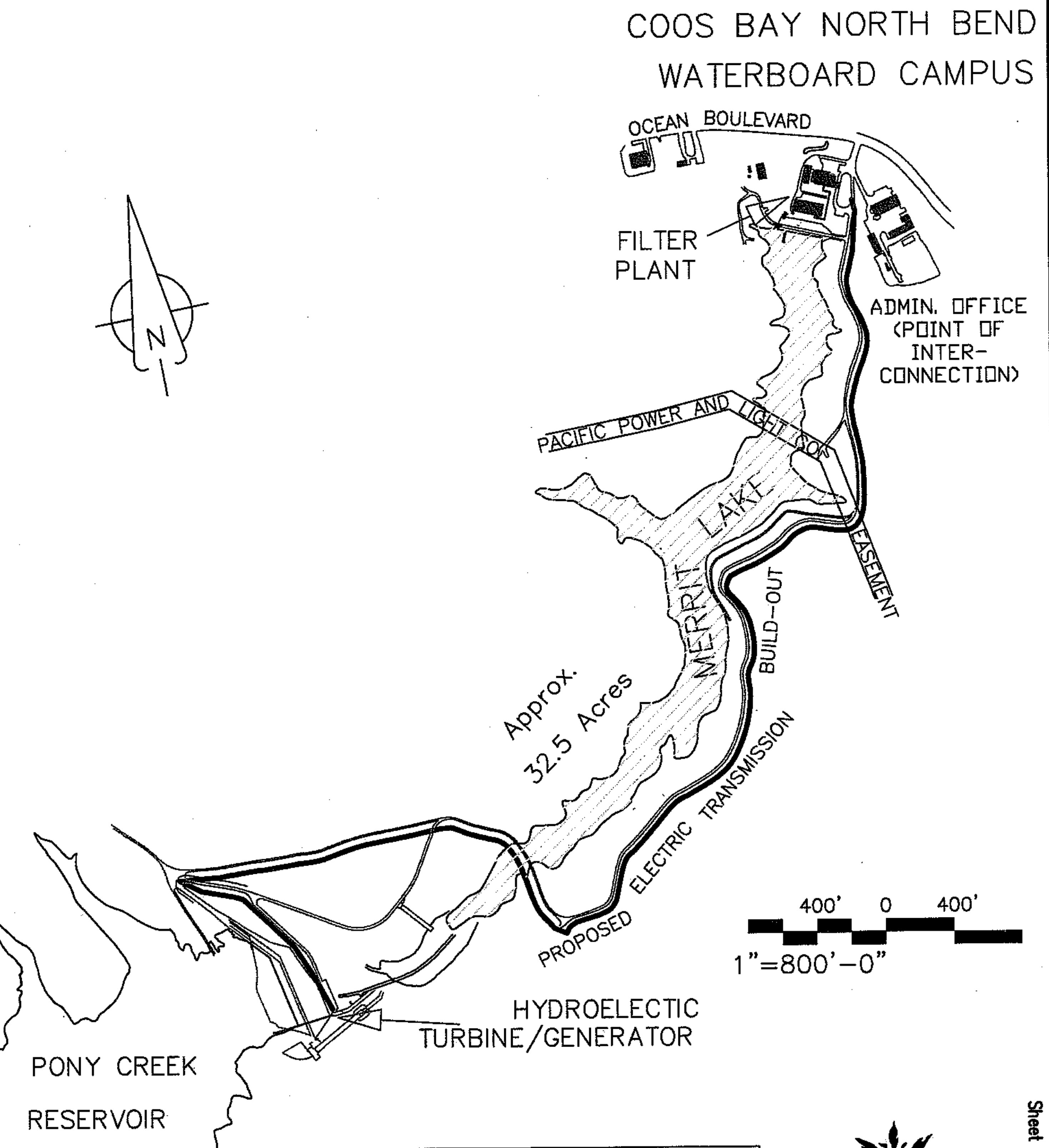
Alternate operating scenarios for future power production will be driven by community water demand and water availability from the two feeder sub-basins of Upper Pony and Joe Ney Reservoirs. Adjusted power yield for future water supply growth were based on preliminary drafts of the Water Conservation and Management Plan for the Coos Bay North Bend Water Board for Moderate Industrial Growth scenario years 2010 and 2020. Under this scenario waters to Upper Pony Reservoir will be fed by above average rainfall and/or augmented supply from the Joe Ney Reservoir through the existing pump station and pipeline (see Figure 1).

Permitting Feasibility

A comprehensive review of applicable permitting mechanisms and agencies was conducted to determine the legal feasibility and develop a permitting budget for the build-out of a hydro-electric

PROPOSED HYDROELECTRIC FACILITIES

FIGURE 2



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facility. This review was based on the installation of a hydro-electric generator along existing conduit at the Upper Pony Creek Dam, conveyance of power to the Water Board Campus along the existing access road corridor, and interconnection to the grid (Figure 2). A discussion of findings in each area follows:

Federal Energy Regulatory Commission, "FERC" - Applicable rules established by FERC for this hydro-electric project may impact two different aspects of project development; licensing and designation as a "Qualifying Facility".

Licensing of the facility, regardless of power use or sale agreement, may be exempted under either of two available hydro-electric licensing exemptions; 1) Small hydro exemptions for projects of 5 Mega Watts or less constructed on dams and 2) Conduit exemptions for generating capacities of 40 Mega Watts or less (municipal) in conduit constructed primarily for purposes other than power generation on non-federal lands. Although the scope of the review process is narrower, the exemption application process includes many of the same steps as an application for a license and must be completed prior to construction. The process includes consultation with interested members of the public as well as compliance determinations for statutes in the Federal Power Act, National Environmental Policy Act and the Fish and Wildlife Coordination Act. (Source: *DRAFT* Guidebook for obtaining Conduit Exemption, Summit Blue Consulting, LLC) Initial consultation with Oregon Department of Fish and Wildlife has been completed and is documented later in this section.

Certification as a Qualifying Facility may be accomplished through FERC's self certification process and would be necessary if the facility owners were to negotiate a power purchasing agreement with the governing utility through a tariff type arrangement. (http://www.ferc.gov/industries/electric/gen-info/qual-fac.asp) A discussion of this option is included under the subsequent section "Power Valuation". Qualifying Facilities fall into two categories: qualifying small power production facilities and qualifying cogeneration facilities.

A small power production facility is a generating facility of 80 MW or less whose primary energy source is renewable (hydro, wind or solar), biomass, waste, or geothermal resources. A cogeneration facility is a generating facility that sequentially produces electricity and another form of useful thermal energy (such as heat or steam) in a way that is more efficient than the separate production of both forms of energy. (http://www.ferc.gov/industries/electric) As a small power production facility, the Water Board may use the self certification process to establish eligibility for interconnection and power sales under the Public Utilities Regulatory Act (discussed below).

Oregon Water Resources Department, "WRD" - A new hydro-electric water right must be applied for and a permit issued prior to construction of the facility. The historical flows included in this evaluation and hydro-sizing are consistent with the existing water storage and use water rights associated with the point of diversion. Under the existing reservoir permits, the potential for higher flows exists through alternate management scenarios which may include accelerated seasonal recharge of UPCR from Joe Ney Reservoir via the existing conduit and pump station if and when the demand for water is accelerated.

The water right application process engages a review of environmental impacts, fish passage, fish screening of the intake, and consistency with the basin management plan. Fish passage and screening review has been initiated for related water rights utilizing the same existing conduit and are discussed below. As hydro-electric generation is not consistent with the South Coast Basin Management Plan, a waiver for this application of waters must be applied for.

Oregon Department of Fish and Wildlife, "ODFW" – As a result of the 2000 water supply expansion project permitting process, ODFW has been intimately involved in the development and management of the UPCR and dam facilities. Initial consultation with ODFW staff and director regarding fish passage and screening waivers has been completed. As the project has been designed for build-out without impacting intake facilities or the permissible flow rates as established by the existing water rights, it is likely that the waivers currently in place for the UPCR will be likewise granted for a hydro-electric facility.

Oregon Department of Environmental Quality, "ODEQ" - Formal consultation with ODEQ would be accomplished through both the FERC licensing exemption process and the WRD water right application. No environmental impacts are anticipated to result from a successful project build-out.

United States Army Corp of Engineers, "USACE" - Formal consultation with USACE will be accomplished through both the FERC licensing exemption process and the WRD water right application. No additional permits are anticipated to be required from USACE as the intake works and power housing were previously constructed under USACE permits and have been completed. The power line build-out from the power house at UPCR to the place of use or point of utility interconnection is not expected to impact wetlands or navigable waterways.

Public Utilities Regulatory Policy Act, "PURPA" - PURPA created an obligation for electric utilities purchase power from and to interconnect with qualifying generation projects. PURPA is implemented at the state level by the Public Utility Commission. (www.pacificorp.com/Article/Article62237.html) As a PacifiCorp service customer, Pacific Power was consulted for this study to investigate interconnection requirements and options. An initial review of the preliminary one line drawing for interconnection through the Water Board's panel was conducted by Pacific Power. No concerns regarding the preliminary interconnection one line were identified. Prior to interconnection the facility owner must enter into a formal Interconnection agreement which determines the physical connection to the utility's transmission or distribution system.

Power Valuation

The value of power produced by the facility is dependent on the method and location of interconnection and the terms of the power purchasing agreement or market value of net-metered on-site use.

Net Metering – "Net metering measures the difference between the electricity from the utility used by the customer and the electricity generated and provided back to the utility. A net metered customer pays the "net" of utility-provided kilowatt hours, "kWhs" minus customer-generated kWhs. If the customer's generator puts more kWhs into the utility than it uses from the utility, the excess energy is credited to the customer's account."(http://www.pacificorp.com/Article/Article59318.html)

The effective value of electricity produced through a net-metering arrangement, as measured in kWh, is equal to the purchase price of a kWh from the utility. A sample Net-Metering Agreement is included as attachment xx of this document. Currently, the cost per kWh to the Water Board is $.054/kWh. The 30 year historical average electricity inflation rate of 3% has been used for cash flow projections.

Power Purchasing Agreements – As defined by PURPA, utilities must purchase power from qualifying facilities. Avoided cost (the cost a utility avoids as a result of the QF) forms the basis for determining QF purchase pricing. The rate for payment of surplus power supplied by the producer to the utility has been established through pricing options published by PacifiCorp and approved by Oregon Public Utility Commission in "Schedule 37, Avoided Cost Purchases from Qualifying Facilities of 10,000 KW or Less".

Currently, and projected through calendar 2013, PacifiCorp is in an energy sufficiency phase during which existing or planned capacity is projected to meet demand. Beyond 2013, PacifiCorp anticipates an energy insufficiency phase at which time the avoided costs of power will experience a step jump and ensuing annual toll increases. Five pricing options are available as defined by Schedule 37 for power purchasing contracts. For the purposes of future the financial analysis of this project, Fixed Avoided Cost pricing has been used with a 50/50 blend of on and off-peak production. A discussion of each of the pricing options can be found in the attached Schedule 37 documentation.

Fixed Avoided Cost: Under this option a prices are fixed at the time of contract signing for up to 15 years with additional lengths of contract (up to 20 total) years based on either the Firm Market Indexed, Banded Gas Market Indexed or Gas Market Indexed Options. Established Fixed Avoided Costs for On and Off-Peak production periods have been documented on page 5 of Schedule 37(attached). Under this scenario, unit (per kWh) power purchases are based on.

Table 2: Projected Net-Metered and Defined Power Purchase Unit Pricing

Calendar Year	Fixed: On-Peak ¢/kWh	Fixed: Off-Peak ¢/kWh	Fixed: Average ¢/kWh	Net-Meter ¢/kWh
2009	3.72	3.05	3.385	5.36
2010	4.82	3.80	4.31	5.52
2011	5.68	4.34	5.01	5.69
2012	6.16	4.50	5.33	5.86
2013	6.30	4.61	5.46	6.03
2014	8.19	6.34	7.27	6.21
2015	8.25	6.36	7.31	6.40
2016	8.13	6.21	7.17	6.59
2017	8.14	6.18	7.16	6.79
2018	8.26	6.26	7.26	6.99
2019	8.57	6.53	7.55	7.20
2020	8.94	6.86	7.90	7.42
2021	9.36	7.25	8.31	7.64
2022	9.41	7.25	8.33	7.87
2023	9.53	7.34	8.44	8.11
2024	8.74	6.50	7.62	8.35
2025	9.07	6.78	7.93	8.60
2026	9.54	7.21	8.38	8.86
2027	9.68	7.31	8.50	9.13
2028	10.03	7.62	8.83	9.40

Projected Return on Investment

The project return on financial investment depends on four driving variables:

1. Project build-out and maintenance expense
2. Available grants, tax credits, and other financial assistance
3. Annual power production
4. Power valuation

A budget of $450,000 has been selected for permitting and build-out of the project per this preliminary scope and design. Maintenance of the facility entails $1,000 of annual upkeep and a rebuild at 10 year increments based on 50% of the turbine/generator unit cost.

Two annual power production models were run; "Base Case" reflects the historical typical flows based on the hydrological model previously presented, Moderate Industrial reflects projected flows through the conduit under the scenario of moderate increases to water consumption through moderate industrial growth. The Moderate Industrial growth projection utilizes a linear increase in consumption from 2010 through 2020 with flat lined usage after 2020 through the duration of the project. Both scenarios were plotted against the two power valuation models of net metering and fixed price power purchase. For net metering, existing utility rates at the administrative offices were annually adjusted at a rate of 3%.

Table 3: Comparison of Annual Power Production and Valuation

Base Case Net-Metered	Base Case Fixed Price	Moderate Industrial Net-Metered	Moderate Industrial Fixed Price
$ 7,504	$ 4,739	$10,318	$ 6,516
$ 7,729	$ 6,034	$10,840	$ 8,463
$ 7,961	$ 7,014	$11,389	$10,034
$ 8,200	$ 7,462	$11,965	$10,888
$ 8,446	$7,637	$12,570	$11,366
$8,699	$10,171	$13,206	$15,441
$8,960	$10,227	$13,875	$15,836
$ 9,229	$10,038	$14,577	$15,854
$9,506	$10,024	$15,314	$16,149
$ 9,791	$10,164	$16,089	$16,702
$10,085	$10,570	$16,903	$17,717
$10,387	$11,060	$17,139	$18,249
$10,699	$11,627	$17,653	$19,185
$11,020	$11,662	$18,183	$19,242
$11,350	$11,809	$18,728	$19,485
$11,691	$10,668	$19,290	$17,602
$12,042	$11,095	$19,869	$18,307
$12,403	$11,725	$20,465	$19,346
$12,775	$11,893	$21,079	$19,623
$13,158	$12,355	$21,711	$20,386

Totals:	**$201,635**	**$197,974**	**$321,163**	**$316,391**

Through this gross analysis of pricing and operational models based on present day projections, the net metering option appears to result in the highest cumulative value of power produced over the next 20 years.

Financial assistance included in the 30 year pro-formas (included as Appendix B of this document) is as follows:

Energy Trust of Oregon: This assistance grant is available through the open solicitation program which is designed to offset incremental project costs. Based on a preliminary review of project build out costs and projected output, a conceptual value of $100,000 was assigned to the Energy Trust Grant. This grant, while not competitive, is reliant on the amount of available funding, and the relative priority based on shovel readiness of other similar projects applying for the same funds.

Oregon Department of Energy: Business Energy Tax Credits, "BETC", issued by ODOE are transferable to taxable entities through the pass through program. The amount of the credit is based on 50% of the net present value of the project based on the projected first 15 years of power production value. This credit is in turn sold by the applicant at a percentage of the face value. This sale percentage is scheduled for reduction to an as of yet undetermined amount for all projects pre-approved after November 3rd, 2009. The face value of the credit (which forms the basis of the value to the municipality) is therefore derived from the projected power production of the project. Accordingly, the BETC value for the two scenarios of Base Case and Moderate Industrial Growth vary.

Financing: The applicant has applied for and been awarded financing for this and the parent project (filter plant upgrade) at a rate of 3.26% for 20 years.

30 year Pro-Formas were prepared for each operational scenario using net-metering at a 3% annual inflationary rate. Under the Base Case, the project is financially infeasible with a 30 year loss. Under the Moderate Industrial Growth scenario, the project has a present day net value of $99,280 with a return on investment occurring in year 22 of the project. (Appendix B)

Project Build-Out Milestones

Determination of power use or purchase agreement – negotiations of firm or non-firm tarriff, as applicable

Simultaneous:

Final Design Completion – Contract Engineer (4 months)

Prepare draft power purchase agreement/pricing provisions – PacifiCorp Commercial and Trading (15 day review)

Simultaneous:

Application for Hydro-Electric Water Right – Water Resources Department (24 months)

Application for Waiver: South Coast Basin Plan – Water Resources Department (24 months)

First Stage of FERC exemption Consultation – Federal Energy Regulatory Commission (2 months)

Simultaneous:

Application for Interconnection agreement – PacifiCorp Transmission Services (18 months)

Second Stage of FERC exemption Consultation - Federal Energy Regulatory Commission (2 months)

Simultaneous:

Construction set bid process – Water Board (3 months)

Third State of FERC exemption Consultation - Federal Energy Regulatory Commission (2 months)

Request final draft of power purchasing agreement - PacifiCorp Commercial and Trading (15 day preparation)

Simultaneous:

Await Receipt of FERC Exemption and Water Right Permits (Including waivers for basin plan, fish passage and fish screening)

Building permit applications – Coos County (1 month)

Construction and commissioning – Water Board & Contractor (3 months)

Appendix A

System Preliminary Design

Prepared by:

Parsons Brinckerhoff

COOS BAY/NORTH BEND WATER BOARD
HYDRO-ELECTRIC FEASIBILITY STUDY
AND
SYSTEM PRELIMINARY DESIGN

Final Document of Findings

Prepared for:

Coos Bay/North Bend Water Board

December 2, 2009

I - Introduction

In an effort to offset the additional power requirements associated with the Pony Creek Water Treatment Plant expansion, the Coos Bay North Bend Water Board (Board) authorized Sol Coast and Parsons Brinckerhoff to undertake a feasibility study and a preliminary design report for the construction of small-scale hydroelectric facilities at the existing Pony Creek Reservoir Dam. The Board has retained a consultant to concurrently design upgrades to the existing treatment plant to increase capacity from 8 MGD to 12 MGD. It is intended that the installation of a small scale hydroelectric generation system would occur in parallel with the upgrades to the treatment plant.

The feasibility study includes evaluation of the existing infrastructure at the dam and the development of concept drawings and a preliminary turbine selection. Specifically included in the report are:

1. Diversion facility requirements for the proposed intake structures at the Pony Creek Reservoir
2. An evaluation of the options for connection of a turbine penstock to the existing infrastructure within the Pony Creek Reservoir Control House
3. An evaluation of the head available to the turbine based on a representative sample of flow and water level data from the reservoir and friction losses within the penstock.
4. Using the evaluations of the existing infrastructure, available head, and flows, a preliminary turbine and generator design will be performed to analyze the most appropriate type and size of generator.
5. A preliminary construction timeline including steps needed to install and test the hydroelectric and electrical transmission facilities.
6. A summary of the normal and bypass operational characteristics including an evaluation of the synchronous bypass infrastructure needed to operate the valves and turbine within the Pony Creek Reservoir Control House.
7. A summary of the anticipated long-term maintenance costs of the facility
8. A preliminary construction cost estimate for the project.

II - Diversion Facility Requirements

The original project assumption was that no fish screening would be included in this project. In discussions with ODFW, the Board has confirmed that fish screening will not be required on the project. The existing intake to the outlet pipe includes a trash rack with 4" bar spacing. A preliminary investigation of hydroelectric turbines of the scale needed on this project show that a maximum passing size of 2" is needed. The 4" spacing of the intake is not sufficient to prevent any passing solids from inflicting damage on the power generation equipment. Therefore, a removable screen will be installed between the turbine shutoff valve and the turbine itself to intercept any particles greater than the passing size of the turbine. The screen will be fitted with quick-release couplings to provide access for cleaning.

III - Penstock Evaluation

The existing water supply intake at the Pony Creek Reservoir flows through a 48" concrete-encased, steel pipe approximately 350 feet to the existing control house. At the existing control house, high flows pass through the 48" pipe, a 48"x36" reducer, and through a knife gate into the stilling basin. When the knife gate is fully open, the high-flow conduit is capable of discharging flows ranging from 170 cfs to 370 cfs at the minimum and maximum pool elevations, respectively.

The existing 48"x36" reducer fitting includes an existing 14" wye leading to a 12" jet flow gate and an 18" outlet. When the jet flow gate is fully opened, the low-flow conduit is capable of passing flows ranging from 21 cfs to 43 cfs at the minimum and maximum pool elevations, respectively.

Two options were considered for supplying flow to the micro-hydropower equipment. The first option was to connect to an existing 36" blind flanged manhole located along the 48" steel conduit as it enters the control house. This would involve the installation of a 36"x20" reducing elbow, a 20"x18" eccentric reducer, and approximately 43 linear feet of 18" conduit. A butterfly valve would be installed directly upstream of the turbine and a 45° bend leading to a 18"x24" draft tube would be installed for the water to outlet into the stilling basin. Currently, the alignment passes through a raised concrete floor which will need to be saw cut for the installation of the 18" conduit and hydroelectric equipment. It is anticipated that the 18" conduit would be re-encased in concrete after installation. The area housing the hydroelectric equipment would be grated for access.

The second option would be to take advantage of the existing low-flow conduit previously mentioned. By installing a butterfly valve, turbine, and draft tube on the existing line, the need for installing a new conduit run would be eliminated.

For the concept plans, the first option was deemed the preferred choice of action due to the operational flexibility that it provides. By maintaining both the high-flow and low-flow conduits as they currently exist, the turbine can be taken offline for maintenance, and lower flows can still be controlled by the low-flow conduit. This capability is unavailable with the second option.

Appendix A contains preliminary drawings of the control house and the proposed hydroelectric facilities.

IV - Head Evaluation

After selecting the appropriate penstock configuration within the control building, an analysis of the available head within the system and the headloss within the penstock was conducted to allow selection of the most efficient turbine for the head and flow characteristics. The available head in the system is determined by subtracting the tailwater elevation in the stilling basin and the headloss within the system from the headwater elevation (water surface) in the reservoir.

A representative sampling of the headwater elevation in the reservoir along with the estimated effluent from the Pony Creek Reservoir was provided by the Board for use in this study. Headwater elevation data including the average, median, minimum and maximum values are shown in Table IV-1. The water surface elevation at the stilling basin, as observed by Sol Coast, was at an elevation 44 ft.

Table IV-1: Headwater Elevation Values at Pony Creek Reservoir

	Headwater Elevation
Average	98.5 ft
Median	97.8 ft
Minimum	89.6 ft
Maximum	106.7 ft

The headloss within the penstock was analyzed using the *Hazen Williams formula* for friction losses through a pipe and friction losses through fittings. The formulas can be seen in Figure IV-1 below.

Friction Loss in a Pipe	Friction Loss in a Fitting
$h_f = \frac{(3.022)(v)^{1.85}L}{(C)^{1.85}(D)^{1.165}}$	$h_f = K \frac{v^2}{2g}$
Where v = Velocity (ft/s) L = Length (ft) C = Hazen Williams coefficient (unitless) D = Pipe Diamter (ft)	Where K= Loss Coefficient (unitless) v = Velocity (ft/s) g = Gravity constant (32.2 ft/sec^2)

Figure IV-1: Hazen Williams Formulas for Friction Head Losses in the Penstock

Friction losses were calculated for approximately 345 linear feet of 42" steel conduit and approximately 43 linear feet of 18" conduit. In addition, a Hazen Williams coefficient (C) value of 125 was used to reflect the condition of steel pipe in future conditions. By calculating the velocity in a given sized pipe from the representative flow values provided, a friction loss value from flow through a pipe was determined for each flow rate experienced by the penstock.

Similarly, the velocities were also used in the friction loss determination for each fitting between the water surface at the Pony Creek Reservoir, to the tailwater surface in the stilling basin. Table IV-2 shows the fittings in the penstock and the corresponding loss coefficient values (K).

Table IV-2: Penstock Fittings and Loss Coefficients

Penstock Fitting	Loss Coefficient (K)
Intake Structure Trash rack	0.5
48"x48" Sluice Gate	0.28
48" Square to Round Transition	0.5
48" Pipe to 36" Flange	0.18
36"x20" Reducing Elbow	0.3
20"x18" reducer	0.05
18" Butterfly Valve	0.04
18" 45° Bend	0.16
18"x24" Draft Tube	0.05

Table IV-3 shows the average, median, minimum and maximum values for the flow from the Pony Creek Reservoir, the friction head in the penstock and the total head available to the turbine in the control house. Figures IV-2 and IV-3 show the frequency of the occurrences of ranges of available head and flow values, respectively, from the representative data provided.

Table IV-3: Penstock Available Head Results

	Pony Effluent Estimation	Friction Head	Head Available
Units	(ft3/s)	(ft)	(ft)
Average	6.8	0.20	54.3
Median	5.8	0.11	53.6
Min	0.5	0.00	45.5
Max	37.7	3.39	62.7

As seen in Table IV-3, the available head in the system ranges from 45.5 ft to 62.7 feet, while the average and median values for head available are 54.3 ft and 53.6 ft, respectively. Figure IV-2 shows that of the 237 data points considered, 14 samples fall between 53.5 and 54.0 feet of available head while only 2 samples fall between 54.0 and 54.5 feet. The most frequent range of occurrences is between 55 and 55.5 feet of available head, at 23 occurrences or 9.7% of the sample.

As seen in Table IV-3, the flow through the system ranges from 0.5 ft³/s to 37.7 ft³/s, while the average and median values for head available are 6.8 ft³/s and 5.8 ft³/s, respectively. Figure IV-3 shows that of the 237 data points considered, 11 samples fall between 6.5 and 7.0 ft³/s while 16 samples fall between 5.5 and 6.0 ft³/s. The most frequent range of occurrences is between 4.5 and 5.0 ft³/s at 20 occurrences or 8.4% of the sample.

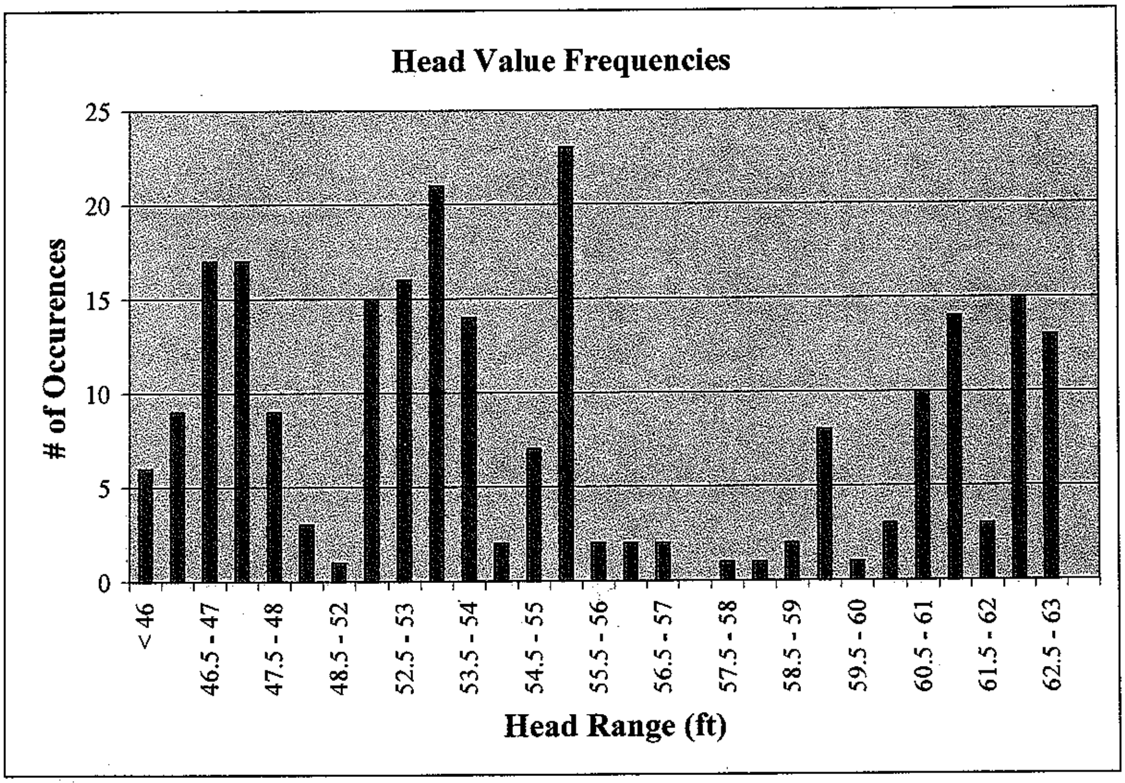

Figure IV-2: Frequency of Occurrences of Available Head at the Control House

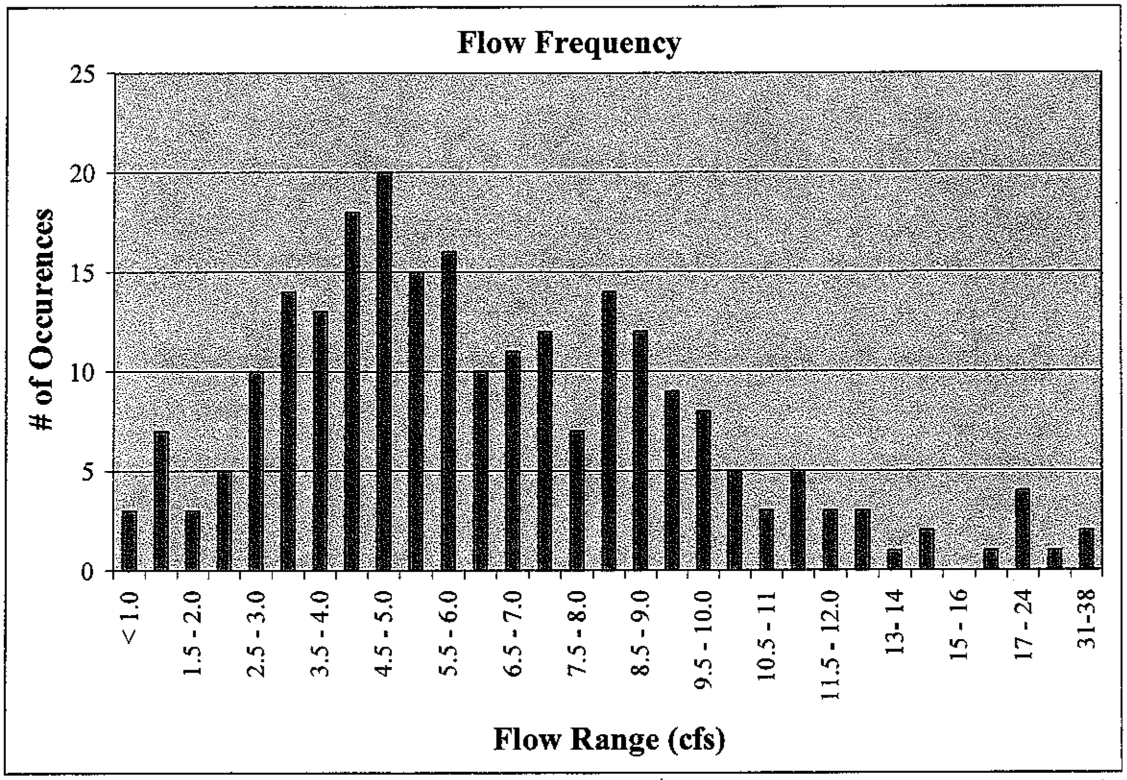

Figure IV-3: Frequency of Occurrences of Flow from the Pony Creek Reservoir

V - Preliminary Turbine and Generator Design

In sizing a turbine and generator, it is important to ensure that the operating range and efficiencies are well suited to take advantage of the most common operating ranges of the water source.

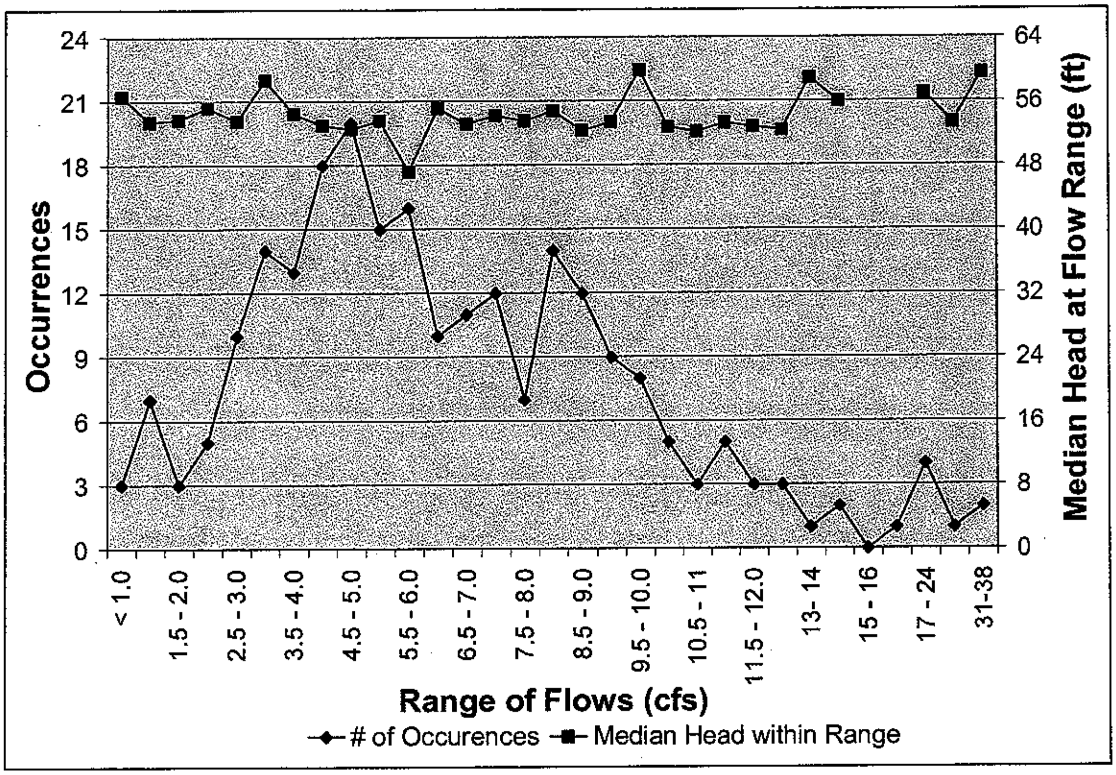

Figure V-1: Comparison of Flow Occurrences to Median Head Available to Turbine

Figure V-1 shows a graph illustrating the number of occurrences of each flow range within the representative data along with the corresponding median head available at each flow range. The axis for the head available is located on the right axis of the graph. The most frequent flow range occurs between 4.5 ft^3/s and 5.0 ft^3/s. The maximum median head value (above 59.9 ft) occurs between 9.5 ft^3/s and 10.0 ft^3/s.

The power generated by a hydroelectric turbine is calculated based on the flow and head values. The hydraulic power equation can be found in Figure V-2, below.

$$P = \frac{(Q)\,(\gamma)\,(h)}{550}\,0.746\,(eff)$$

Where P = Power (kW)

Q = Flow Rate (ft^3/s)

γ = Specific Weight of Water (62.4 lb/ft^3)

h = Available Head (ft)

eff = Power Unit Efficiency (%)

Figure V-2: Hydraulic Power Equation

The graph in Figure V-3 was developed by calculating the yearly energy output for each range of flows using the median flow value and median total head available in each range. As shown by the graph, the highest energy output occurs in the flow range between 8.0 ft^3/s and 9.0 ft^3/s. The median available head values in this range are approximately 53 feet. Therefore, by selecting a turbine and generator that operate most efficiently in this range, the maximum amount of energy can be generated from the site.

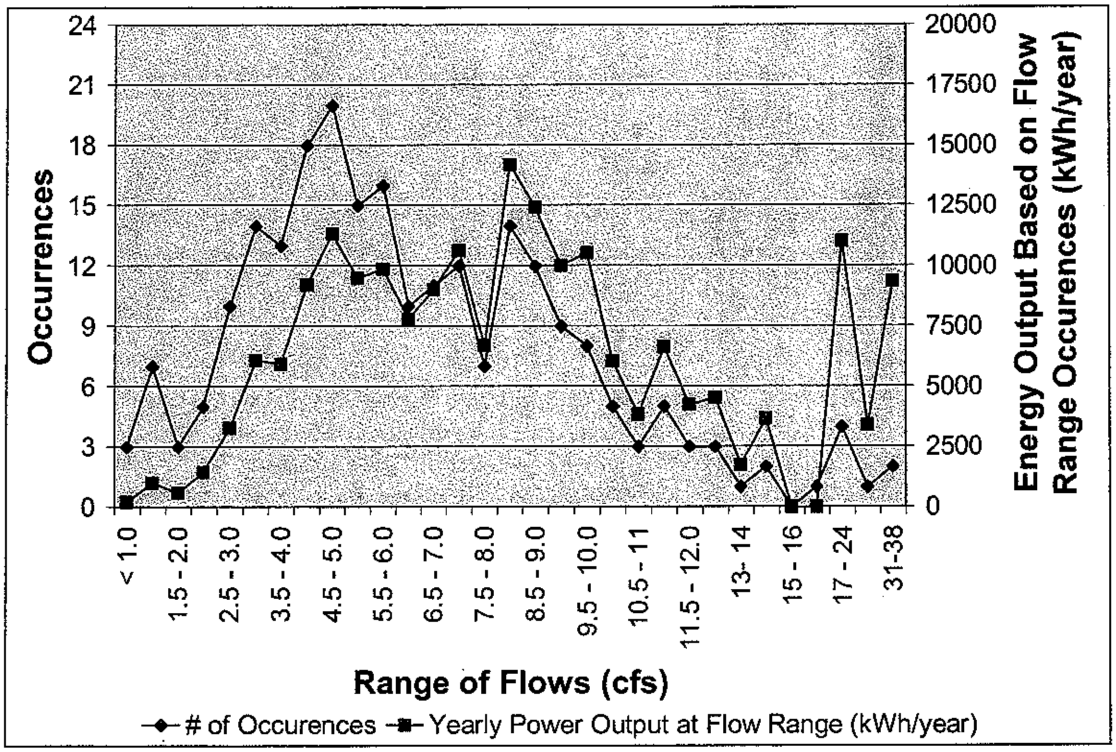

Figure V-3: Comparison of Flow Occurrences to Yearly Energy Output

The types of turbines most suited for the flow and head requirements of the project are an S-Type Kaplan unit, a Crossflow unit, and a Francis unit. Typically Francis and Crossflow turbines take up more space than the Kaplan unit. Therefore, due to the confined space available in the control house, an S-Type Kaplan Unit is the more feasible option for the project. To accommodate the wide range and frequency of flow rates from the Pony Creek Reservoir, the manufacturing of the turbine unit would typically be customized for the specific project conditions. A linear direct drive configuration is shown in the preliminary design drawings. A generic diagram of an S-Type Kaplan unit along with a turbine performance design curve is included within Appendix B. Figures V-4 and V-5 show pictures of a direct drive, S-Type Kaplan Turbine unit and the Kaplan turbine propeller, respectively. Offset belt drive configurations are also available, as shown in Appendix B. Final turbine/generator configuration selection will be made in final design.

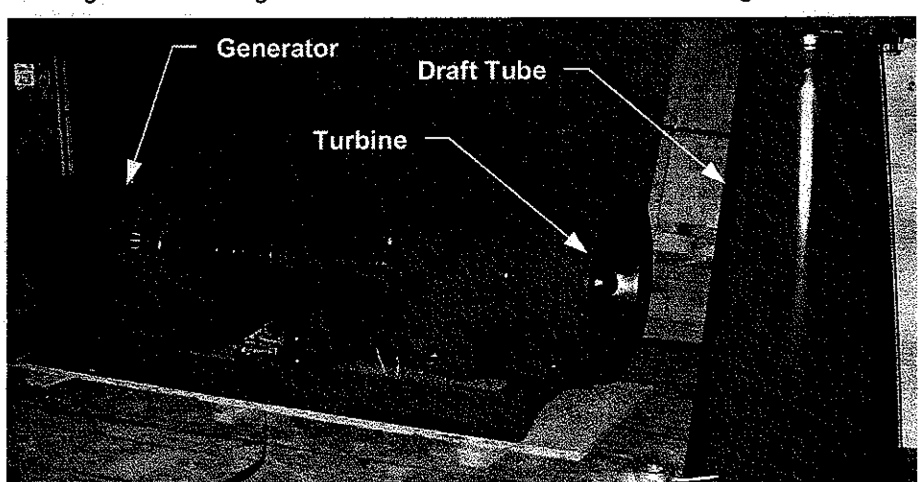

Figure V-4: S-Type Kaplan Turbine/Generator

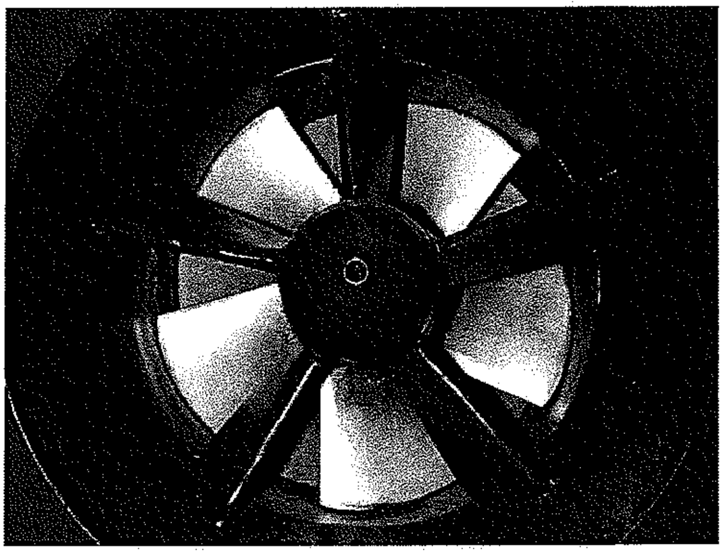

Figure V-5: S-Type Kaplan Turbine Propeller

Based on the preliminary turbine design curve in Appendix B, an estimation of the annual energy output can be made using the equation in Figure V-2. The median flow and available head values for each range of flows were used in the equation along with the corresponding efficiency for each flow based on the graph in Appendix B to determine power capacity at each flow. The power capacity was then multiplied by the percentage time of occurrences per year and 8,760 hours per year to determine the total energy output per year for each range of flow. By summing the output for each flow range, an estimated yearly energy output of approximately 139,000 kWh per year is possible when capturing all of the flows from the Pony Creek Reservoir up to 15 cfs. Flow above 15 cfs only account for 3% of the annual flow occurrences and were disregarded as these flows will most likely be bypassed to prevent damage to the turbine from the subsequent runaway speeds that might occur. Figure V-6 is a graph illustrating the estimated yearly energy output from the turbine at each flow range from the Pony Creek Reservoir.

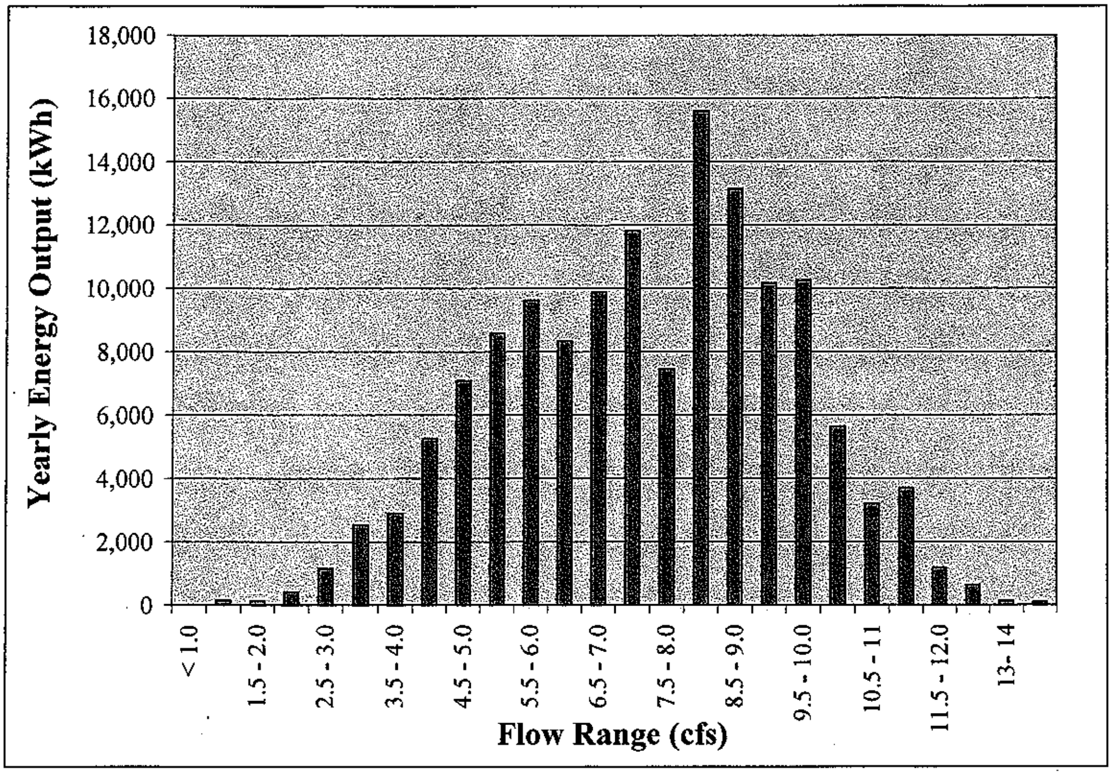

Figure V-6: Annual Projected Turbine Energy Output

VI - Construction Timeline

Until the proposed turbine, generator, and valves are on site, the existing equipment will continue to function as is does now. It is not possible to connect the piping to the existing blind flange until the turbine is in place and is securely fixed in its final location. The thrust on the Turbine Shutoff Valve (TSV) without the turbine fixed in place would distort the piping so that it would make placing the turbine/generator (T/G) in its final location impossible.

When the equipment is all securely in place, there would have to be a short outage to remove the existing blind flange to attach the flange to the new TSV and the new T/G. With the new TSV closed, the flow through the existing facilities could be restored. With everything ready to make the final connections, the transition could be completed in one day.

Testing would involve slowly opening the TSV and gradually bringing the T/G up to the design speed (called synchronous speed). If there were any problems, the TSV would be closed and the problems addressed. The startup procedure would be duplicated. If there were no problems when the T/G reached the design speed, the existing gate at the outlet could be slowly closed and the T/G could take all the water available up to the capacity of the T/G.

A list of preliminary technical specifications and final design drawings required for final construction can be found in Appendix C and D, respectively. A preliminary inventory of the construction materials, structural modifications, and instrumentation needed during construction can be found in Appendix E.

VII - Operational Characteristics

VII.1 - Normal Operation

The existing control gate and the TSV will both be automated. Normally the existing gate would be closed and the TSV would be open and all the water would go through the T/G. If there was a grid failure (power outage) closing time for the TSV and opening time for the existing gate would be coordinated to maintain the existing flow. The closing time for the TSV will be set so as to not let the T/G reach a sustained high speed that could cause damage.

When the power grid is restored, the TSV will open slowly until the T/G unit is up to speed, and then the existing gate will be slowly closed and the TSV fully opened until all the water is going through T/G again.

The entire operation will be automated and sent by SCADA to an agreed upon remote location. The entire system can be monitored and controlled remotely. There will also be remote/local hand- off-on controls at the facility so any problem can be diagnosed at the site. Power to open and control the gates during a power outage will be by a battery bank. There will be lights in the powerhouse and on the deck where the electrical equipment is located

VII.2 - Electrical Transmission Requirements

The electrical generator will convert the mechanical energy from the hydroelectric turbine to electrical energy. The preliminary design calls for a 480 volt generator. A hydraulic controller will be installed to synchronize the turbine/generator with line voltage. The power will be transmitted using a 3-phase underground conduit from the control house to the existing metering panel location, approximately 5,500 linear feet. Pull boxes will be needed every 500 feet along the transmission line for maintenance access. At the existing metering panel, a transformer will be needed to boost the 480 volt electrical output to what the power is at the water treatment plant. At this point, the existing meter will be replaced with a net meter and the electrical transmission line will be connected from the transformer to the net meter to send the electricity back to the grid. A manual disconnect switch will also be installed for utility personnel usage. A preliminary electrical one-line diagram can be found in Appendix A.

When a power failure occurs on the grid, power will be needed to close the turbine shut off valve (TSV) and to open the by pass valve to the existing outlet. That will require a small, rechargeable battery bank. A rectifier system will control charging the battery bank and transforming the DC current in the batteries to 480 volt AC. When power is restored, the gate to the existing outlet closed and the TSV ramps up to maintain reasonably uniform flow to the down stream water treatment plant.

VII.3 - Synchronous Bypass Requirements

An important aspect for this project is the provision of a synchronous bypass system in order to allow for the transfer of flows from the turbine penstock to low-flow bypass conduits in the event of a loss of power. Without this feature, the turbine could increase speed to the extent that it would cause damage if it ran at that speed for a prolonged period. This condition is called run-away speed. As the speed increases, the flow of water through the turbine is reduced. The turbine blades run so fast that the water can't enter at as high a rate as it does at the design speed (called synchronous speed). The isolating valve associated with the turbine must be closed in the event of a loss of power

The resultant change in flow can cause large pressure concentrations and waves within the system, known as a water hammer. The consequences of this situation can be detrimental to the turbine as well as piping and valves within the system.

In order to prevent water hammer, the opening and closing of valves within the system has to be synchronized to maintain a consistent pressure across the system. During emergency events or routine maintenance cycles, there may be a need to transfer flow from the proposed turbine penstock to either the existing high or low-flow bypass lines. In order to transfer flows between these lines, the TSV on the power generation conduit will need to be closed while opening the knife gate or jet flow gate on the low flow conduit. An automatic controller will be provided to automatically operate these valves in tandem.

A magnetic flow meter will be installed upstream on the control house and send a signal to the controller. In order to prevent water hammer effects, the automatic controller will open and close the valves downstream of the flow meter at a rate which maintains, as far as practicable, a consistent flow up stream of the flow meter.

It should be noted that as power is restored, the turbine can not be brought back on line immediately. It would have to be stopped and then slowly brought up to synchronous speed before being brought on line. After the unit is at synchronous speed, the speed does not change as the flow is increased. Increased flow results in increased torque and increased power.

VIII - Anticipated Maintenance

The frequency of maintenance for this turbine would include standard monthly maintenance which might include greasing of bearings, depending upon the manufacturer selected. In addition, monthly cleaning of the screen upstream of the turbine should be performed monthly to ensure efficient operation of the turbine. Major overhauls of the system should be budgeted every 10 years to replace bearings and other crucial components degraded from wear and tear. The approximate cost of a major overhaul to the system is projected to be about 50% of the total capital cost of the turbine unit itself.

IX - Preliminary Construction Cost Estimate

Table IX-1 contains a summary of the estimated construction and installation cost for the project. The current estimate for the project is $435,000. Included in this price are equipment purchase and installation, and transmission line construction and interconnection. Uncertainties regarding the transmission line and the utility interconnection warrant a contingency of 30% at this point. It is important to note the estimate does not include costs for design or inspection services.

Table IX-1: Preliminary Construction Cost Estimate

Equipment:	$ 75,000
Installation:	$210,000
Transmission line:	$ 50,000
Subtotal:	$335,000
30% Contingency:	$100,000
Total Cost:	**$435,000**

APPENDIX A
CONCEPT DRAWINGS

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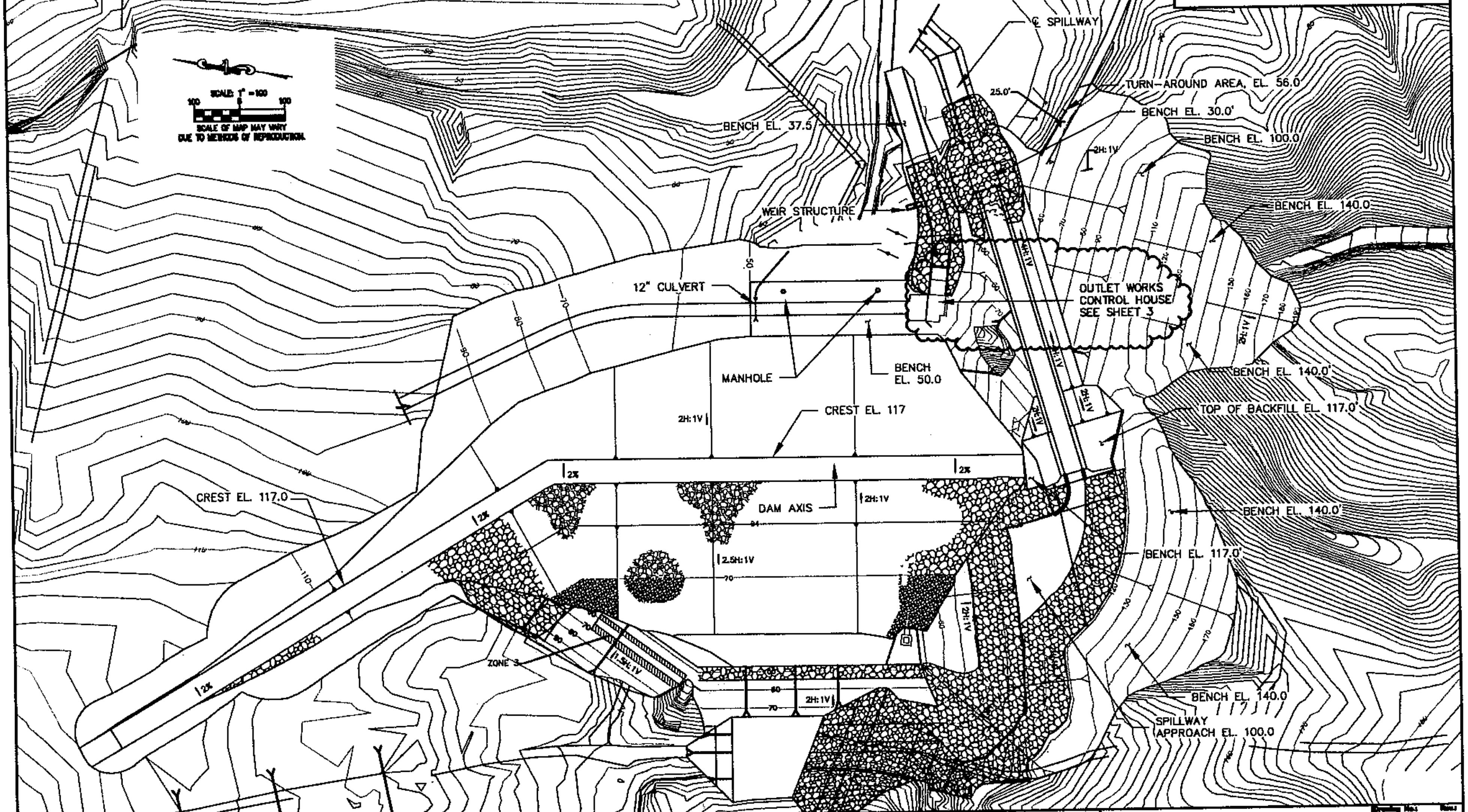
PRELIMINARY DESIGN



No.	Date	By	Chk.	Revisions

Designed By: EG
Drawn By: EG
Checked By: JH
Approved By: JH

PB PARSONS BRINCKERHOFF
400 S.W. Sixth Ave, Portland, OR 97204

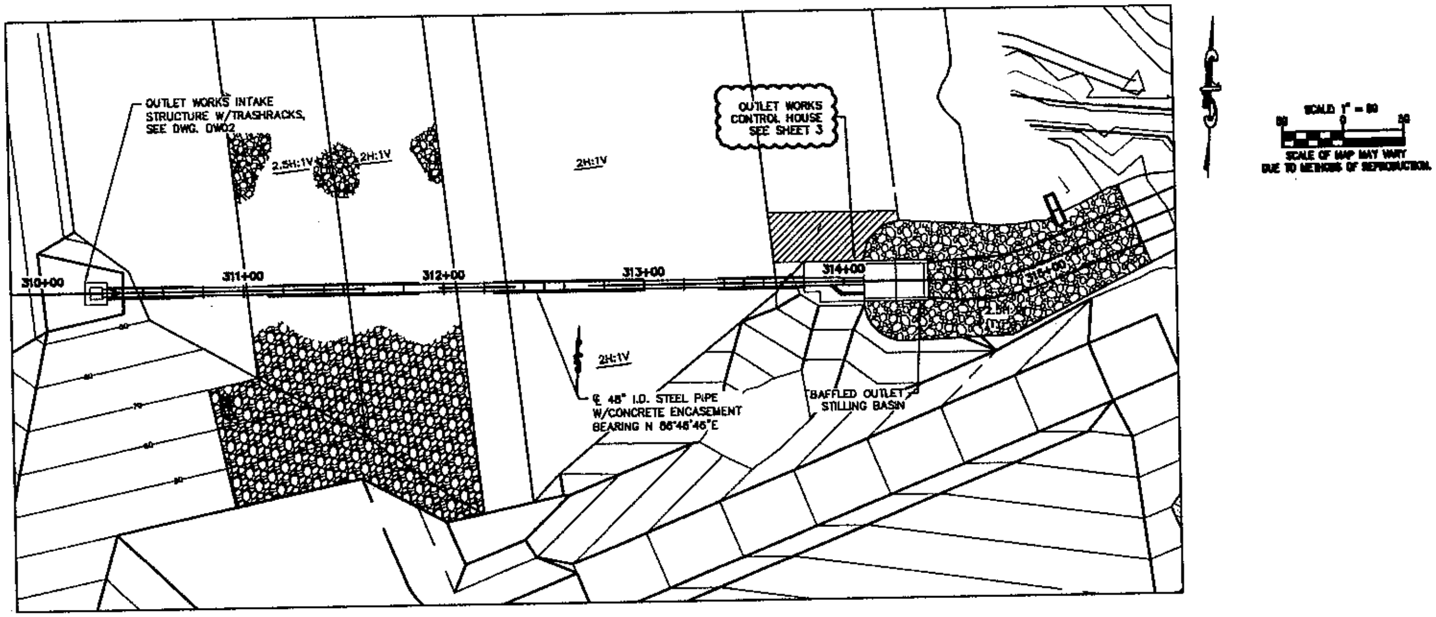
Scale: AS SHOWN
Filename: OVERALL_PLAN.dwg
Contract No.: 60401W
Date: 06/01/09

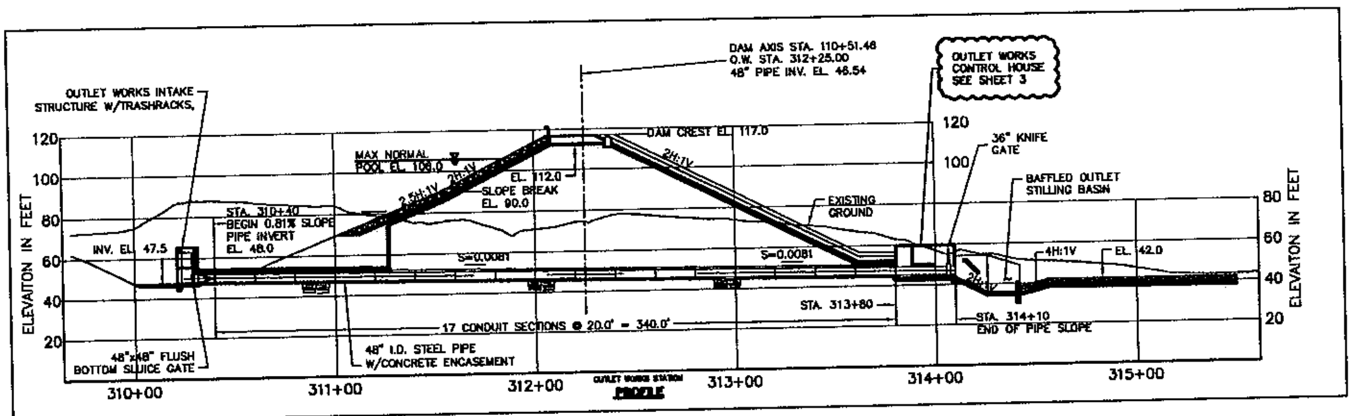
COOS BAY NORTH BEND WATER BOARD
PRELIMINARY HYDROELECTRIC SYSTEM DESIGN

SITE PLAN

Drawing No.: 1
Rev.:
Sheet No.: 1 of 3

PRELIMINARY DESIGN





No.	Date	By	Chk.	Revisions

Designed By:	EG
Drawn By:	EG
Checked By:	JH
Approved By:	JH

PB PARSONS BRINCKERHOFF
400 S.W. Sixth Ave, Portland, OR 97204

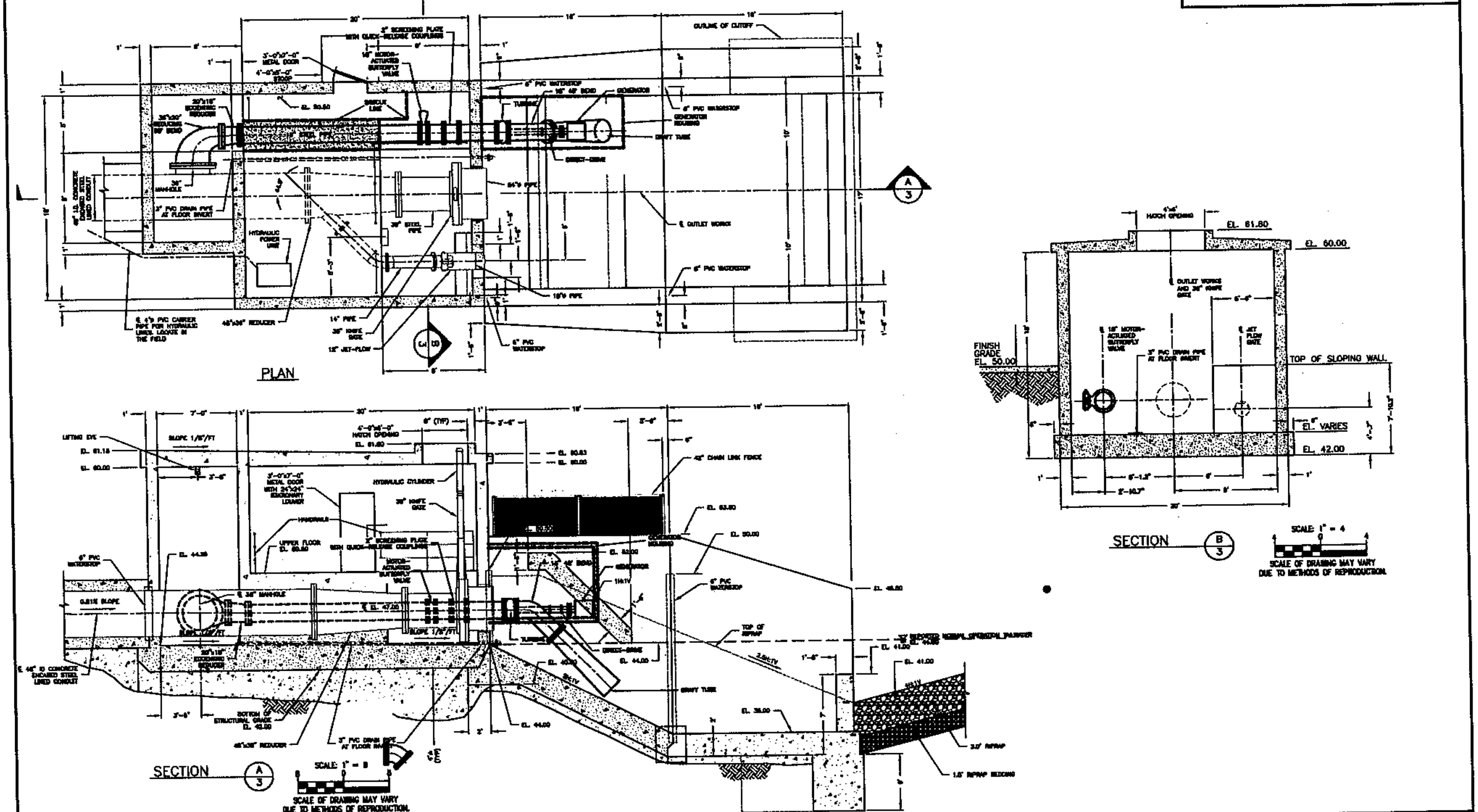
Scale:	AS SHOWN
Filename:	OVERALL_SECTION.dwg
Contract No.:	80401W
Date:	06/01/09

COOS BAY NORTH BEND WATER BOARD
PRELIMINARY HYDROELECTRIC SYSTEM DESIGN

OVERALL SECTION

Drawing No.: 1
Rev.:
Sheet No.: 2 of 3

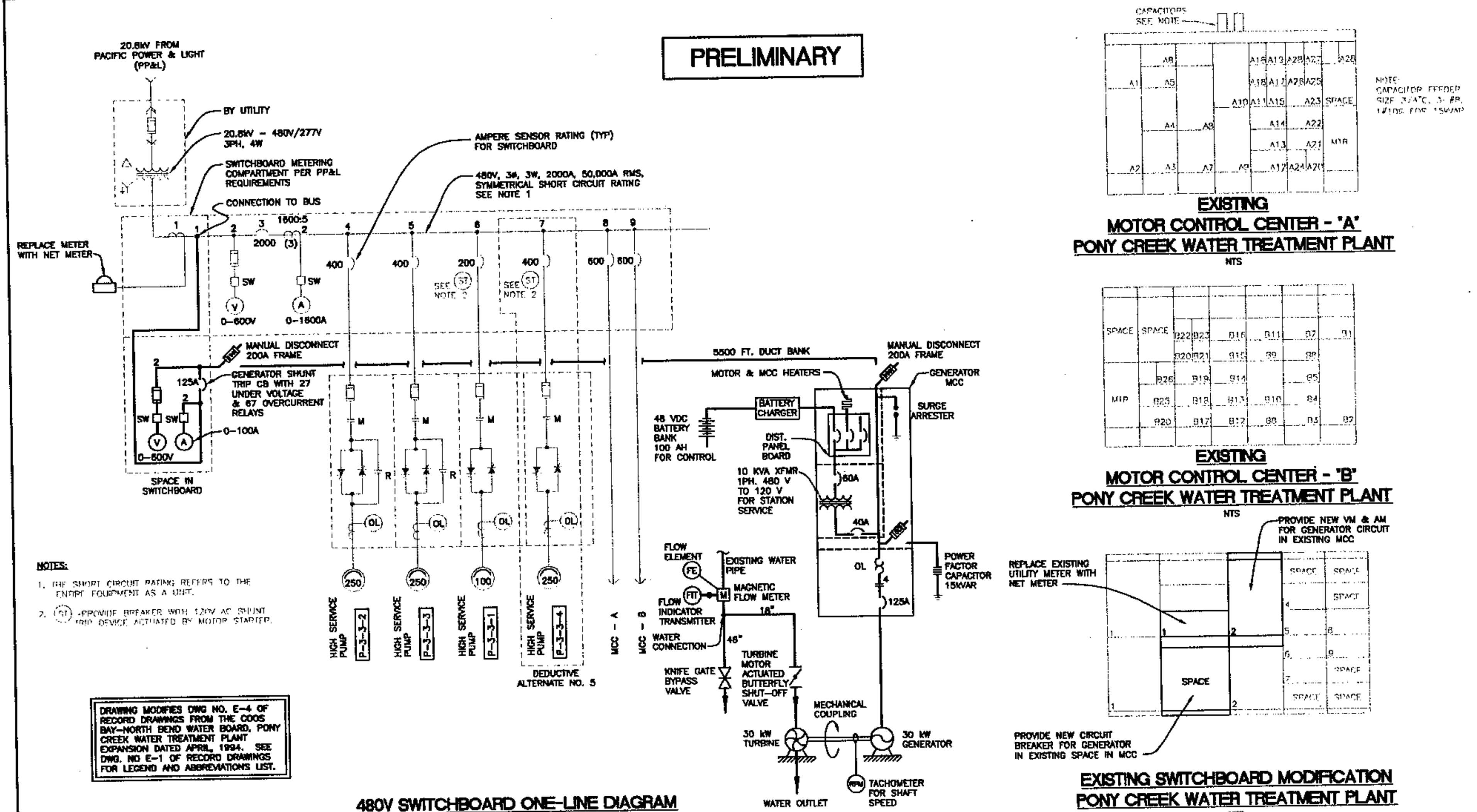
PRELIMINARY DESIGN



Designed By: EG	Scale: AS SHOWN	COOS BAY NORTH BEND WATER BOARD	Drawing No.: 3
Drawn By: EG	Filename: CONTROL_PLAN.dwg	PRELIMINARY HYDROELECTRIC SYSTEM DESIGN	Rev.:
Checked By: FE	Contract No.: 80401W	PROPOSED SECTIONS	Sheet No.: 3 of 3
Approved By: JH	Date: 06/01/09		

PB PARSONS BRINCKERHOFF
400 S.W. Sixth Ave. Portland, OR 97204

PRELIMINARY



NOTES:

1. THE SHORT CIRCUIT RATING REFERS TO THE ENTIRE EQUIPMENT AS A UNIT.
2. (ST) -PROVIDE BREAKER WITH 120V AC SHUNT TRIP DEVICE ACTUATED BY MOTOR STARTER.

DRAWING MODIFIES DWG NO. E-4 OF RECORD DRAWINGS FROM THE COOS BAY-NORTH BEND WATER BOARD, PONY CREEK WATER TREATMENT PLANT EXPANSION DATED APRIL, 1994. SEE DWG. NO E-1 OF RECORD DRAWINGS FOR LEGEND AND ABBREVIATIONS LIST.

No.	Date	By	Chk.	Revisions
0	10/05/09	EMC	FSW	PRELIMINARY SUBMITTAL FOR REVIEW

Designed By: F. WALIEDDINE
Drawn By: E. CANTILLER
Checked By:
Approved By:

PB PARSONS BRINCKERHOFF
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Scale: N.T.S.
Filename:
Contract No.:
Date:

ELECTRICAL SWITCHBOARD
ONE LINE DIAGRAM, ELEVATIONS

Drawing No.: E-4A
Rev.:
Sheet No.: 1 of 1

Appendix B
Hydroelectric Facility Diagram & Performance Curve

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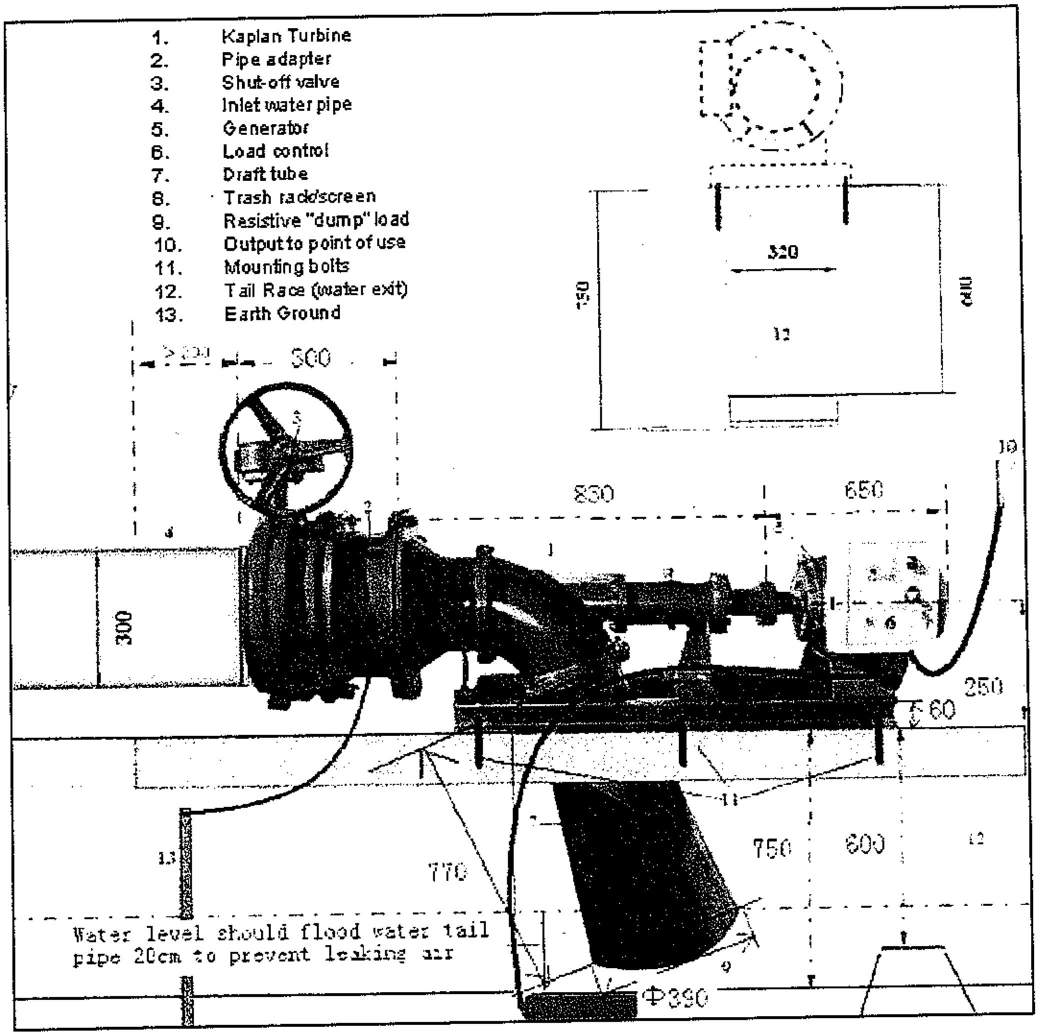

Figure B-1: Direct Drive, Inline Turbine/Generator Configuration

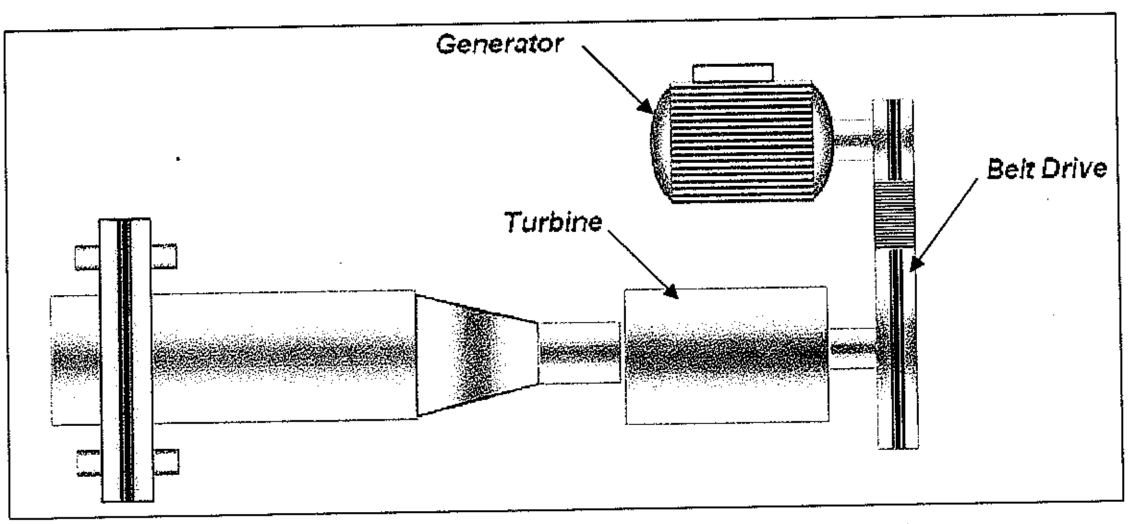

Figure B-2: Offset Belt Drive Turbine/Generator Configuration

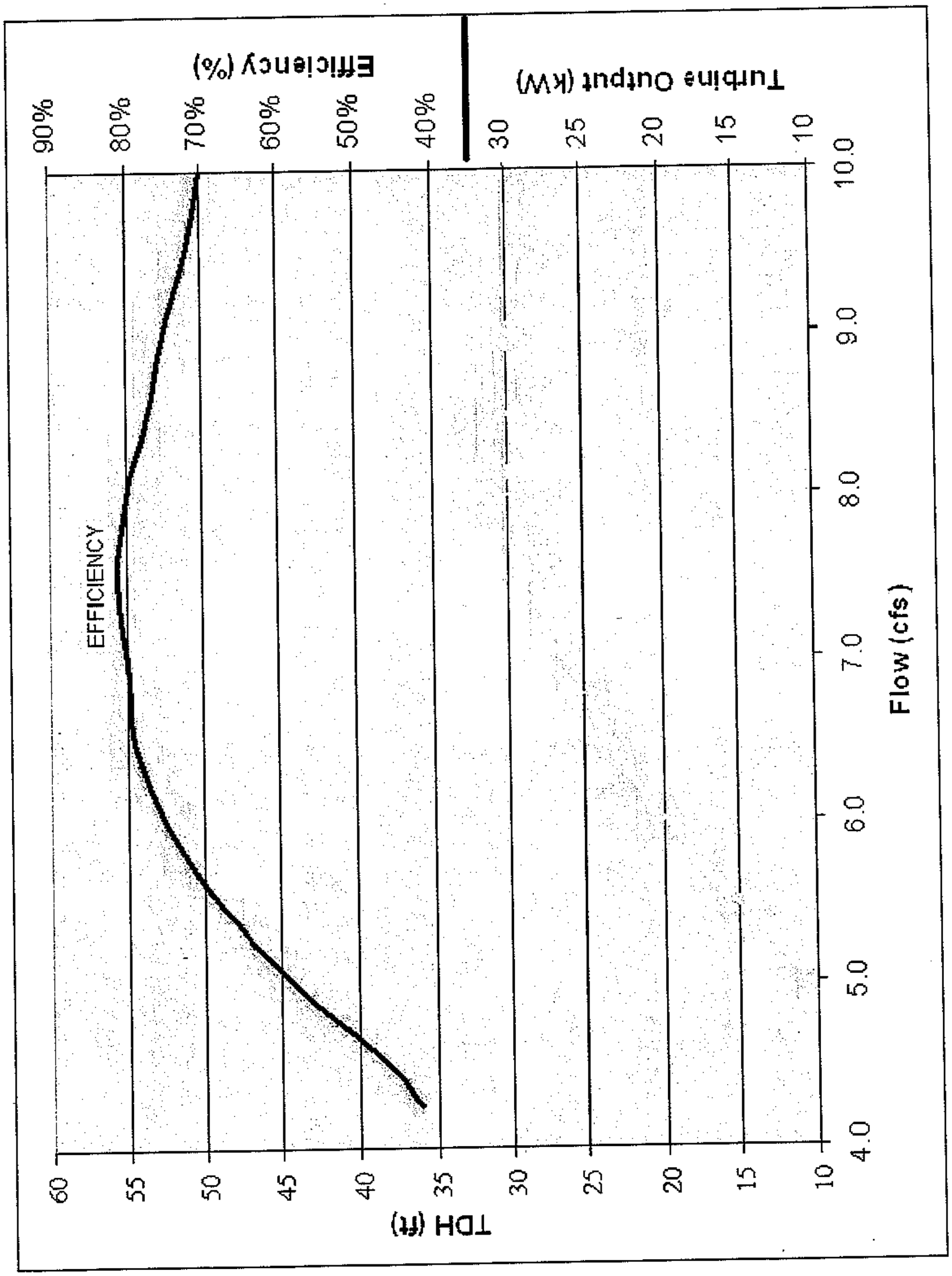

Figure B-3: Turbine Power Output/Efficiency Chart

Table B-1: Preliminary Hydroelectric Turbine Power Output Table

Flow Ranges	Median Flow within Range (cfs)	Median Head within Range (ft)	% of Occurrences	Efficiency	Power Capacity (kW)[1]	Yearly Energy Generation (kWh)[2]	Cumulative Energy Generation (kWh)
< 1.0	0.58	56.7	1.3%	5%	0.1	15	15
1.0 - 1.5	1.22	53.5	3.0%	10%	0.6	143	158
1.5 - 2.0	1.64	53.8	1.3%	15%	1.1	124	283
2.0 - 2.5	2.34	55.3	2.1%	20%	2.2	405	687
2.5 - 3.0	2.73	53.6	4.2%	25%	3.1	1,145	1,832
3.0 - 3.5	3.29	58.8	5.9%	30%	4.9	2,540	4,372
3.5 - 4.0	3.73	54.6	5.5%	35%	6.0	2,896	7,268
4.0 - 4.5	4.29	53.1	7.6%	41%	7.9	5,258	12,526
4.5 - 5.0	4.79	52.6	8.4%	45%	9.6	7,090	19,616
5.0 - 5.5	5.24	53.7	6.3%	65%	15.5	8,584	28,200
5.5 - 6.0	5.81	47.3	6.8%	70%	16.3	9,627	37,827
6.0 - 6.5	6.28	55.2	4.2%	77%	22.6	8,346	46,173
6.5 - 7.0	6.83	53.3	4.6%	79%	24.3	9,887	56,060
7.0 - 7.5	7.25	54.3	5.1%	80%	26.6	11,820	67,880
7.5 - 8.0	7.94	53.6	3.0%	80%	28.8	7,457	75,337
8.0 - 8.5	8.22	54.9	5.9%	79%	30.1	15,599	90,936
8.5 - 9.0	8.79	52.4	5.1%	76%	29.6	13,136	104,072
9.0 - 9.5	9.25	53.5	3.8%	73%	30.5	10,162	114,234
9.5 - 10.0	9.76	59.9	3.4%	70%	34.6	10,244	124,478
10.0 - 10.5	10.21	52.8	2.1%	67%	30.6	5,649	130,127
10.5 - 11	10.89	52.3	1.3%	60%	28.9	3,204	133,331
11.0 - 11.5	11.08	53.3	2.1%	40%	20.0	3,698	137,029
11.5 - 12.0	11.88	52.9	1.3%	20%	10.6	1,179	138,208
12 - 13	12.77	52.4	1.3%	10%	5.7	628	138,836
13- 14	13.22	59.0	0.4%	5%	3.3	122	138,959
14 - 15	14.54	56.1	0.8%	2%	1.4	102	139,061

1: $\text{Power Capacity} = \frac{\text{(Median Flow Rate * Specific Weight of Water * Median Head)}}{550} * 0.746 * \text{Efficiency}$

2: Yearly Energy Generation = Power Capacity * 8,760 hrs/year * % of Occurrences

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APPENDIX C
LIST OF SPECIFICATIONS

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DIVISION 02 - EXISTING CONDITIONS	
20100	SITE PLAN
20101	LOCATION OF FACILITIES
24119	SELECTIVE STRUCTURE DEMOLITION
DIVISION 03 - CONCRETE	
30130	MAINTENANCE OF CAST-IN-PLACE CONCRETE
33000	CAST-IN-PLACE CONCRETE
33001	CONCRETE GROUT
35300	CONCRETE TOPPING
DIVISION 05 - METALS	
55100	METAL STAIRS
55213	PIPE AND TUBE RAILINGS
55300	METAL GRATINGS
DIVISION 11 - EQUIPMENT	
110101	SUPPLY AND INSTALL 30 kW TURBINE
110201	SUPPLY AND INSTALL 30 KW GENERATOR
110301	SUPPLY AND INSTALL ALL RELATED VALVES AND PIPING
DIVISION 22 - PLUMBING	
220500	COMMON WORK RESULTS FOR PLUMBING
220513	COMMON MOTOR REQUIREMENTS FOR PLUMBING EQUIPMENT
220519	METERS AND GAGES FOR PLUMBING PIPING
220523	GENERAL-DUTY VALVES FOR PLUMBING PIPING
220553	IDENTIFICATION FOR PLUMBING PIPING AND EQUIPMENT
DIVISION 26 - ELECTRICAL	
260513	MEDIUM-VOLTAGE CABLES
260523	CONTROL-VOLTAGE ELECTRICAL POWER CABLES
260526	GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS
260529	HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS
260533	RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS
260536	CABLE TRAYS FOR ELECTRICAL SYSTEMS
260543	UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS
260544	SLEEVES AND SLEEVE SEALS FOR ELECTRICAL RACEWAYS AND CABLING
260548	VIBRATION AND SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS
260553	IDENTIFICATION FOR ELECTRICAL SYSTEMS
260573	OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY
260913	ELECTRICAL POWER MONITORING AND CONTROL
261116	SECONDARY UNIT SUBSTATIONS
261200	MEDIUM-VOLTAGE TRANSFORMERS

261300	MEDIUM-VOLTAGE SWITCHGEAR
262600	POWER DISTRIBUTION UNITS
262713	ELECTRICITY METERING
262726	WIRING DEVICES
262816	ENCLOSED SWITCHES AND CIRCUIT BREAKERS
262913	ENCLOSED CONTROLLERS
263600	TRANSFER SWITCHES
264200	CATHODIC PROTECTION
265100	SCADA
266000	CONNECTION TO EXISTING ELECTRICITY GRID
267000	EXCAVATION AROUND ELECTRICAL UTILTIES
DIVISION 28 - ELECTRONIC SAFETY AND SECURITY	
280513	CONDUCTORS AND CABLES FOR ELECTRONIC SAFETY AND SECURITY
280544	SLEEVES AND SLEEVE SEALS FOR ELECTRONIC SAFETY AND SECURITY PATHWAYS AND CABLING
281300	ACCESS CONTROL
281600	INTRUSION DETECTION
DIVISION 33 - UTILITIES	
330500	COMMON WORK RESULTS FOR UTILITIES
337149.13	OVERHEAD MEDIUM-VOLTAGE WIRING
337753	MEDIUM-VOLTAGE UTILITY RECLOSERS

APPENDIX D
LIST OF DESIGN DRAWINGS

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CIVIL FACILITIES

1 TITLE SHEET AND LOCATION MAP
2 LIST OF DRAWINGS
3 GENERAL NOTES AND ABREVATIONS
4 ACCESS TO THE EXISTING POWERHOUSE
5 GENERAL PLAN OF THE EXISTING POWERHOUSE
6 GENERAL PLAN AND TYPICAL SECTIONS OF THE PROPOSED NEW TURBINE AND GENERATOR
7 DRAWING OF THE PROPOSED PENSTOCK CONNECTION TO THE NEW TURBINE AND GENERATOR
8 REQUIRED CONCRETE DEMOLITION AND OPERATION DURING CONSTRUCTION
9 DEWATERING REQUIREMENTS FOR CONSTUCTION OF THE NEW TURBINE AND GENERATOR
10 DETAILS OF THE PENSTOCK CONNECTION TO THE EXISTING PIPE AND GATE DETAILS OF THE PENSTOCK CONNECTION TO THE POWERHOUSE
11 DETAILS OF THE PENSTOCK DIMENSIONS, BEND ANGLES, LOCATIONS AND PIPE SUPPORTS
12 EQUIPMENT OUTLINES AND DETAILED DIMENSIONS
13 MISCELANIOUS STRUCTURAL DETAILS
14 DETAILS OF PERSONELL ACCESS, HAND RAILS, STAIRS AND OTHER SAFETY REQUIREMENTS
15 PROVIDE EROSION CONTROL AROUND THE OUTLET OF THE NEW TURBINE AND GENERATOR

ELECTRICAL FACILITIES

1 ELECTRICAL SYMBOLS, ABBREVIATIONS
2 GENERAL SITE LAYOUT FOR THE ELERICAL WORK
3 LOCATION OF ALL OF THE ELETRICAL EQUIPMENT
4 SINGLE LINE DISGRAM NUBBER 1
5 SINGLE LINE DISGRAM NUBBER 2
6 STATION SERVICE PLANS NUBBER 1
7 STATION SERVICE PLANS NUMBER 2
8 THREE LINE DIAGRAMS NUBBER 1
9 THREE LINE DIAGRAMS NUBBER 2
10 ELEMENTARY DIAGRAMS NUBBER 1
11 ELEMENTARY DIAGRAMS NUBBER 2
12 SCADA DIAGRAM
13 SCADA ENCLOSURE
14 INTERCONNECTION DIAGRAMS NUBBER 1
15 INTERCONNECTION DIAGRAMS NUBBER 2
16 CONDUIT PLANS AND GROUNDING DETAILS NUBBER 1
17 CONDUIT PLANS AND GROUNDING DETAILS NUBBER 2
18 LIGHTING AND STATION SERVICE
19 MISCELANIOUS ELETRICAL DETAILS
20 CONTROL DIAGRAMS NUBBER 1
21 CONTROL DIAGRAMS NUBBER 2
22 AC AND DC PANELBOARD SCHEDULES
23 LAY OUT OF THE UNDER GROUND ELETRICAL SERVICE
24 DETAILS OF THE UNDER GROUND ELETRICAL SERVICE NUBBER 1
25 DETAILS OF THE UNDER GROUND ELETRICAL SERVICE NUBBER 2
26 INTERFACE WITH THE EXISTING POWER SUPPLY

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