In-Conduit Hydropower Project – Phase I Report

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Submitted to:

Executive Office of Energy & Environmental Affairs
Department of Environmental Protection

August 2013

ALDEN RESEARCH LABORATORY, INC.

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1 BACKGROUND

Massachusetts has more than 600 public water systems (PWS) and publically-owned treatment works (POTW) wastewater facilities that could potentially benefit from the installation of an in-line hydropower system. As the energy costs for operating these facilities can often be quite high, the ability to offset some or all of that cost by harnessing the energy dissipated by a pressure reducing valve or other head drop through the system can provide substantial benefits. Furthermore, these projects help to meet the State of Massachusetts' Renewable Portfolio Standard (RPS) goal and reduce dependency on foreign energy sources.

Existing PWS and POTW facilities offer a unique opportunity to harness the renewable energy of flowing water. Furthermore, there is a potential to generate the energy in both an environmentally- and financially-conscience manner. Hydropower generation can be contentious with regard to the potential environmental impacts associated with the construction of new dams and the passage issues. However, the installation of a turbine into an existing, operating facility would allow for electricity generation without incurring negative impacts associated with hydropower.

When generating hydroelectric power, there are several factors which make the business challenging, including permitting, energy value and flow rates. Hydro generation at PWS and POTW facilities has significant advantages over traditional hydropower projects for several reasons. Hydropower is typically regulated by the Federal Energy Regulatory Commission (FERC) and the permitting associated with conventional hydroelectric projects can be burdensome, particularly for small projects. FERC conduit exemptions allow for a streamlined permitting process for projects in which the flow conveyance conduit is primarily used for non-power purposes, as would be the case at a PWS or POTW facility. The ability to utilize the FERC conduit exemption will reduce the permitting burden through a streamlined process and reduced project boundary. The value of energy will fluctuate as a function of supply and demand when sold on the open market to the electric grid. A review of ISO New England value of energy generated indicates an average of about $0.04/kWh, which is significantly lower than the approximate $0.07-$0.15/kWh paid for electricity used at the treatment facilities. Therefore, if the electricity generated can be used on-site to offset electricity which would otherwise cost $0.07-$0.15/kWh, it has now retained that higher value with significantly less or no variation. Finally, conventional hydropower is subject to the natural hydrologic cycle for generation, typically resulting in extended periods of low generation (summer) and low revenue. Conduit hydropower projects located in PWS and POTW facilities are not subject to the hydrologic cycle as flow is a function of plant operation and demand, reducing unpredictable periods of low generation.

The potential benefit of in-line conduit hydropower projects for PWS and POTW facilities is clear. However, the technological challenges associated with development can be complex. The head and flow regimes of these sites present challenges as they are not typically within the design range of most conventional turbines, making the identification of an acceptable turbine challenging. Furthermore, a superior understanding of the host facility is critical to ensuring that the hydropower options do not impact the primary operations of the PWS and POTW facilities.

This report summarizes an investigation of existing turbine technologies which may be applicable to PWS and POTW facilities. In addition, it summarizes an investigation into the characteristics of existing in-conduit hydropower installations.

2 OBJECTIVE

The objective of this report is to provide summary data on available generating technologies as well as existing installations to serve as guidance for potential developers. The summary of technologies is intended to assist in identifying suitable turbines as a function of the site characteristics as well as the anticipated head and flow conditions. The case studies provide a unique insight into project challenges while developing an understanding of typical installation configurations, cost and technology data. Ultimately, this information will allow for some cost savings and efficiency to potential project developers as they complete initial studies.

3 REVIEW OF CURRENT IN-LINE HYDROPOWER TECHNOLOGIES

3.1 Methodology

The review of in-line hydropower technologies commenced with a review of Alden's internal library and electronic database of hydropower resources. In addition, web-based reviews of technological information from professional journals and scholarly proceedings were reviewed for pertinent information. Specific reviews were completed for manufacturer literature, Federal Energy Regulatory Commission (FERC) submittals and case study information. Reviews focused on identifying technologies applicable to high head/low flow conditions or low head/high flow conditions which would be applicable to PWSs and POTWs, respectively. Technologies identified were investigated for a variety of parameters including operating requirements, installation requirements, commercial availability, system requirements (head and flow range), efficiency, costs, and power output. Following an initial review of informational sources, a survey was developed and submitted directly to the manufacturers for additional input.

3.2 Findings

Following identification of potential technologies, investigation was completed to better understand the technology including its operational characteristics and applicability to PWS and POTW installations. Table 1 summarizes information available for the identified technologies. In addition to conventional hydroelectric turbines which harness energy utilizing head pressure, hydrokinetic (HKE) turbines have been identified as a potential technology for very low head sites. HKE turbines generate as a function of water velocity rather than head pressure.

Table 1. Summary of Identified Technologies

Company	Potential Application	Turbine Type	Technology Name/Model	Head Range	Flow Range	Unit Size	Power Output Range	Water Speed	Lab/Pilot Tests Conducted	Installations	Commerc-ially Available	Approximate Cost (USD)
ABS Alaskin Inc.	POTW	Reaction, propeller	The Aquair UW Hydro	≥ 1.5 ft	N/A	N/A	0.06 kW (8.8 f/s) 0.1 kW (13.2 f/s)	≥ 3 f/s	--	--	Yes	$1,500
ABS Alaskin Inc.	PWS	Impulse, Pelton	The Harris Pelton	Approx. 5-300 ft	0.01 - 0.3 cfs	--	≤ 1 kW	N/A	--	--	Yes	$2,000
ABS Alaskin Inc.	PWS	Impulse, turgo	The Water Baby Turbine	50-500 ft	0.01 -0.07 cfs	2 in ø	0.025-0.250 kW	N/A	--	--	Yes	--
Alternative Hydro Solutions	PWS	HKE	Darrieus Water Turbine	≤ 4 ft	--	5-10 ft ø	1-4kW	V ≥ 2.5 f/s	--	No	Yes	Varries depending on water speed
Atlantis Resources Corporation	POTW	HKE	AN series	N/A	N/A	--	--	--	Yes	--	Yes	--
Canyon	PWS, POTW	Various	Various	30-3000 ft	0.5-500 cfs	Varies	5-25,000 kW	N/A	Yes	About 30 PWS & POTW installations	Yes; 24-56 weeks lead time	$250/kW - $5,000/kW
Cornell Pump Co	PWS, POTW	Pump as Turbine (PAT)	Various	30-500 ft	0.5 - 17 cfs	12.5-38 in ø	10-350 kW	N/A	Yes	Yes	Yes	5 K – 50 K based on standard materials and configuration
Energy Systems Design	POTW	Reaction propeller	The LH-1000 Hydro	2-10 ft	1-2.2 cfs	--	0.09 -1 kW	N/A	--	--	Yes	$3,000-$4,000

Company	Potential Application	Turbine Type	Technology Name/Model	Head Range	Flow Range	Unit Size	Power Output Range	Water Speed	Lab/Pilot Tests Conducted	Installations	Commerc-ially Available	Approximate Cost (USD)
Energy Systems Design	PWS, POTW	Impulse, Turgo	The Stream Engine Hydro	10-200 ft	0.02 -0.2 cfs	--	≤ 1 kW	N/A	--	--	Yes	--
Gault Green Energy	PWS, POTW	Reaction	--	9.8-20 ft	14-190 cfs	1.5-5 ft ø	11-285 kW	N/A	--	Various	Yes	--
GCK Technology	POTW	HKE	Gorlov Helical	N/A	N/A	--	--	≥2 ft/s	Yes	Amazon River, Brazil; Uldolmok Strait, South Korea	Yes	--
Gilkes	PWS, POTW	Reaction, propeller, Kaplan	Kaplan	High and Low	--	--	--	N/A	--	Yes	Yes	--
Hydrocoil Power, Inc.	PWS, POTW	Reaction, Screw-	Helical Hydrocoil Turbine	13-66 ft	--	6-12 in ø	2-8 kW	N/A	--	--	Yes	--
Hydrovolts	POTW	Reaction	WF-10-15-Waterfall	6-16 ft	Flow ≥ 8 cfs	Width - 5 ft Depth - 4 ft	2-14 kW	N/A	--	Delta Diablo Sanitation District, West Sound Utility District	Yes	LCOE[1] between $.03-$.08, depending on site
Hydrowatt	POTW	Reaction, waterwheel	Overshot, breastshot	3-32 ft	3.5-250 cfs	--	--	N/A	--	--	--	--
Leffel	PWS	Francis	Various	--	--	--	--	N/A	Yes	Various	Yes	--

[1] Levilized cost of energy (LCOE)

Company	Potential Application	Turbine Type	Technology Name/Model	Head Range	Flow Range	Unit Size	Power Output Range	Water Speed	Lab/Pilot Tests Conducted	Installations	Commerc-ially Available	Approximate Cost (USD)
Lucid	PWS, POTW	Vertical axis spherical	LucidPipe	3-13 ft	18-94 cfs	Pipe ø: 2-8 ft	16-50 kW	N/A	Yes	Lemona Pump Station - Riverside, CA	Yes	$0.04 to $0.08 per kWh LCOE
Mavel	POTW	Reaction, propeller, kaplan	TM3, TM5, TM10	5-20 ft	5-175 cfs	13-40 in ø	0.7-180 kW	N/A	Yes	Poland, Japan, and Latvia	Yes	--
Natel Energy	POTW	Reaction	Hydroengine, Models: SLH-10, 50, 100, 200, 500	6.6 -20 ft	20-1,550 cfs	31-63 in ø	32-1,300 kW	N/A	Yes; at Alden	Buckeye, AZ.	Yes for the SLH 10 and SLH 100.	± $700/kW
Ossberger	PWS, POTW	Crossflow	Ossberger Crossflow	8 -600 ft	10-460 cfs	11.8-49 in ø	10-3,000 kW	N/A	Yes	yes	Yes	>250/kW (Turbine only)
PowerPal	PWS	Turgo	T1, T2, T5, T8, T16	25-100 ft	0.7 – 2.8 cfs	--	0.6-20 kW	N/A	--	Yes	Yes	--
Rainbow Power	PWS	Impulse, Pelton	Hyd-200	23-492 ft	≤ 0.1 cfs	--	--	N/A	--	--	Yes	$3,000
Ritz-Atro	POTW	Reaction, Screw-type	Hydrodynamic Screw Turbine	≤ 33 ft	Flow ≤ 200 cfs	--	≤ 300	N/A	--	Yes	Yes	--
Tidal Energy Pty Ltd.	POTW	HKE	Davidson-Hill Venturi (DHV) Turbine	N/A	N/A	5-33 ft ø	4.6-5,500 kW	6.5-20 f/s	Yes	QSEIF Grant Sea, Australia	Yes	$110,000 for 5 ft ø

Company	Potential Application	Turbine Type	Technology Name/Model	Head Range	Flow Range	Unit Size	Power Output Range	Water Speed	Lab/Pilot Tests Conducted	Installations	Commerc-ially Available	Approximate Cost (USD)
Toshiba	PWS	Reaction, kaplan	Hydro-eKIDS	6-14 ft	3-150 cfs	2.5-6.3 in ø	5-200 kW	N/A	Yes	POTW & PWS facilities	Yes	--
VLH	POTW	Reaction, propeller	VLH	4.6-10.5 ft	0.8-2.4 cfs	12-18 ft ø	114-496 kW	N/A	Yes	No	No	--
Voith	PWS	Reaction, propeller, Kaplan	Ecoflow	10-20 ft	30-150 cfs	11.4-30 in ø	25-175kW	N/A	Yes	Yes	Yes	--
Walker Wellington LLC.	PWS, POTW	Reaction	W4e	≥ 5 ft	≥1.5 cfs	20-84 in ø	3-500 kW	N/A	Yes; at Alden	Dover, NH POTW	Yes	>$30,000 depending on size

Table 1 identifies 28 technologies with potential for PWS or POTW installations. These turbines range from operating flow conditions of 0.8 cfs to over 2,000 cfs and a range of head from 1.5 ft to over several hundred feet. Although extensive efforts have been made to identify suitable turbine technologies and manufacturers, this table does not necessarily represent every manufacturer. Should a potential project move forward to a feasibility analysis stage, it is prudent to complete a review of any new technologies as well as to contact those in Table 1 for their most recent technology data.

4 REVIEW OF EXISTING HYDROPOWER PROJECTS AT PWS & POTW FACILITIES

4.1 Methodology

A review of FERC authorized in-line/conduit projects in New England was completed to identify those which are representative of potential PWS or POTW hydropower developments in Massachusetts. Although the head and flow conditions at PWS and POTW systems can vary significantly, it has been assumed that potential projects for application will be 200 kW or less. There are some existing projects in Massachusetts that exceed this threshold; however, they are all within the Massachusetts Water Resources Authority (MWRA) system which is not generally representative of potential developments throughout the state.

Following identification of suitable projects in New England, an additional review of authorized projects was completed in an effort to gain supplementary insight into project developments. Reviews looked at identifying projects throughout the country which fit the criteria discussed above. Focus was made on projects which were developed within the last 20 years as these projects will be more representative of the regulatory environment and technologies that are currently available.

Following identification of projects, research was completed on the FERC elibrary[2] to investigate project characteristics including the development type, generation equipment, head, flow, power, and energy associated with each project as well as the installation configuration and any potential environmental issues associated with the project. In addition, information such as the equipment manufacturer, installation contractor, capital cost, operation and maintenance (O&M) costs, incentives utilized, O&M level of effort, general performance, and challenges were investigated. Finally, information pertaining to how the hydropower system was integrated into the PWS/POTW system, including any impacts was look into.

Information discovered was primarily found in permitting documents such as the FERC exemption application. Investigation also included contacting project representatives. A survey was developed to assist project representatives in providing the requested information; however, often it was not required as phone correspondence was adequate. It should be noted that some information obtained through the elibrary represents the permitted conditions which may vary slightly from the as-built conditions.

4.2 Project Identification

There are a total of 236 FERC authorized conduit exemption projects listed by FERC[3]. Of these projects, there are a total of 7 operational projects located in Massachusetts as shown in Table 2. Three projects are less than 200 kW while four exceed the power threshold. The majority of the

[2] http://elibrary.ferc.gov/idmws/search/fercgensearch.asp
[3] http://www.ferc.gov/industries/hydropower/gen-info/licensing/exemptions.asp

projects are located within water supply systems; however, the Deer Island Project is located at the effluent channel of the Deer Island wastewater treatment facility.

Table 2. Summary of FERC authorized conduit exemption projects in Massachusetts

Docket Number	Project Name	Authorization Issue Date	Authorized Capacity (KW)	Licensee	Waterway
13658	COLTSVILLE FLOW CONTROL STATION	04/23/10	66	CITY OF PITTSFIELD (MA)	CLEVELAND RESERVOIR
14483	SACKETT FILTRATION PLANT	03/27/13	80	WESTFIELD WATER RESOURCES DEPT	SACKETT FILTRATION PLANT
13400	LORING ROAD	08/07/09	200	MASSACHUSETTS WATER RES AUTH (MA)	
9983	ASHLEY RESERVOIR	02/11/87	225	CITY OF PITTSFIELD (MA)	ASHLEY RESERVOIR
11412	DEER ISLAND	11/09/93	2000	MASSACHUSETTS WATER RES AUTH (MA)	DEER ISLAND TREATMENT PLANT
10688	COSGROVE	01/19/90	3400	MASSACHUSETTS WATER RES AUTH (MA)	WACHUSETT RESERVOIR
10689	OAKDALE	01/19/90	3500	MASSACHUSETTS WATER RES AUTH (MA)	WACHUSETT RESERVOIR

New England has a total of 12 in-conduit POW/POTW hydropower facilities of which six are 200 kW or less in power capacity. These projects are listed Table 3 and are the projects identified for further investigation.

Table 3. Summary of FERC authorized conduit exemption projects in New England with a maximum capacity of 200 kW identified for review

Docket Number	Project Name	Issue Date	Authorized Capacity (KW)	Licensee	Waterway	ST
13658	COLTSVILLE FLOW CONTROL STATION	04/23/10	66	CITY OF PITTSFIELD (MA)	CLEVELAND RESERVOIR	MA
14483	SACKETT FILTRATION PLANT	03/27/13	80	WESTFIELD WATER RESOURCES DEPT	SACKETT FILTRATION PLANT	MA
13400	LORING ROAD	08/07/09	200	MASSACHUSETTS WATER RES AUTH (MA)	--	MA
13164	VEAZIE ENERGY RECOVERY	01/16/09	75	BANGOR HYDRO-ELECTRIC CO (ME)	--	ME
13638	KEENE WATER TREATMENT FACILITY	05/26/10	62	CITY OF KEENE, NEW HAMPSHIRE	HAMPSHIRE WATER TREATMENT FACILITY	NH
13269	BENNINGTON WATER TREATMENT	01/09/09	17	TOWN OF BENNINGTON, VT	--	VT

In addition to the projects listed in Table 4, projects outside of the initial study zone were reviewed if they had characteristics suitable to those likely to be found in Massachusetts and were constructed in the last 15 years. It should be noted that the FERC conduit exemption list includes projects on structures such as canals which were not further considered.

Table 4. FERC authorized conduit exemption projects outside of New England identified for review

Docket Number	Project Name	Issue Date	Authorized Capacity (KW)	Licensee	Waterway	ST
14059	FROSTBURG LOW HEAD	06/27/11	75	CITY OF FROSTBURG, MD	PINEY RIVER RESERVOIR	MD
13635	RICE RESERVOIR	10/29/10	25	CITY OF GLOVERSVILLE	CAMERON RESERVIOR	NY
13732	VERNON STATION	09/03/10	25	CITY OF PORTLAND WATER BUREAU	BULL RUN WATERSHED	OR
13466	WASTEWATER TREATMENT PLANT OUTFALL	10/18/11	50	CITY OF GRESHAM	COLUMBIA RIVER	OR

4.3 Case Studies

The following projects were identified as similar in size to those which would be developed in Massachusetts. Efforts to find technical, financial, and performance information for each project was made; however, data such as project cost was not always available.

- Bennington Water Treatment Plant (VT)
- Sackett Filtration Plant (MA)
- Rice Reservoir (NY)
- Vernon Station (OR)
- Waste Water Treatment Outfall (OR)
- Keen (NH)
- Frostburg (MD)
- Coltsville (MA)
- Veazie (ME)
- Loring Road (MA)

Project Name: Bennington Water Treatment

FERC Project Number: P-13269

Location: Bennington, VT

FERC Authorization Date: 01/09/09

Authorized Capacity: 17 kW

Estimated Annual Production of facility: 140,000 kWh/year

Head: 115 ft

Turbine Flow Rate: 3 cfs

Installation Type: Within gravity line for water transfer

Equipment Manufacturer/Vendor: Canyon Hydro

Energy Use: All energy is used on-site

Description: The turbine is installed within a conduit used to transfer raw water by gravity from a storage reservoir to the Town's municipal water treatment facility. The treatment plant operates throughout the day and night with equalized flow. The power plant operates automatically when the treatment plant is operating but will not operate during backwash cycles.

Contact Info: Stuart Hurd, 205 South St., Bennington, VT 05201. 802-447-1037. shurd@benningtonvt.org

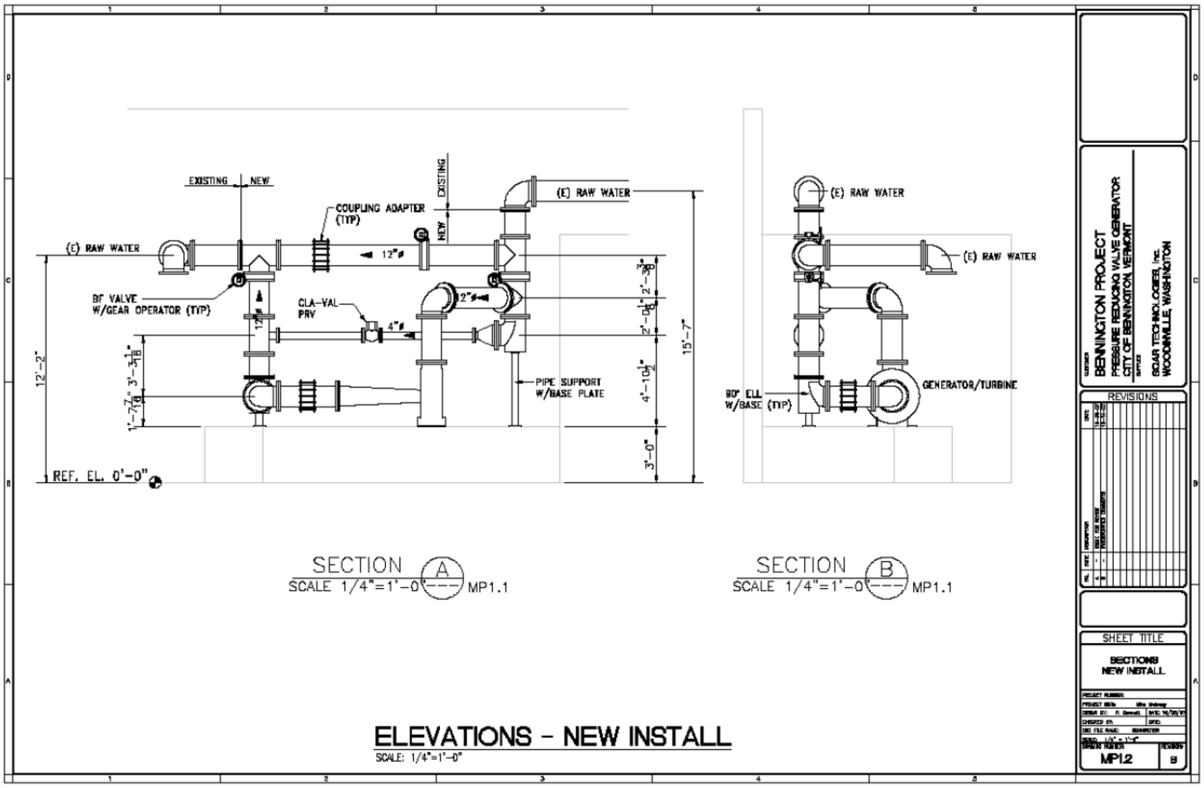


Figure 1. Bennington Water Treatment System Schematic (FERC)

Project Name: Sackett Filtration Plant Hydroelectric Project*

Project Under Construction*

FERC Project Number: P-14483

Location: Westfield, MA

FERC Authorization Date: 03/27/13

Authorized Capacity: 80 kW

Description: The proposed project will consist of an approximately 16 ft long, 12 in diameter intake pipe, a powerhouse with a single generating unit, and an approximately 9.5 ft long, 12 in diameter outlet pipe. The maximum generating capacity will be 80 kW and the system is estimated to generate about 470,000 kWh/yr.

Raw water flows from the Granville Reservoir through a 15,000 ft long conduit to the Sackett water treatment facility. The proposed system will be located completely within the existing water treatment plant building. The project will include a bypass to direct flows to the water treatment system during excess flow situations or if the project needs to be taken off line.

Contact Info: Westfield Water Resources Dept. David Billips, Superintendent, 28 Sackett Street, Westfield, MA 01085. 413-642-9325. D.billips@cityofwestfield.org

Westfield Water Resources Dept. Charles Darling, Systems Engineer, 28 Sackett Street, Westfield, MA 01085. 413-572-6270. D.billips@cityofwestfield.org

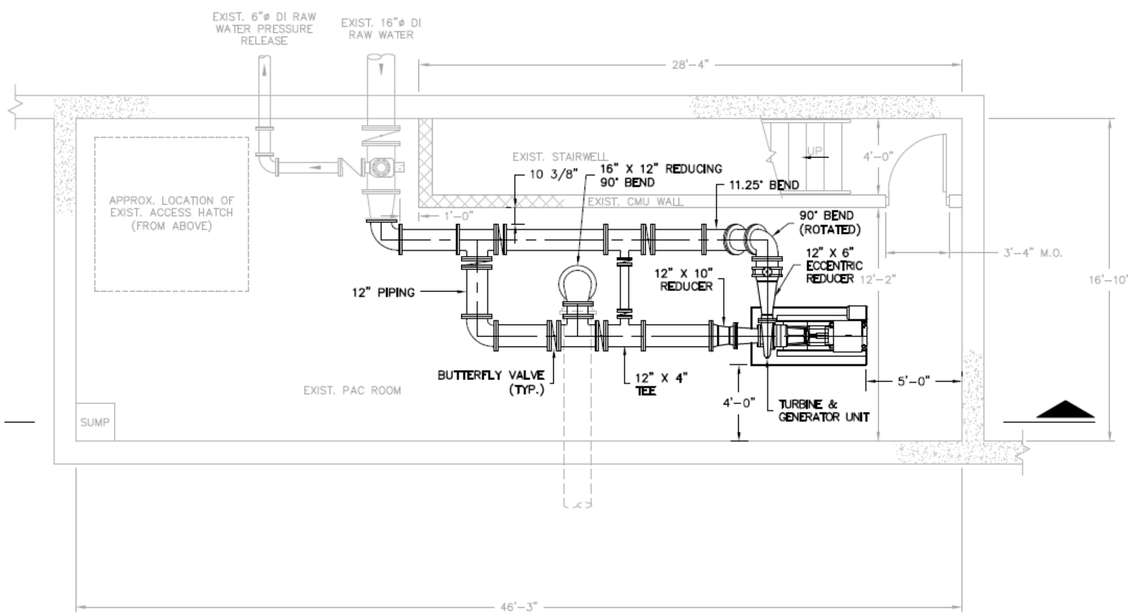


Figure 2. Proposed Sackett Reservoir Hydropower System Plan View

Project Name: Rice Reservoir

FERC Project Number: P-13635

Location: Gloversville, NY

FERC Authorization Date: 10/29/10

Authorized Capacity: 18 kW

Estimated Annual Production of Facility: 192,000 kWh/year

Head: Gross 134 ft. Approximately 110 ft net.

Turbine Flow Rate: 2.8 cfs

Installation Type: Installed at the discharge end of the Rice Reservoir aeration block. 18 in conduit.

Equipment Type: Turgo

Equipment Manufacturer/Vendor: DLLD Co. Ltd

Generator: 240V; three phase

Installation Contractor: All installation was done in-house.

Energy Use: All energy is used on-site.

Total Cost: Total project cost of $70,000; $35,000 was turbine/generator package.

Incentives Utilized: None

Description: The system consists of an 18 kW turgo turbine installed within an existing aerator ring. The ring forms a collection pit below the aerator block and allows the conduit flow from the block to be collected in a 24 in diameter discharge culvert pipe and continue to Rice Reservoir. The turbine is mounted on the top of the aerator block and has a bypass as well as discharge from the housing.

Contact Info: Mr. Christopher Satterlee, Superintendant Gloversville Water Works, 3 Frontage Road, PO Box 1100, Gloversville, NY 12078. 518-773-4518. csatterlee@gloversvillewater.com

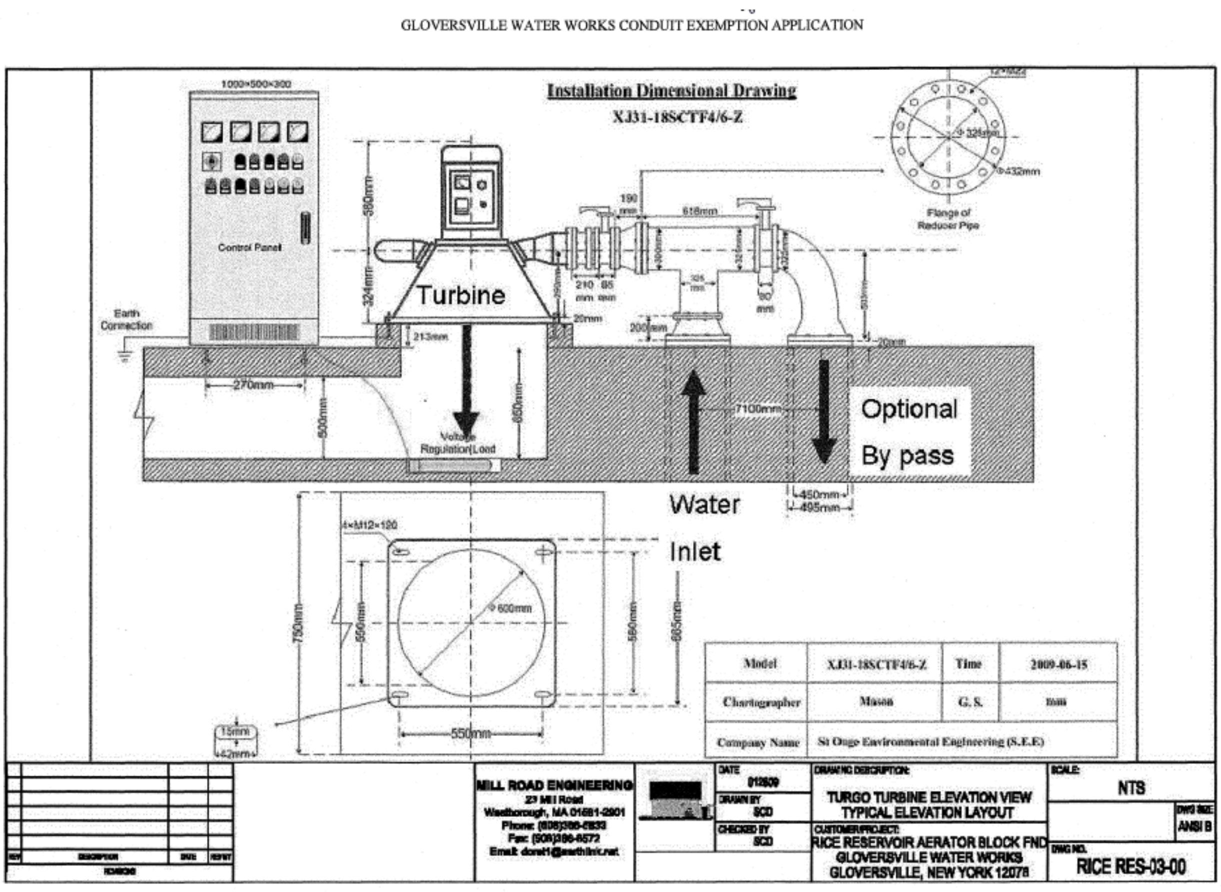


Figure 3. Rice Reservoir Water Treatment System Overview

Project Name: Vernon Station

FERC Project Number: P-13732

Location: City of Portland, OR

FERC Authorization Date: 09/03/2010

Authorized Capacity: 25 kW

Estimated Annual Production of Facility: 205,900 kWh

Head: 40-52 ft

Turbine Flow Rate: 7-10 cfs

Installation Type: In parallel with an existing PRV

Equipment Type: Pump operating as Francis turbine

Equipment Manufacturer/Vendor: Cornell 10 TR1

Generator: 240V, 3 phase

Description: The 25 kW hydroelectric facility is located within a municipal water system vault. The facility generates power using potable water that would otherwise flow through a PRV in the municipal water distribution system. The project is sited at the Vernon Water Tank Site, located in an urban, residential neighborhood in Portland. The project was installed within the existing water tanks at the site, as well as a below-ground vault. The project utilizes the energy associated with the pressure differential between the Mt. Tabor distribution pressure zone and the local distribution system. The turbine is in parallel with the existing PRV valves in order to provide a reliable water supply in the event of an interruption of generator operation.

The annual average flow rate through the conduit where the turbine is located is approximately 15.1 cfs, of which approximately 10 cfs is used for power generation. A portion of the water flowing through the system continues to flow through an existing PRV.

Contact Info: Bryan Robinson, City of Portland Water Bureau, 1900 N. Interstate, Portland, OR 97227. 503-823-7221. bryanrobinson@ci.portland.or.us

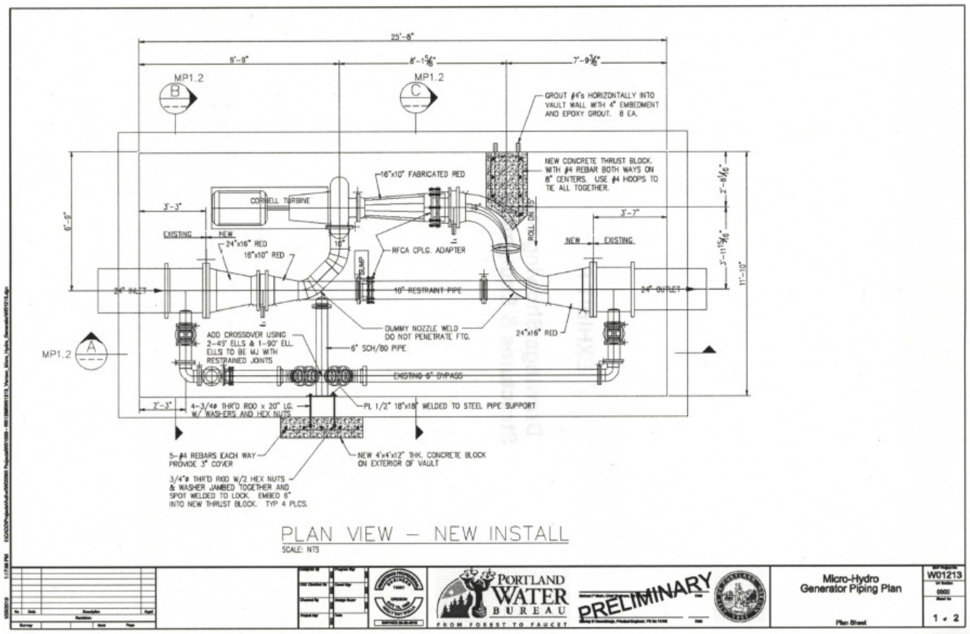


Figure 4. Plan View of Portland, OR Hydroelectric System

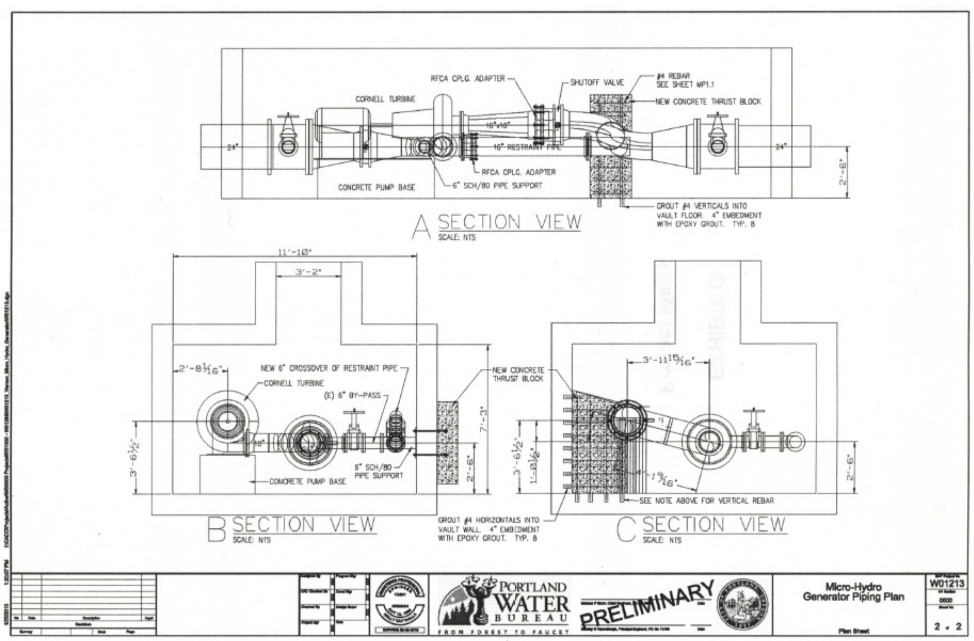


Figure 5. Sections Through of Portland, OR Hydroelectric System

Project Name: Wastewater Treatment Outfall

FERC Project Number: P-13466

Location: Gresham, OR

FERC Authorization Date: 10/18/11

Authorized Capacity: 50 kW

Estimated Average Annual Energy: 413,000 kWh/yr

Head: 30.5 ft, the head at the facility is measured by taking the difference between the water surface elevation in the flow meter and the elevation of the turbine less the hydraulic losses.

Flow: 26 cfs

Installation Type: POTW outfall

Turbine efficiency: 50%-94%

Generator: 480V; 3 phase

O&M: The facility will operate 24 hours per day, 7 days per week. Power generation is continuous with only slight variation in output. It is operated automatically, unmanned, and monitored and maintained similarly to effluent pumping stations that routinely operate in the POTW distribution system.

Cost: Estimated at $800,000

Incentives Utilized: 50% funding through state business energy tax credit and grant from Energy Trust of Oregon

Power Use: All electricity that is generated is sold to the local utility under a power sales agreement.

Description: The powerhouse was constructed at the POTW outfall between Marine Drive and the Columbia River. The powerhouse draws water from the existing 4 ft outfall pipe and discharges water back into the 4 ft outfall pipe immediately upstream of the start of the 4.5 ft outfall diffuser. The turbine and generator are housed in a 12 ft by 16 ft concrete powerhouse while some electrical controls and equipment are housed in a 10 ft square concrete building. The source of water is effluent treated at the City of Gresham's POTW where it enters a distribution system which consists of buried pipe prior to discharging from the existing outfall into the Columbia River. Water is available on a year-round basis from the POTW operations.

Contact Info: Michael Nacrelli, P.E., City of Gresham, OR, Department of Environmental Services, 1333 NW Eastman Parkway, Gresham, OR 97030

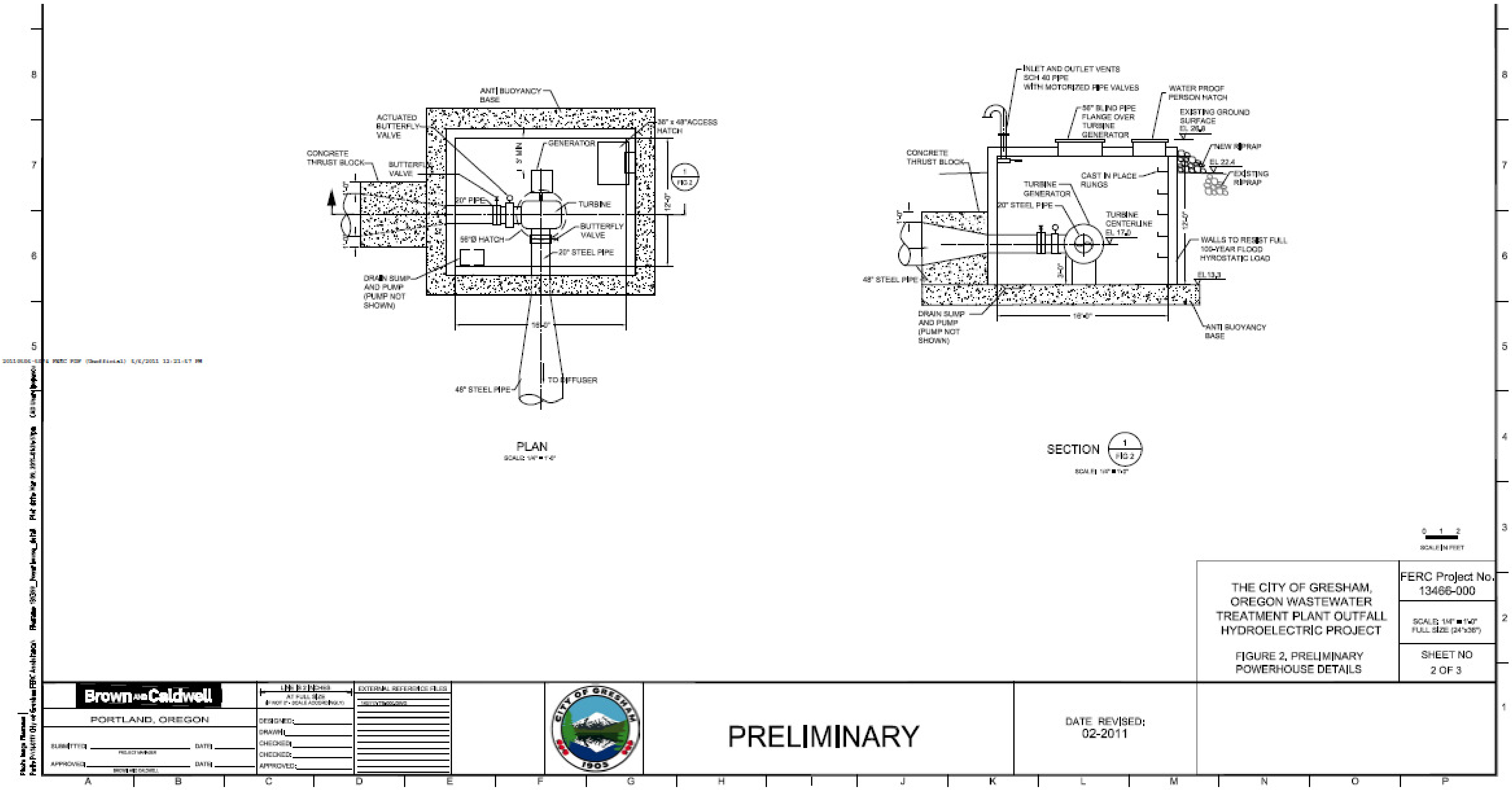


Figure 6. Figure of Gresham, OR Hydroelectric System

Project Name: Keen Water Treatment Facility

FERC Project Number: P-13638

Location: Keen, NH

FERC Authorization Date: 05/26/10

Authorized Capacity: 54 kW

Estimated Annual Production of Facility: It has been estimated that 180,000 kWh was generated during the first year of operations (2012).

Head: 100 ft

Turbine Flow Rate: 4.7 cfs

Installation Type: Parallel with PRV in new bypass system.

Equipment Type: PAT

Equipment Manufacturer/Vendor: Cornell PAT

Contractor: Contractors did all of the work; no in house work. Sorenson Systems was contracted for the controls and turbine procurement, Rentricity for the engineering.

O&M: Very little required. Once supervisory control and data acquisition (SCADA) bugs were worked out, no issues. Existing personnel are able to handle any O&M.

Cost: The total project cost was $575, 000 with the turbine, generator and controls costing about $156,000. The City received 50% grant through a Federal Recovery Act program. At this time, the City has not pursued renewable energy certificates but is considering for the future.

Scheduling: Permitting took about 6-8 months. Project took about 1.5 years.

Impact to Treatment Facility: None

General Performance: Good. The two different turbines allow for good tracking of the flow. Site visits are welcome.

Environmental Issues: None. Fish entrainment was initially discussed but was not ultimately an issue requiring mitigation.

Description: The facility consists of two turbine generating units installed in parallel with the PRV. The system begins at the Babbidge Reservoir which is approximately 2 miles from the water distribution system. From the reservoir, the water is gravity fed through a 20 in diameter conduit to the treatment facility. Inside the treatment facility, a valve reduces the incoming water pressure for discharge to the treatment process. The turbines are installed in a bypass parallel to the existing PRV. Unit 1 generates a peak of 36 kW utilizing 3.1 cfs, unit 2 generates a peak of 18 kW utilizing 1.6 cfs.

Contact Info: John MacLean, City Manager, City of Keene, 3 Washington Street, Keen, NH 03431. 603-357-9804. jmaclean@ci.keene.nh.us

Project Name: Frostburg Low Head

FERC Project Number: P-14059

Location: Frostburg, MD

FERC Authorization Date: 06/27/11

Authorized Capacity: 75 kW

Estimated Annual Production of Facility: Initial estimates were at 240,000 kWh/yr. Actual generation is about 15-20% higher than estimates.

Head: 384 ft

Turbine Flow Rate: 1.5 cfs

Installation Type: Reservoir transfer

Equipment Type: Pelton

Equipment Manufacturer/Vendor: Canyon Hydro teamed with an integration company

Generator: synchronous, 480V; 3phase

Pipe Diameter: 12-in

O&M: Less than 5K per year. No new dedicated employees required.

Incentives: Net metering is utilized and has made this project financially viable.

Impact to treatment Facility: None

General Performance: Excellent

Environmental Issues: None

Description: The system is connected to an existing 12 in gravity raw municipal water line that supplies the City of Frostburg's municipal water treatment plant. The facility consists of one Canyon Industries 75 kW capacity generating unit connected to an existing 12 in gravity water line. The project takes advantage of the 384 ft of head from the flow equalization tank on the summit of Big Savage Mountain to the turbine. Water exits the hydroelectric plant and discharges into the City's existing raw water reservoir. The plant is enclosed in a 13 ft by 22 ft prefabricated building resting on a gravel pad.

Contact Info: Christopher Hovatter, P.E., Director of Public Works, 59 East Main Street, P.O. Box 440, Frostburg, MD 21532. 301-689-6000X23

Project Name: Coltsville Flow Control Station

FERC Project Number: P-13658

Location: Pittsfield, MA

FERC Authorization Date: 04/23/10

Authorized Capacity: 66 kW

Estimated Annual Production of Facility: 355,000 kWh/yr.

Head: The average pressure entering the Coltsville Flow Control Facility is 165 psi (381 ft). The average pressure requirement on the downstream end of the Coltsville Flow Control Station is 98 psi (226 ft). Therefore there is an average of 67 psi (155 ft) of available head at the Coltsville Flow Control Station.

Turbine Flow Rate: 7.2 cfs

Installation Type: Within bypass parallel to PRV

Equipment Type: PAT

Equipment Manufacturer/Vendor: Canyon, Cornell 6 TR2

Generator Information: US Motors 1200 rpm, 480 VAC, 60 Hz, 3 ph, induction generator

Description: The City of Pittsfield owns and operates the Cleveland Water Treatment Plant on Cleveland Reservoir. The City withdraws an average of approximately 8 mgd from Cleveland Reservoir for treatment at the Cleveland Water Treatment Plant. Approximately 7.6 mgd of potable water then flows from the Cleveland Water Treatment Plant, through 25,000 ft of transmission line, and into the Pittsfield water distribution system. An average of 3.8 mgd of the potable drinking water passing through the Cleveland Water Transmission Main flows through the existing Coltsville Flow Control Station at the interface of the City's water distribution system. The Coltsville Flow Control Station is an integral part of the City of Pittsfield water system in that it reduces the pressure of the water entering the City from 165 psi to 98 psi. Parallel to this pressure reduction system, the turbine has been installed as an alternate means of pressure reduction through energy recovery. However, the system has been installed with four actuating butterfly valves which will bypass the hydroelectric system and allow uninterrupted flows in the event of a turbine issue.

Contact Info: Bruce Collingwood, P.E. Commissioner, Department of Public Works & Utilities, City Hall, 70 Allen Street, Room 200, Pittsfield, MA 01201. 413-499-9330.

Project Name: Veazie Energy Recovery

FERC Project Number: P-13164

Location: Bangor, ME

FERC Authorization Date: 01/16/09

Authorized Capacity: 60 kW

Estimated Annual Production of Facility: 590,000 kWh was original estimate. Actual generation is lower.

Head: 315 ft

Turbine Flow Rate: 7.8 cfs

Installation Type: In-conduit, replacement of existing PRV

Equipment Type: PAT

Equipment Manufacturer/Vendor: Canyon Industries

Turbine Speed: 1,200 RPM

Efficiency: Turbine (90%)

Generator: 60 Hz, 480V; 3 phase

Conduit Diameter: 24 in

O&M: Minimal, replaced hydraulic hose and coil. Less than $5K/year.

End Use: All energy is used within the municipal system.

Total Cost: $193,000, turbine and installation was about $120K. Not all costs were initially accounted for such as cost of incorporation into SCADA and valves which created challenges in the later stages of project implementation.

Incentives Utilized: None; project was independently financed.

Environmental Issues: Agencies were concerned with reservoir management, water surface elevations and bypass flows; however, mitigations or changes were not required as part of the permitting process.

Impacts to Existing Treatment Facility: None.

Description: The system has two pressure reducing valves at the Veazie control valve facility. One valve is located on each of the 24 in pipes feeding water under the Penobscot River from the west side of the river to the Veazie facility through gravity feed. The district has replaced one of the valves with a horizontal shaft, turbine/generator unit. Water is supplied from the reservoir to the ozone plant and then travels downhill 15 miles to Bangor where the energy recovery turbine is installed. All system components including the turbine and valves were incorporated into the SCADA programming to relieve any water hammer issues. In addition, the system was designed to allow for black start through the installation of a uninterruptable power supply (UPS) battery system.

Contact Info: Richard Phillips, 947-4516X405. richard.phillips@bangorwater.org

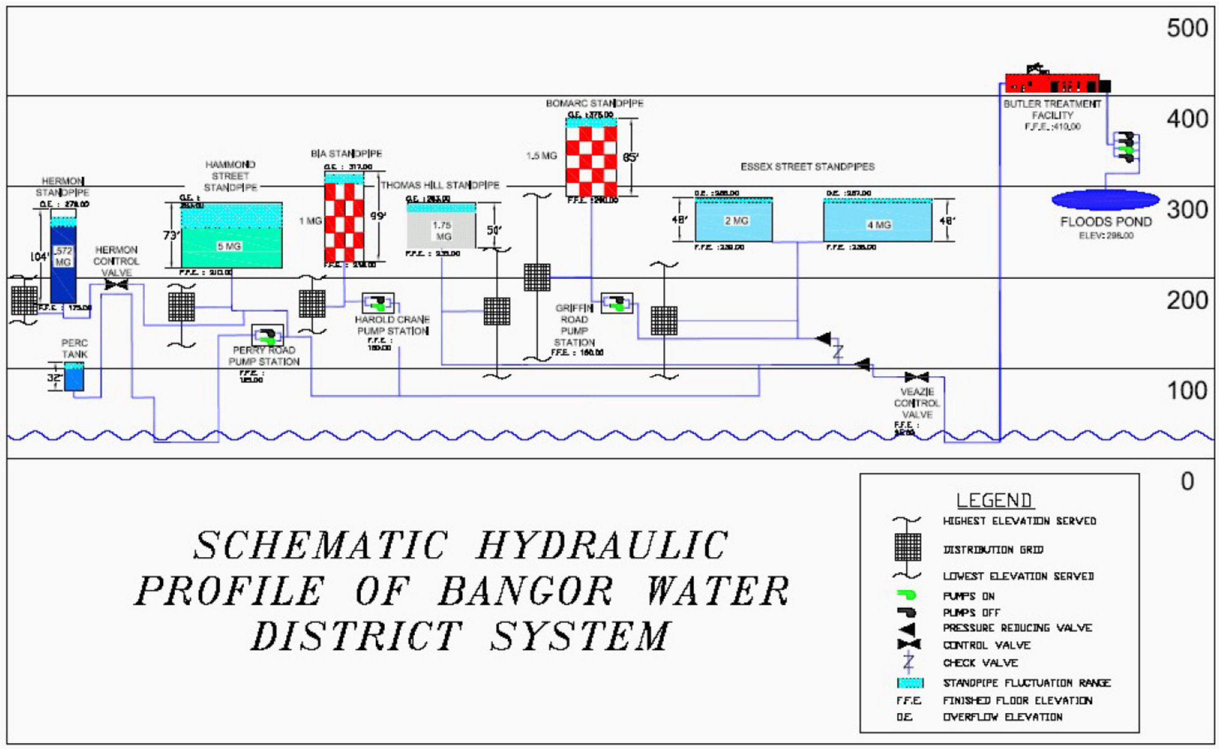


Figure 7. Schematic of Hydraulic Profile of Bangor Water District System.

Project Name: Loring Road

FERC Project Number: P-13400

Location: Weston, MA

FERC Authorization Date: 08/07/09

Authorized Capacity: 200 kW

Estimated Annual Production of Facility: 1,207,000 kWh/year (projected), Actual: 1,359,016 kWh (year one), 1,229,351 kWh (year two)

Head: 75 ft

Turbine Flow Rate: 39 cfs

Installation Type: Alternative to dissipation of energy through sleeve valve. Installed on bypass parallel to sleeve valve.

Equipment Type: Francis

Equipment Manufacturer/Vendor: Leffel

O&M: When there is a major storm event is anticipated, the turbine will be taken offline.

Energy Use: Use about 25% onsite remainder is sold to grid.

Total project cost: 1.875 total construction cost

Incentives: Total of 1.8 million in incentives (Recovery Act & Massachusetts Technology Collaborative, now the Mass CEC). Class 1 REC contract for about \$0.05/kWh; LIHI certification was received for RECS.

Schedule: Permitting FERC: 9 months.

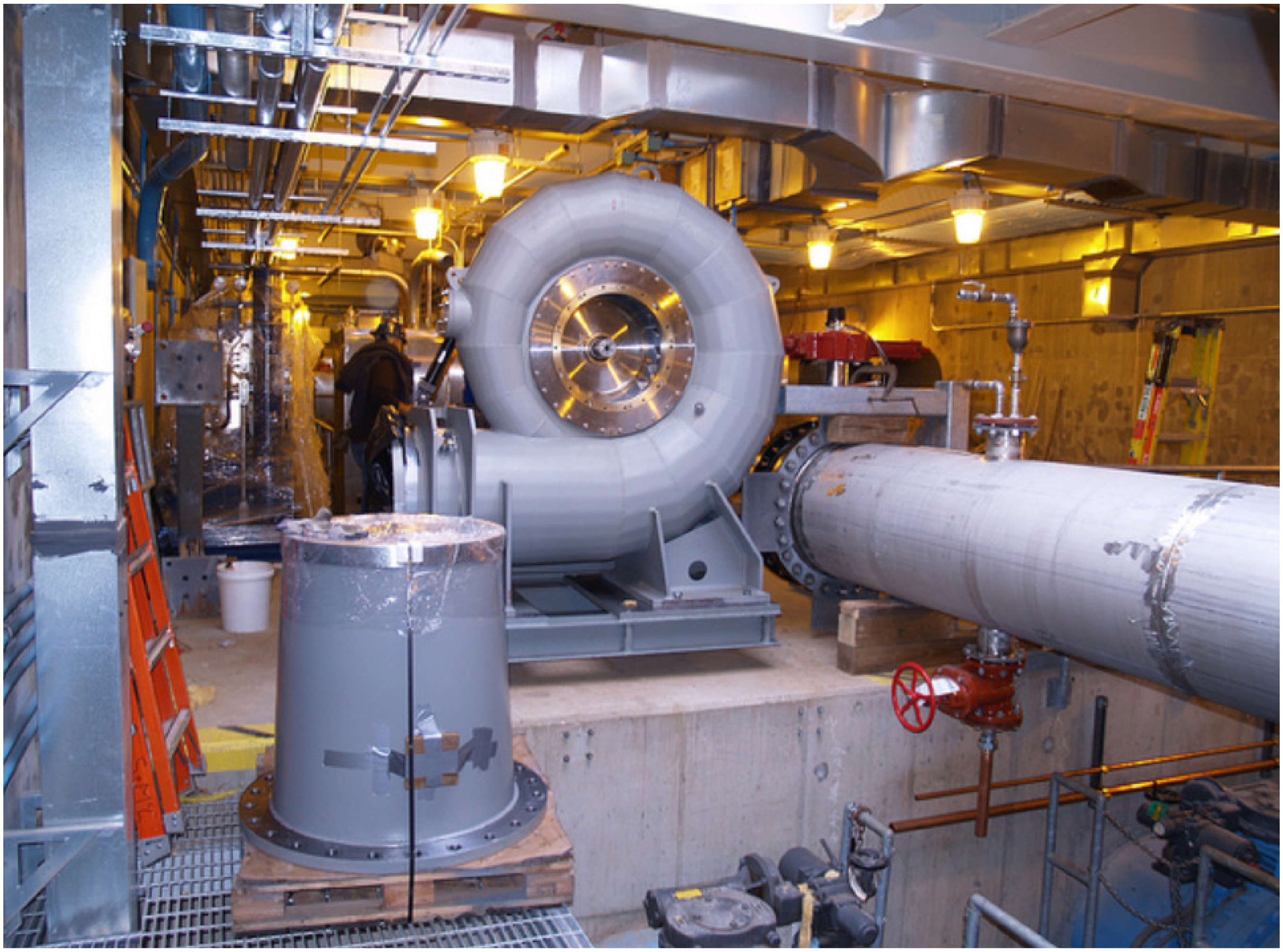
Impact to operations systems: None.

General Performance: Good.

Environmental issues: None.

Description: MWRA operates a PWS system providing water to 50 communities. Close to its center of demand, MWRA has constructed a network of tanks to protect and store treated drinking water. The water is continuously used and replenished. From the tanks, water is distributed to the community. The hydroelectric system is located at the Loring Road covered storage facility in Weston Valve Chamber One and has been integrated into the existing SCADA system. The authorized capacity is 200 kW; however, in winter the average generation is about 100 kW due to lower demands.

Contact Info: Pamela Heidell, Policy and Planning Manager, MWRA, Charlestown Navy Yard. Building 39, 100 First Avenue, Boston, MA 02129. 617-788-1102.



5 DISCUSSION

The information summarized in this report is intended to assist a potential developer in completing preliminary project evaluations. Identifying suitable technologies for POTW and PWS facilities can be challenging due to the head and flow resources typically available. The summary data provides a variety of information on available turbines including the type, head / flow range, performance data, existing installations and cost. This information will be useful in identifying the availability of suitable turbines and provide guidance when performing due diligence for site development. Information on the cost of equipment was provided by some manufacturers and varies significantly between turbine types. Although this information is useful for planning purposes, the financial information developed through the case study review may be more useful for early project evaluation as it includes all aspects of project development including the turbine.

The technology review identified many which are applicable to POTW and PWS facilities. Some technologies have features such as the ability to adjust to head/flow conditions and maintain higher efficiencies while others are much simpler "off the shelf" type technologies. There will be some variation between units regarding energy generation with some being more applicable to particular flow regimes. In addition, there are significant variations in equipment cost with more expensive equipment typically being more complex machinery which is able to generate at a high efficiency over a wide range of flows through flow adjustment. There are several technologies such as the Walker Wellington and Lucid units which have been developed specifically for the unique conditions of POTW and PWS sites. However, there is opportunity for the development of additional technologies, particularly for the low head conditions at POTW systems. The primary technology for sites with less than a few feet of head (POTW sites) are those which utilize the velocity of moving water (HKE) rather than head pressure. However, HKE units tend to have low energy density and require high water velocities making financial viability challenging.

The case studies provide information about developed projects including: available resources, performance, equipment manufacturer, and financial incentives. Although information was not available for all projects, a variety of information was acquired which provides valuable insight when considering a development. In reviewing case studies of existing installations, it appears that there are a variety of factors influencing the success of a project. Financially the projects are often difficult; however, two factors were identified as means of mitigating costs. The first is that many developments were completed with in-house resources for some engineering and installation. The capital costs of these projects tend to be significantly less than those where contractors are utilized for a majority of the project. The second method of increasing the financial viability of a project is to utilize incentives. In some cases the project owner was reimbursed for up to half of initial development cost which has a significant implication on financial feasibility. The case study information was sufficient to develop ranges of $/kw and $/kWh, power factor, and schedule which can be applied to proposed projects for estimating purposes. This information is further discussed in the Phase II report.

Environmental concerns during project development were identified including: fish entrainment, reservoir and shoreline management issues, and bypass flows. Most project owners/representatives indicated that these were issues brought up by resource agencies during consultation; however, ultimately no mitigations were required as existing infrastructure was found to be suitable.

All of the projects which were studied are PWS rather than POTW developments. Based on the information found during both the technological and case study investigation indicate that POTW projects have two additional challenges compared to PWS projects. In general, available technologies for POTW projects are not as suitable as those for PWS applications and often HKE technology is the most suitable technical option. In addition, the energy generation potential at a POTW plant is typically less than that at a PWS facility making the development more financially challenging. Actual development potential at POTW and PWS facilities in Massachusetts will be investigated during Phase II of this project.

The technology and case study data summarized in this report should be used as a resource when considering a potential development. The list of turbines included is not necessarily exhaustive; however, it can be used as a quick reference to facilitate both preliminary estimates of project performance as well as initial discussions with manufacturers. Every PWS and POTW system is unique and should be evaluated individually; however, the case studies provide some guidance on factors to consider and typical development layouts for consideration.