CITY OF GOLDEN

Hydropower Feasibility

DRAFT

SMALL HYDRO CONSULTING

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EXECUTIVE SUMMARY

The City of Golden supplies municipal drinking water to its residents through a system of reservoirs and pipelines connected to Clear Creek. Six sites within the system were identified to have excess head and flow which could be used to generate electricity. This project and report are divided into two Tasks. Task 1 considered all of the sites at a high level and recommended the most favorable sites to move forward into Task 2. Task 2 considered the most favorable sites in more detail including development of a conceptual design, cost estimate and high-level economic analysis. The main characteristics of all of the sites considered are listed in the table below.

Site	Head (ft)	Flow (cfs)	Approximate Capacity	Annual Generation (MWh)	Permitting/Issues
Lower Urad					
Service Spillway	88	8.2-4.5	52-23 kW	240 - 123	FERC Exemption, poor access
Main Outlet	67	8.2-4.5	40-18 kW	185 - 99	FERC Exemption
Secondary Outlet	69	8.2-4.5	40-18 kW	148 - 86	FERC Exemption, higher headloss
Valve Chamber	69	60 gpm	300 Watts	Battery charge	May be Non-jurisdictional
Upper Urad	88	8.2-4.5	52-23 kW	240 - 123	Distance to Powerlines is significant
Chute into Lower Urad	130	8.2	75 kW	350	FERC Exemption, Located on Mine Property
City PRVs	~150	<100 gpm	<5 kW	Battery charge	Intermittent flow and lack of electricity demand
City Water Supply Intake	0	5 - 10	0	0	Insufficient flow for available turbines
Guanella Reservoir	25	3.5	6 kW	12.7	FERC Exemption/Low Generation and Revenue

The Task 1 review of all sites showed that hydropower development at the City Water Supply Intake is not technically feasible due to low flows and no excess pressure. Upper Urad will not be economically feasible (as compared to Lower Urad) because of the distance from powerlines. Very small turbines could be used at either the City PRV stations or in the Valve Chamber of Lower or Upper Urad to charge batteries needed to power remote monitoring or control systems. The small capacity and low generation at Guanella Reservoir make it unlikely to be economically feasible.

Lower Urad Reservoir and the Chute into Lower Urad Reservoir are both technically feasible and show promise to be economically feasible provided a number of conditions are met. For Lower Urad, 1) a net metering arrangement could be utilized in partnership with the Henderson Mine, 2) the dam falling under FERC jurisdiction for dam safety is acceptable and 3) the condition of the existing outlet works is acceptable for pressurization. For the Chute into Lower Urad, 1) a net metering arrangement could be utilized in partnership with the Henderson Mine and 2) the Henderson Mine is willing to allow modifications to the existing structure.

Task 2 considered the Lower Urad Reservoir sites and the Chute into Lower Urad Reservoir in more detail. The relatively small size of all of these projects poses a challenge for development at a dam. There are a number of fixed costs, such as permitting, which any project must incur regardless of size. Given that a smaller project will

generate less electricity and therefore less revenue annually, these fixed costs can make a smaller project economically infeasible.

A conceptual design for each of the three alternatives at Lower Urad Reservoir are presented in the report along with the estimated cost and a high-level economic analysis. The Chute into Lower Urad is a structure owned by the Henderson Mine. It is also a part of their environmental remediation plan. Initial discussions have indicated that the mine would not be interested in altering this structure in any way, which would be required to construct a hydropower project.

At Lower Urad Reservoir, the secondary outlet was found to be the most cost effective and likely the most acceptable to Dam Safety. However, the revenue generated would not be sufficient to payback the project cost in a reasonable amount of time. If power prices increase, or grants become available to assist with the development cost, this could reduce the payback period and make the projects viable in the future.

INTRODUCTION

The City of Golden initiated this study to investigate the potential of the City's water system to generate electricity with hydropower. The City stores water in high elevation reservoirs. Water from these reservoirs (Lower Urad and Guanella) is discharged when needed into Clear Creek. The water treatment plant diverts from Clear Creek and distributes water through the city. There are multiple locations within the system where pressure (head) and flow could be utilized to generate electricity.

Both the technical and economic feasibility of adding hydropower to a site needs to be considered. Task 1 of this report focuses on the technical feasibility including quantifying the resource available (head and flow), selecting the appropriate turbine, and estimating the annual generation for each site. Some comments are made with regards to economic feasibility. The Task 2 section of this report considers the cost and economics associated with the most promising sites.

Depending on the site, permitting can amount to a large percentage of the total project cost and effort required for development. Almost all hydropower projects fall under the jurisdiction of the Federal Regulatory Energy Commission (FERC). There are three main tracts depending on the project; License, Exemption or Non-Jurisdictional. Licenses are the most intensive and are generally required for projects greater than 10 MW with new construction of a dam or other major components of the project. The less intensive Exemption process can be used if the project is smaller than 10 MW and constructed using an existing dam or conduit. A small class of projects is considered "non-jurisdictional" if they are constructed within a working water system, or are not connected to the grid <u>and</u> not constructed on a natural waterway.

A tour of the system was conducted and all of the sites evaluated briefly to discover opportunities and potential flaws with respect to development. A description of each site, the general configuration, turbine selection, energy generation estimates, and permitting required is included in the next sections. The sites considered include the following;

- Lower Urad Reservoir
- Upper Urad Reservoir
- Chute into Lower Urad Reservoir
- City Pressure Reducing Valves
- City Water Supply Intake
- Guanella Reservoir

The goal of Task 1 is to evaluate all sites briefly and identify the best site to investigate further in Task 2.

LOWER URAD

Lower Urad Reservoir is located in Clear Creek County approximately 1/2 mile south of Berthoud Falls on the property of the Henderson Mine. The dam was constructed in 1964 as a water supply reservoir for the Urad Mine Operations. Presently, the reservoir is used for municipal water supply for the City of Golden. Woods Creek passes through the reservoir. Storage in the reservoir is generally maintained full except when storage is utilized during drought conditions. Inflows from Woods Creek enter the reservoir on the west end and pass over the spillway.

Figure 1: Lower Urad Reservoir

HYDROPOWER POTENTIAL

There are three outlets to the Lower Urad Reservoir, the service spillway, the main outlet and a secondary outlet. The main and secondary outlet are not used regularly. The valves are exercised annually and the main outlet is used for deliveries during drought periods, discharging below the spillway into Woods Creek. The service spillway is used regularly to pass Woods Creek flows downstream when the reservoir is full. This release pattern could be altered if a turbine was added, although total releases would remain the same. A gauging station is located on Woods Creek and records flow downstream of the outlet discharges.

The main outlet works consists of a 30” steel pipeline and a 14” steel bypass pipeline both encased in concrete. Valves (a 24” butterfly and 10” gate) are located in a Valve Chamber in the middle of the embankment with a tower to the surface for access (Figure 4). The 30” outlet terminates at a stilling basin (Figure 2). The 14” outlet turns 90 degrees just upstream of the stilling basin and crosses the toe of the embankment for a distance of approximately 100 feet to a secondary stilling basin (Figure 3). This 14” line is not currently in service.

Figure 2: Main 30" Outlet Stilling Basin

Figure 3: Secondary 14" Outlet Stilling Basin

It is possible that a small turbine could be installed within the valve chamber (Figure 4). The space is very limited and could only accommodate a very small turbine that could generate electricity required for a remote monitoring or controls system. If there is a need for small amounts of power this could be feasible, although relatively difficult due to access.

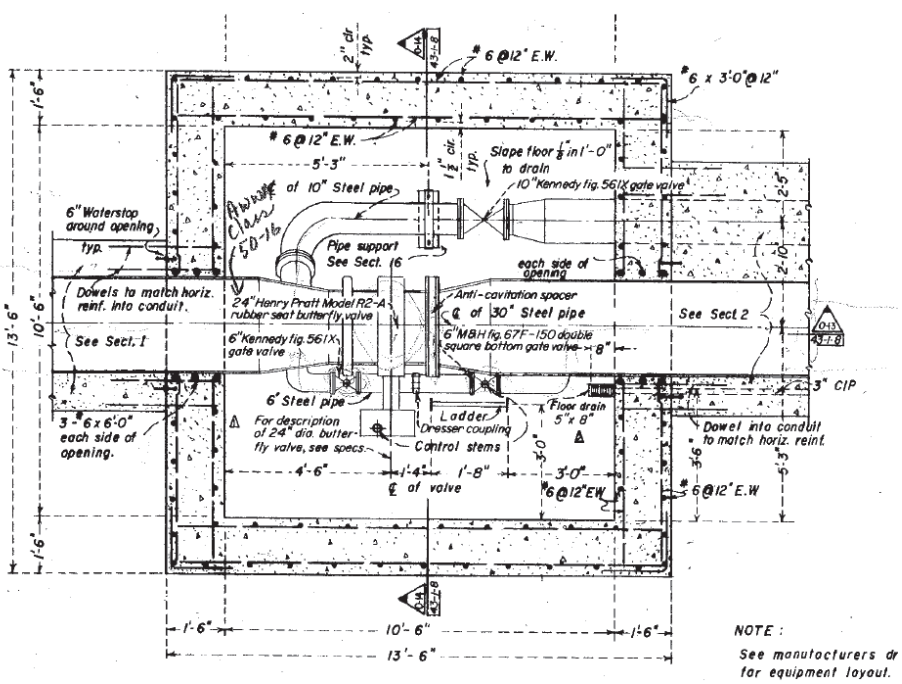


Figure 4: Lower Urad Valve Chamber

SOAR Hydropower, now merged with Canyon Hydro, offers a 300-Watt maximum output turbine that can be installed in a 2” bypass line around a Pressure Reducing Valve. Similarly, this turbine could be installed within the Valve Chamber on the existing bypass line. The small control panel would be connected to the turbine, shutoff valve and a battery bank to provide power to low-power equipment. A full brochure is included in the Appendix.

Figure 5: SOAR Microhydro turbine and controls

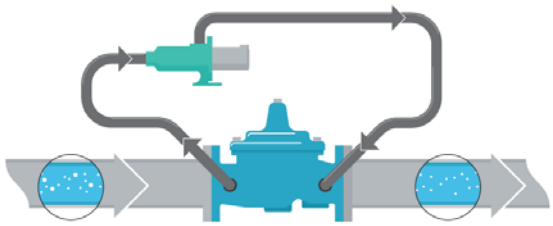


Figure 6: SOAR Microhydro concept layout

The Service Spillway is a 25-foot-wide rectangular chute with an ogee section at the entrance and a flip bucket dissipater at the downstream end. The Service Spillway is used most regularly because no active control is required to maintain the reservoir elevation and discharge any inflows.

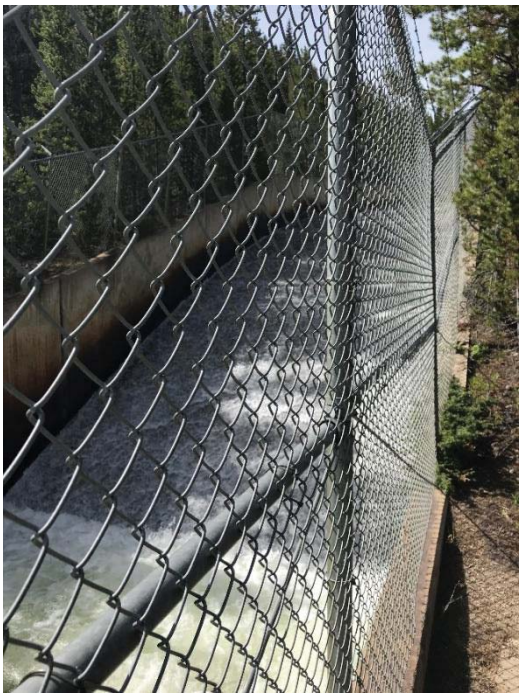


Figure 7: Ogee Section of Service Spillway

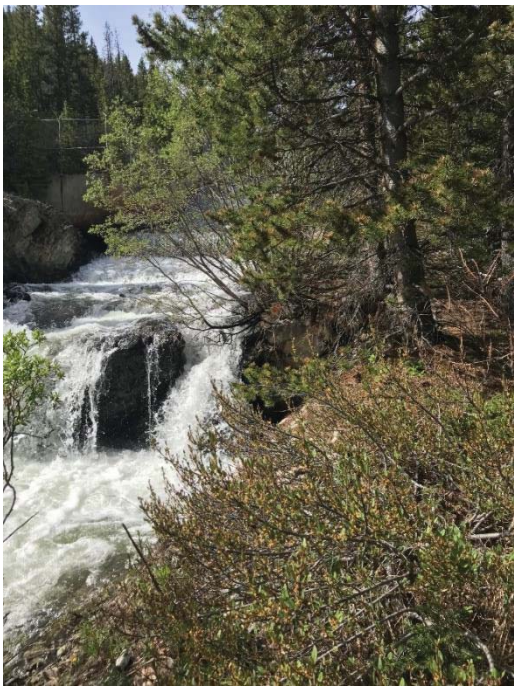


Figure 8: Downstream end of Service Spillway

For both of the piped outlets, the turbine could be installed at the discharge of the outlet within the stilling basin. In order to install a turbine on the spillway, a penstock would need to be constructed along the side of the spillway and extended a distance downstream to increase the head available to the turbine.

FLOW AVAILABLE

The flow available to use for hydroelectric generation will be the same regardless of the location of the unit. All flow which is measured at the Woods Creek Gaging Station (WC-60) could be passed through a turbine located on any outlet of the dam. Mean daily flow measurements for the years of 2005 through 2017 are shown in Figure 9.

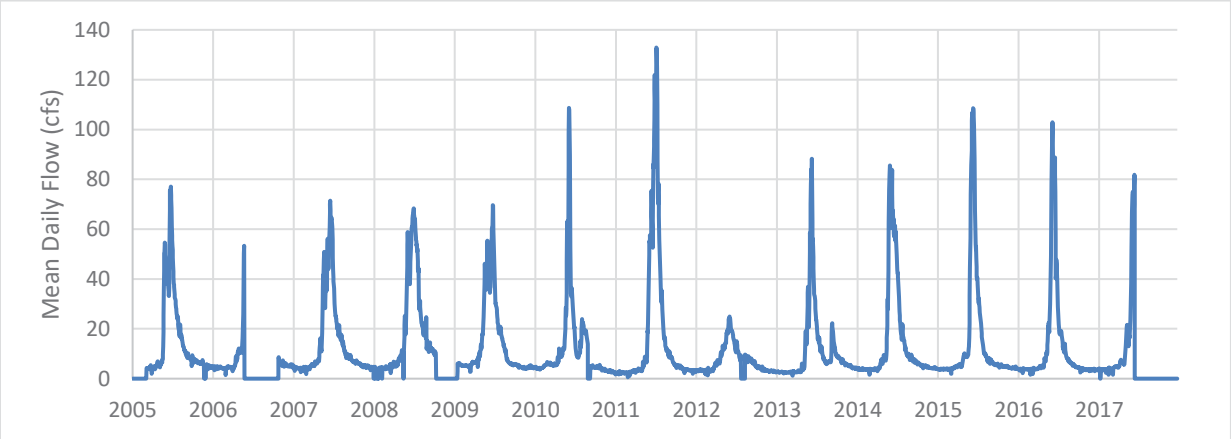


Figure 9: Mean Daily Flow over time

These same measurements were used to develop the following flow duration curve (Figure 10). This curve simply reorders the daily data from largest to smallest and plots against the percentage of time the flow is exceeded. This chart allows us to see how often low and high flows are seen and size the unit accordingly.

This flow duration curve is fairly typical of high elevation reservoirs in Colorado with a high and short duration of peak flow and a steadily declining low flow period. Any turbine has a range of flow within which it can operate, so selecting a high design flow will shorten the time which the turbine is able to operate. Comparing several design flows, Table 1 below shows that using the 30% exceedance flow (8.2 cfs) provides the most energy with the lowest capacity (and therefore lowest turbine costs). The additional cost of doubling or tripling the size of the turbine would not be recovered with the small amount of additional generation. The capacity listed is associated with the head available at the main outlet, but the relationship will be the similar for any of the turbine locations.

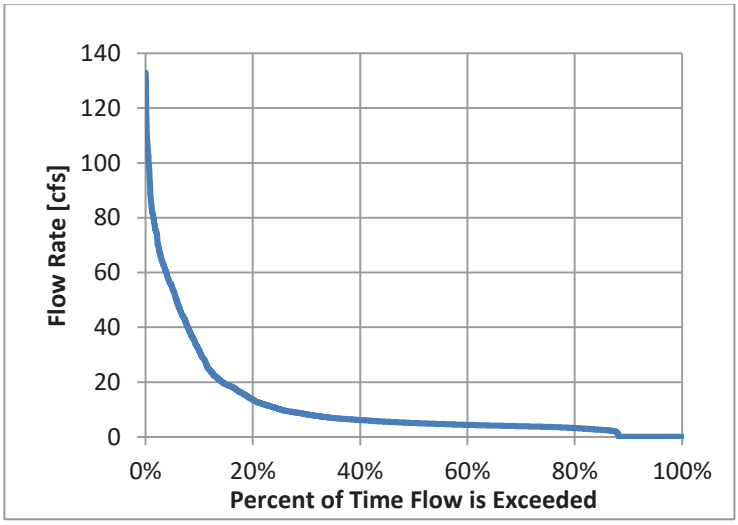


Figure 10: Flow Duration Curve

Table 1: Design Flow Comparison

Design Flow (cfs)	Capacity (kW)	Total Generation (MWhs)
8.2	*40*	*185*
10	49	177.1
15	73	174.2
20	98	181.2
25	122	187.1
30	147	193.6

HEAD AVAILABLE

The head available to a turbine is measured as the upstream water surface minus the downstream water surface and any losses through the penstock. Therefore, the head available to the turbine will depend on the size of the penstock (outlet) and the elevation of the turbine discharge.

Site	Upstream Water Surface (feet)	Headloss at 8.2 cfs (feet)	Downstream Water Surface (feet)	Net Head Available (feet)
Lower Urad				
Service Spillway	10,040	1.9	9,950	88.1
Main Outlet	10,040	0.2	9,973	66.8
Secondary Outlet	10,040	1.7	9,969	69.3
Valve Chamber	10,040	1.7	9,969	69.3

TURBINE SELECTION

Turbine selection is based on the magnitude and variability of head and flow available. Generally, sites with head between 70 and 90 feet of head can utilize a variable or fixed flow Francis Turbine. A variable flow Francis is more traditional and has the ability to adjust to flows down to 50% of the design flow. A fixed flow Francis is also known as a Pump-as-Turbine (PAT). It is simply a pump running in reverse. They are generally less expensive and parts are readily available, but they do lack adjustment in the flow and are restricted to models available. For this head and flow range, the closest PAT available can accept 4.5 cfs.

Table 2: Turbine Table 2 shows a comparison of the output and capacity of fixed and variable flow Francis turbines at each of the locations.

Table 2: Turbine Comparison

Lower Urad	Flow	Capacity	Annual Generation
Service Spillway			
Francis	8.2 cfs	52 kW	240 MWh
Pump-as-Turbine	4.5 cfs	23 kW	123 MWh
Main Outlet			
Francis	8.2 cfs	40 kW	185 MWh
Pump-as-Turbine	4.5 cfs	18 kW	99 MWh
Secondary Outlet			
Francis	8.2 cfs	40 kW	148 MWh
Pump-as-Turbine	4.5 cfs	18 kW	86 MWh
Valve Chamber	60 gpm	300 W	

PERMITTING REQUIREMENTS

Lower Urad Reservoir is located on a natural waterway, Woods Creek, and is not confined within a constructed water system. A Small Hydropower Exemption would be required from FERC to develop hydropower on any of the outlets or the spillway. By obtaining an Exemption from FERC, the jurisdiction over Dam Safety would also be shared with FERC and the Colorado Dam Safety Branch. The requirements of FERC dam safety are the same as Colorado dam safety, but it would add another regulatory body.

It may be possible that adding the small unit to the Valve Chamber would be considered non-jurisdictional as it would not be connected to the grid and all of the generated power would be consumed on site. This is a bit of a gray area, because the dam is located on a natural waterway. There are several similar projects in Colorado that are not regulated by FERC.

CHALLENGES/OPPORTUNITIES

Access: Access for construction and maintenance would need to be constructed to any of the sites. An access road does lead to the toe of the dam and would only be extended about 50 -100 feet to the main and secondary outlet stilling basins. Accessing the base of the spillway will be more difficult as the outlet channel will need to be crossed.

Interconnection: This site is close to a pumping station operated by the Henderson Mine. The pumping station is located on the upstream bank of the reservoir and takes seepage through the tailings pile and pumps it back up to a water treatment plant above the tailings pile. Three phase power is available at the pumping station and the line would need to be extended approximately 2000 feet to the turbine and generator. This would allow for net metering the pumping station with the hydropower plant by providing power to the “back of the meter”. The hydropower would have to feed directly into the meter of the pumping station. Because the owner of the hydropower would not be the same owner as the pumping station, an agreement would need to be made to share in the benefits. If a net metering arrangement were not used, the powerline would only need to be extended approximately 600 feet to the three-phase line that feeds the pumping station.

UPPER URAD

Figure 11: Upper Urad Reservoir

Upper Urad Reservoir is located approximately 2 miles southwest of Lower Urad Reservoir, upstream on Woods Creek. The Reservoir was originally constructed as a water supply reservoir for the Urad Mine similar to Lower Urad, but is currently used for recreation and flood control only. The dam and outlet works layout is very similar to Lower Urad. The head and flow available at Upper Urad is also very similar to that available at Lower Urad.

HYDROPOWER POTENTIAL

For the purposes of this first phase of investigation, we can assume that the hydropower potential at Upper Urad is the same as that at Lower Urad. All flows that pass through Upper Urad continue downstream to Lower Urad and are measured in Woods Creek. The height of the two dams are similar, and both are maintained full the majority of the time.

CHALLENGES/OPPORTUNITIES

The most significant challenge with this site as compared to Lower Urad is the location and proximity of powerlines and access. The cost and effort associated with developing hydropower at this site is very similar to Lower Urad, with the additional cost of extending power lines to the site. The cost of extending three phase power to Upper Urad, over 1 mile, could approach an additional $100,000.

As the purpose of this study is to prioritize opportunity and identify future conditions which may improve feasibility, Upper Urad would take a second place to Lower Urad due to this additional cost. If power were extended to the site for another reason, development of hydropower at the site could be reconsidered.

CHUTE INTO LOWER URAD

The area between Lower and Upper Urad Reservoirs is the site of the Urad mine. The area has undergone restoration since the closing of the mine which has included vegetation of tailings piles and routing of Woods Creek through the area. The reach of Woods Creek immediately upstream of Lower Urad Reservoir has been channelized into a concrete lined chute to avoid the tailings pile and dam.

Figure 12: Chute into Lower Urad

HYDROPOWER POTENTIAL

There are two general approaches to developing hydropower within this chute. One, the entire head of the chute could be utilized by piping the length of the chute, similar to the approach presented for the Lower Urad service spillway. Or two, a hydrokinetic turbine could be installed in the stilling basin. A hydrokinetic turbine does not take advantage of the head, only the velocity of the flowing water.

PENSTOCK APPROACH

The flow available at this site is very similar to that measured in Woods Creek below Lower Urad reservoir. There may be times when the reservoir is not full which would change the flows available here from what is measured at the Woods Creek gaging station. For the purposes of this evaluation, it is a reasonable approximation to use Woods Creek flows.

The head available from the top to the bottom of the chute is approximately 130 feet. An 18-inch penstock could easily be buried beside the chute for a distance of approximately 600 feet. An intake structure would need to be added at the top of the chute to direct flow into the penstock and screen out any debris. The turbine and powerhouse could be located at the base of the chute with discharge directed into the chute stilling basin.

A turbine at this site would have a capacity of approximately 75 kW and generate 350 MWhs annually.

HYDROKINETIC APPROACH

Denver Water currently hosts a demonstration site on the South Boulder Inlet Canal which feeds Ralston Reservoir. Several hydrokinetic turbines have been installed in series along the canal. The turbines are not yet producing electricity, but they are planning to soon. Denver Water has several turbines on site that are not being utilized and there is the potential for a partnership with the City.

Hydrokinetic turbines utilize the velocity in the water, similar to a wind turbine. The units are placed within the flow and as velocity increases, power output increases. The turbines require sufficient depth to submerge the blades. The Chute has high velocity through the inclined section, but very low (supercritical) depth. The only area with sufficient depth is within the stilling basin at the bottom of the chute. The purpose of the stilling basin is to decrease velocity and reduce the energy in the water. Because of this, the power potential is only 1 to 2 kW in this location.

Figure 13: Emrgy turbine at Denver Water South Boulder Inlet Canal

CHALLENGES/OPPORTUNITIES

This site is located adjacent to the Henderson Mine pumping station. The three-phase line would only need to be extended approximately 350 feet to the base of the chute. A similar net metering arrangement to the Lower Urad site could be considered. The minimal power potential of the hydrokinetic option does not warrant further study. The penstock option would require significant modification to the existing structure, and preliminary conversations with Henderson Mine employees indicate that is not an option.

CITY PRESSURE REDUCING VALVES

The City Water Treatment Plant, located on Clear Creek, is at a lower elevation than most of the service taps it supplies. To provide pressurized water to the service taps, water is pumped from the treatment plan to several tanks located above the service areas. To balance the pressure to different elevations, pressure zones are created and controlled with Pressure Reducing Valves (PRVs).

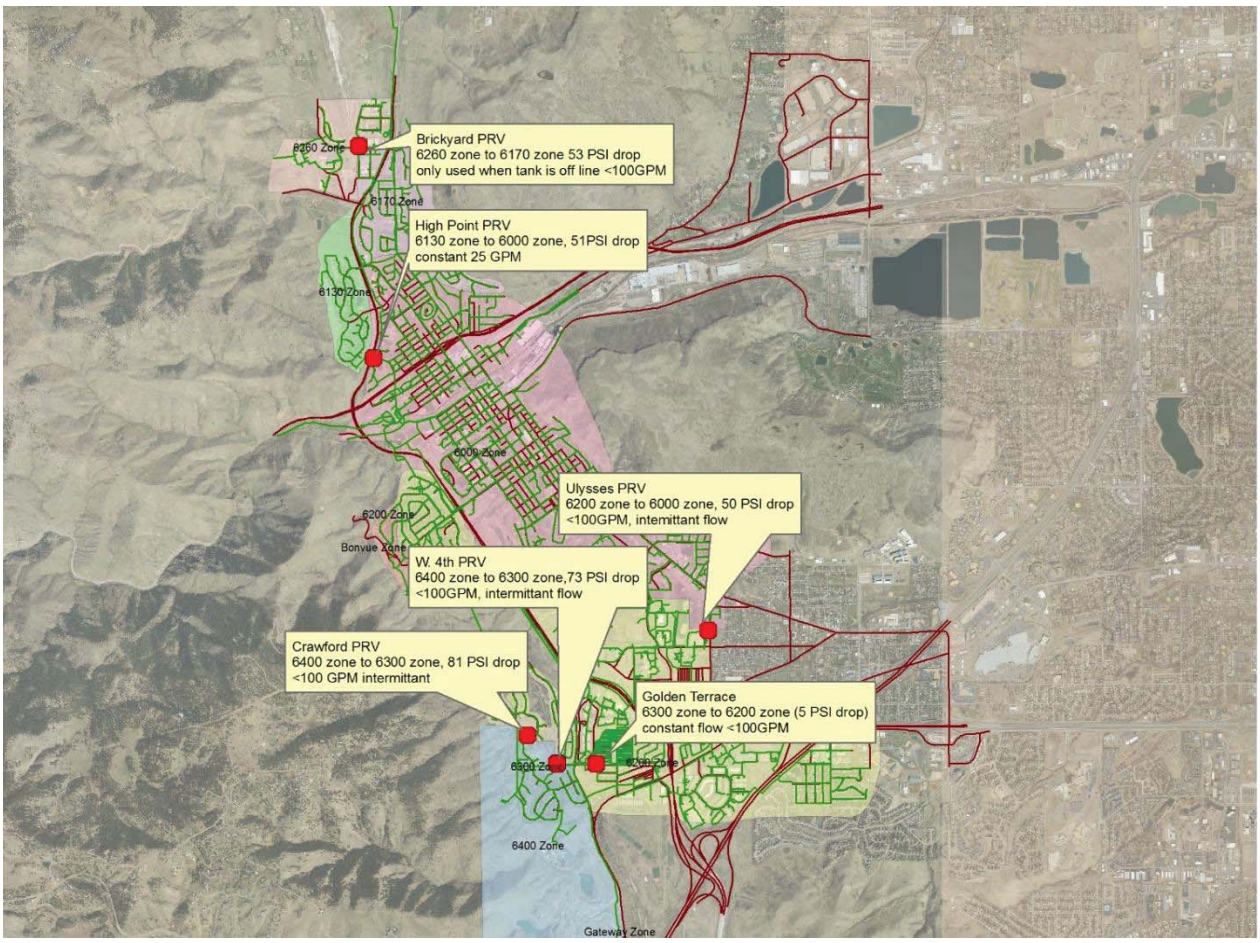


Figure 14: Golden Pressure Reducing Valves

HYDROPOWER POTENTIAL

Table 3 summarizes the pressure drop, flow and potential maximum capacity for electricity generation. The largest capacity is only about 5 kW and would only produce that much electricity a portion of the time. These sites will not be economically feasible for exporting power or net metering for several reasons; 1) no electrical load nearby to offset, 2) intermittent flow, and 3) the small capacity.

Table 3: City PRVs

PRV Name	Excess Pressure	Flow	Regularity?	Potential Capacity (kW)
Brickyard	53 psi	<100 gpm	Rarely	3.6
Highpoint	51 psi	25 gpm	constant	0.9
Ulysses	50 psi	<100 gpm	intermittent	3.4
W 4th	73 psi	<100 gpm	Intermittent	4.9
Crawford	81 psi	<100 gpm	Intermittent	5.4
Golden Terrace	5 psi	<100 gpm	Intermittent	0.3

There is one situation where adding a very small amount of hydropower at one of these distribution PRVs may make economic sense. If there is a need for data acquisition, remote monitoring or control at one of these PRV's that is also distant from a reliable power supply, such as the grid, self-generating a small amount of power to charge batteries may be reasonable.

The same turbine recommended for within the Valve Chamber at Lower Urad Reservoir could be used inside the PRV Vault. The turbine can be installed on a 2" bypass line around the PRV and can fit in most PRV vaults. The small control panel would be connected to the turbine, shutoff valve and a battery bank to provide power to low-power equipment. A full brochure is included in the Appendix.

PERMITTING REQUIREMENTS

Installing a hydroelectric generator on a man-made conduit serving municipal uses is considered Non-jurisdictional to FERC. A Notice of Intent should be filed with FERC to allow FERC to officially make a determination that the project is outside of FERC's jurisdiction. FERC is required to issue a determination within 45 days of receiving the notice. A copy of the Notice of Intent template is included in the Appendix.

CHALLENGES/OPPORTUNITIES

These types of distribution PRVs can be a challenge for hydropower. They generally operate only on demand of the service taps, resulting in intermittent flow and fluctuating excess pressure. The turbine is not able to generate constantly and will sit idle for a large percentage of the time. There is also the challenge of exporting the power from within the distribution system. There is generally no electrical demand at these PRV vaults spread through the distribution area. Adding hydropower to PRVs near an electrical demand that can be offset maximizes the value of the electricity generated.

CITY WATER SUPPLY INTAKE

The City's Water Treatment Plant diverts water from Clear Creek at the City Water Supply Intake. This intake is located at the headgate for the Church Ditch, approximately 3000 feet upstream of the treatment plant. Water is diverted from Clear Creek into a buried pipeline that discharges into the settling ponds at the treatment plant. A flow control valve and flow measurement device are located in a vault buried just downstream of the intake. At this location the pipe is flowing full at a low point.

Figure 15: City Water Supply Intake control valve and vault

HYDROPOWER POTENTIAL

Daily diversion records for the past two years are shown in Figure 16, and range from about 2 to 10 cfs. There is minimal pressure available in this pipeline and only the use of a hydrokinetic type turbine is possible.

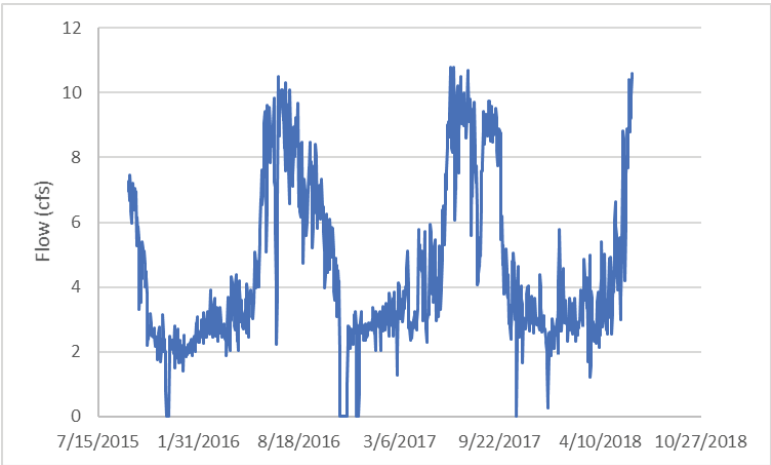


Figure 16: Diversions of City Water Supply Intake

Table 4: Lucid Energy turbines (http://lucidenergy.com/how-it-works/)

Size	Minimum Flow Required	Power Capacity
24"	35 cfs	18 kW
42"	95 cfs	50 kW
60"	198 cfs	100 kW

There is one turbine currently on the market that is specifically designed for sites like this. The turbine rotates by the flow of water and only minimally reduces the pressure in the pipeline. The specifications for the three sized turbines available are listed in Table 4, and the turbine is shown in Figure 17. The flows in the pipeline are not sufficient to provide the minimum flow required by these turbines. Because there is minimal pressure at this location, a traditional low head turbine is not likely to be feasible.

Figure 17: Lucid Energy Turbine Schematic

PERMITTING REQUIREMENTS

This site would be considered Non-Jurisdictional to FERC and the Notice of Intent process could be used.

CHALLENGES/OPPORTUNITIES

There is insufficient flow in the pipeline to utilize the Lucid Energy turbine.

GUANELLA RESERVOIR

Guanella Reservoir is located near Empire and provides additional storage for the City's water system. The reservoir was constructed on the site of a gravel pit, and is located off the channel of Clear Creek. Water is diverted into the reservoir and released through the outlet works back into Clear Creek when required.

The outlet works consists of a rectangular concrete tower with outlet gates and an overflow service spillway. The outlet pipe through the dam is not pressurized, and could not be used for hydropower. One option at this site would be to install a siphon over the dam to provide pressurized water to a turbine without disturbing the existing outlet works or the integrity of the dam.

A siphon intake can only operate when the water suface elevation is within approximtely 20 feet vertically of the crest of the dam elevation. Because the reservoir is maintained full most of the time, this should not be a limitation.

Figure 18: Guanella Reservoir Outlet Works

HYDROPOWER POTENTIAL

There is approximately 25 feet of head between the reservoir water surface elevation and the outlet channel. Figure 19 shows the reservoir elevation and discharge over time. The reservoir elevation only fluctuates regularly about 5 feet, except years when the storage is utilized e.g. 2011-2012. Discharge is generally less than 5 cfs with annual peaks of approximately 15-20 cfs. A general upward trend in discharge can also be seen. Energy generation estimates will be based on this period of historic record, which may be conservative given this upward trend.

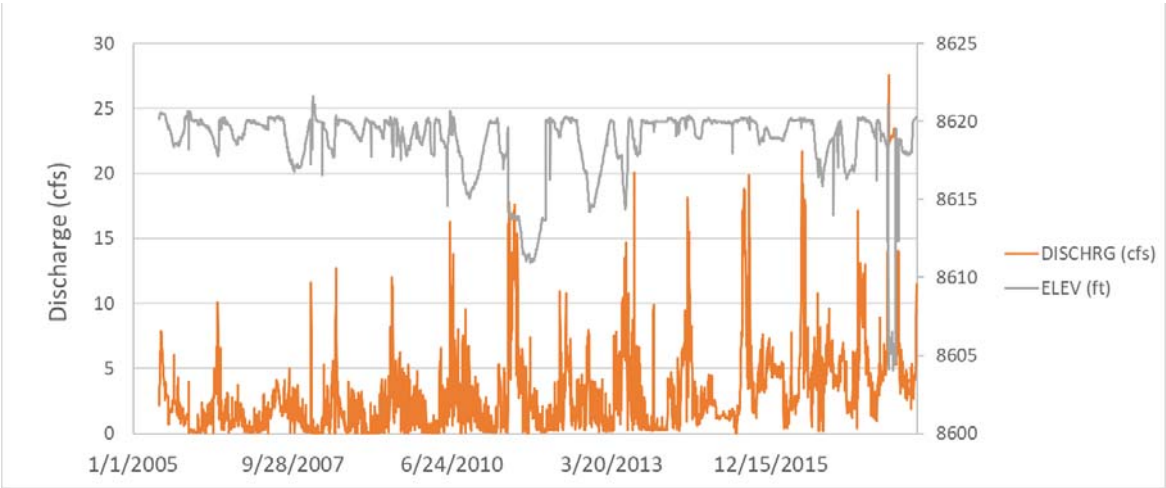


Figure 19: Guenalla Reservoir elevation and discharge

Reordering the daily elevation and discharge measurements into flow and head duration curves result in Figure 20 and Figure 21. A Cross Flow turbine was selected for this site because of its ability to operate at low heads - less than 25 feet - and its ability to generate efficiently over a large range of flows. The steep flow duration curve shows that flows are extremely variable and there isn't a constant flow for any amount of time.

The 6 kW Cross Flow would operate at a design flow of 3.5 cfs and a design head of 25 feet. It is able to operate down to 0.5 cfs and generate an average of 12.7 MWhs annually (using a higher design flow of 5 cfs did not increase annual generation).

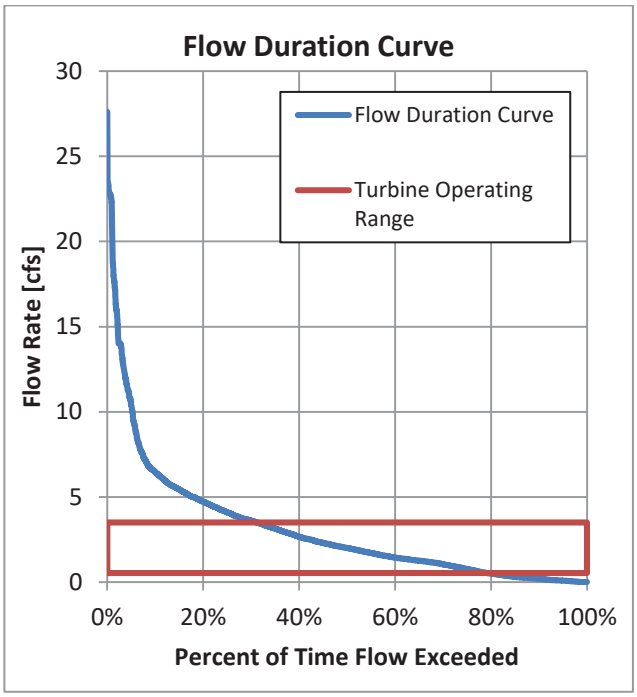


Figure 20: Flow Duration Curve

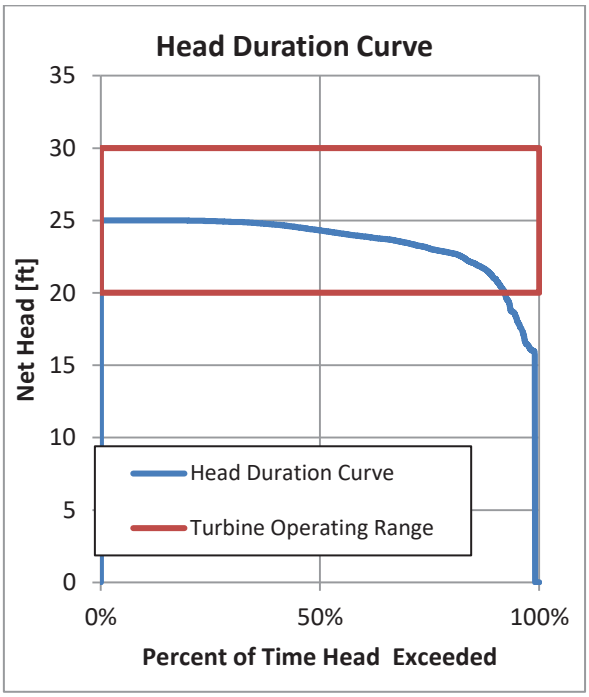


Figure 21: Head Duration Curve

PERMITTING REQUIREMENTS

Adding hydropower to Guanella reservoir would require a Small Hydropower Exemption from FERC. It would also put the dam under FERC dam safety jurisdiction.

CHALLENGES/OPPORTUNITIES

The permitting costs and implications to dam safety are likely to exceed the benefit provided by the small capacity and small amount of electricity generated.

TASK 1 - CONCLUSIONS AND RECOMMENDATIONS

Hydropower Development at the City Water Supply Intake is not technically feasible due to low flows and no excess pressure. Upper Urad will not be economically feasible (as compared to Lower Urad) because of the distance from powerlines. Very small turbines could be used at either the City PRV stations or in the Valve Chamber of Lower or Upper Urad to charge batteries needed to power remote monitoring or control systems. The small capacity and low generation at Guanella Reservoir make it unlikely to be economically feasible.

Lower Urad Reservoir and the Chute into Lower Urad Reservoir are both technically feasible and show promise to be economically feasible provided a number of conditions are met. For Lower Urad, 1) a net metering arrangement could be utilized in partnership with the Henderson Mine, 2) the dam falling under FERC jurisdiction for dam safety is acceptable and 3) the condition of the existing outlet works is acceptable for pressurization. For the Chute into Lower Urad, 1) a net metering arrangement could be utilized in partnership with the Henderson Mine and 2) the Henderson Mine is willing to allow modifications to the existing structure.

Continued analysis of hydropower development at the Lower Urad Reservoir and the Chute into Lower Urad Reservoir is recommended in Task 2 with initial focus on the conditions listed above.

TASK 2 – INTRODUCTION

Task 1 found that Lower Urad Reservoir and the Chute into Lower Urad were the sites with the most potential for successful development. The relatively small size is challenging for development at a dam. There are a number of fixed costs, such as permitting, which any project must incur regardless of size. Given that a smaller project will generate less electricity and therefore less revenue annually, these fixed costs can make a smaller project economically infeasible.

A conceptual design for each of the three alternatives at Lower Urad are presented below along with a cost estimate and a high-level economic analysis.

The Chute into Lower Urad is a structure owned by the Henderson Mine. It is also a part of their environmental remediation plan. Initial discussions have indicated that the mine would not be interested in altering this structure in any way, which would be required to construct a hydropower project.

The design and cost of the Chute into Lower Urad would be similar to the Service Spillway at Lower Urad with a slightly different intake structure, longer penstock and about twice the capacity (because of the increased head). This site would be economically more favorable and simpler to permit than the Lower Urad sites. However, participation and wiliness from the mine is essential for the project's success.

The following sections explain the conceptual design and economics of the Lower Urad sites. Utilizing the secondary outlet is the most cost effective and likely the most acceptable to Dam Safety. However, the revenue generated would not be sufficient to payback the project cost in a reasonable amount of time. If power prices increase, or grants become available to assist with the development cost, this could reduce the payback period and make the projects viable in the future.

LOWER URAD CONCEPTUAL DESIGN ALTERNATIVES

Three locations or configurations at Lower Urad Reservoir were shown to be technically feasible 1) using the main outlet 2) using the secondary outlet and 3) installing a new penstock alongside the service spillway. The conceptual design and major components of each design are described below. The capacities noted in Task 1 sections above were estimated based on available head and flow and average turbine properties, the capacities noted below are actual turbine capacities quoted from a turbine manufacturer.

Site	Design Flow (cfs)	Net Head (feet)	Capacity (kW)	Turbine Type	Annual Generation (MWh)
Lower Urad					
Main Outlet	8.2	66.8	31	Cross-Flow	185
Secondary Outlet	5.2	69.3	21	Pump-as-Turbine	96
Service Spillway	8.2	88.1	40	Francis	204

MAIN OUTLET

The main outlet consists of a 30" steel pipe encased in concrete with a valve chamber located mid length. The portion of pipe upstream of the valve chamber was designed to operate under pressure, when the valve is closed.

The portion of pipe downstream of the valve chamber was originally designed to operate without pressure, discharging to atmospheric pressure without a downstream valve. By adding a turbine to the downstream end of the pipeline, pressure will be created throughout the length of the outlet pipe.

The entire outlet pipe could be lined to withstand the full pressure of the reservoir. However, lining an outlet without emptying the reservoir can be challenging. The lining needs to terminate at the upstream end, and at Lower Urad, there is a 24" butterfly valve in the valve chamber. It may be possible to dismantle and cut a section of pipe downstream of the valve within the valve chamber to access the upstream end of the lined section. The cost estimate is based on a relatively easy lining cost, any complications to this process would add cost to the estimate. Any plan to line the outlet pipe would need to maintain the discharge capacity of the existing outlet works.

A bifurcation is required at the downstream end of the pipe to add both the turbine and a shutoff valve. The shutoff valve would force water into the turbine, and also allow the outlet works to operate when the turbine is not operating.

A Cross Flow turbine was found to be most cost effective at this site, operating over a large range of flows at relatively high efficiency. The turbine controls can be programmed to maintain the reservoir elevation ("level control") at the top of the spillway. This would ensure that all flows coming into the reservoir are discharged through the turbine. If the turbine is operating at full capacity, excess flow would be routed over the spillway. Also, the level control could be overridden if another discharge flow rate from the reservoir is desired. This operating scheme could be utilized similarly for all three alternatives.

SECONDARY OUTLET

The secondary outlet is a 14" steel pipe encased in concrete. It is unclear from the original drawings if this pipe was designed to operate under pressure. The design documents refer to a "Pump Supply Line", and if this was used to supply a pump station, it may have been designed to operate under pressure. This secondary outlet is also not critical to the operation of the reservoir and therefore does not need a bypass valve to be installed. A drain would be added to the pipeline to ensure that the pipe could be emptied, but the line can be operated, or shutdown using the valve in the main valve chamber.

The Cross Flow turbine was also found to be the best option for this outlet. The characteristics are very similar to the main outlet and the Cross Flow turbine will operate over the large range of flows.

SPILLWAY

The Lower Urad Reservoir Service Spillway is a rectangular concrete chute with an Ogee weir at the top end. This weir is a shaped block of solid, reinforced concrete. The shape of the spillway allows for a smooth hydraulic exit from the reservoir. It is possible to modify this ogee weir to include an intake for the penstock. Floating debris may pass over this weir and be excluded from the water going to the turbine. A tyrolean type intake with a coanda, wedge wire screen will be self cleaning and maintain the hydraulics of the spillway.

Figure 23 shows a Tyrolean Intake where water falls through a screen on the top of the structure and is then directed in to the rectangular open channel into the page. A pipe would be installed at the point where the channel exits the wall of the spillway. The screen can be manufacturered to match the curvature of the ogee wier. This configuration would not reduce the capacity of the existing spilway. The strength of such an intake and the

modification to the smooth spillway would need to be considered in depth to prevent any damage to the existing infrastructure in the case of a flood condition when the spillway is running the most flow.

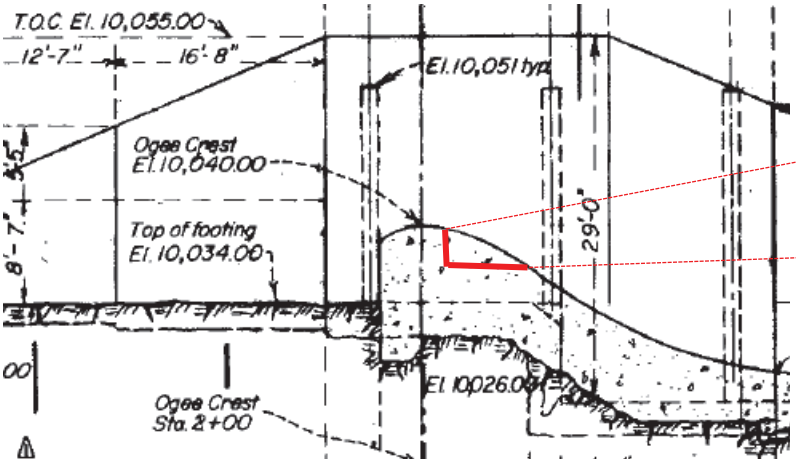


Figure 22: Lower Urad Spillway

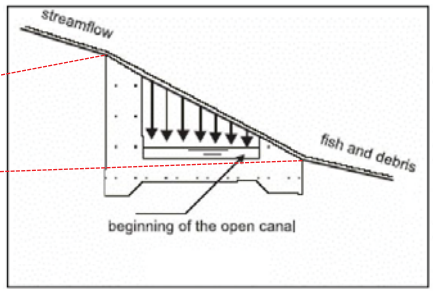


Figure 23: Tyrolean Intake

Another possible intake configuration would be a siphon intake, the penstock could still run aside the spillway, and then extend downward into the reservoir. This type of configuration does not alter or modify the dam or spillway in any way, posing less of a dam safety concern. The siphon would need to be initiated with a vacuum pump system, which can be operationally challenging. A recent project in Colorado implemented such a siphon intake (see Figure 24).

Figure 24: Siphon Intake at Humphreys Dam

Either the Cross Flow turbine or the Francis turbine could be implemented at this site. The Francis turbine is more expensive, but allows for a larger range of operating flows. The total cost is similar for either turbine selected.

LOWER URAD COST ESTIMATES

The total estimated cost of each of the three Lower Urad sites is summarized in the table below and itemized cost estimates are provided in the following sections.

	Main Outlet	Secondary Outlet	Service Spillway
Net Head	67 feet	69 feet	88 feet
Design Flow	8.2 cfs	8.2 cfs	8.2 cfs
Capacity	31 kW	31 kW	40 kW
Annual Generation	185 MWh	185 MWh	204 MWh
Total Estimated Cost	***$754,115***	***$636,760***	***$838,780***
Cost per kW	$24,326.29	$20,540.65	$20,969.50

To provide some perspective on the cost of small hydropower, this chart was developed by Oak Ridge National Laboratory based on recently constructed projects. While this is the average cost, the highest cost projects that have been constructed are in the $10,000/kW range.

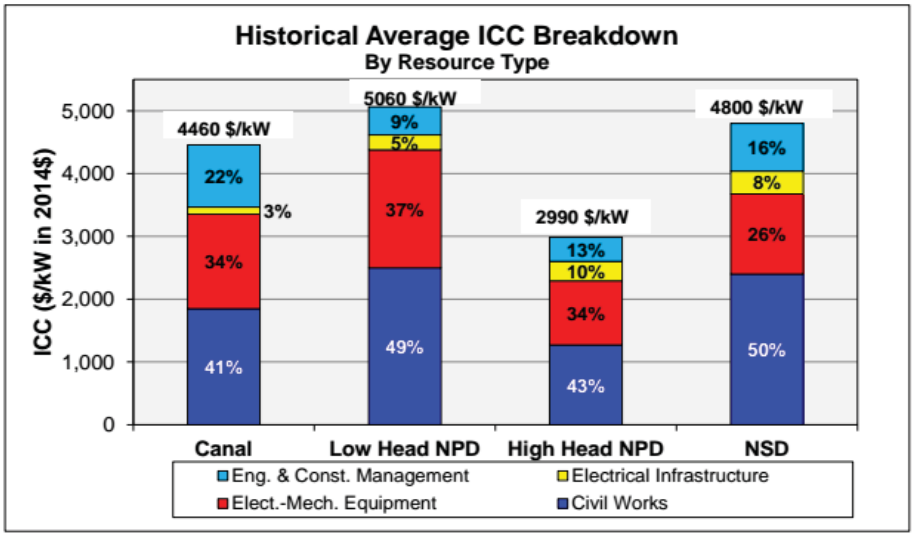


Figure 3. ICC ($/kW) breakdown by resource of recently constructed and under construction hydropower projects.

MAIN OUTLET

	Main Outlet		
Item	*Unit Price*	*Quantity*	*Total Cost*
Turbine, Generator and Controls	$ 190,000	1	$ 190,000
Intake Modification	$ 20,000	1	$ 20,000
Penstock	$ 72	50	$ 3,600
Outlet lining	$ 240	225	$ 54,000
Powerhouse Substructure	$ 100,000	1	$ 100,000
Powerhouse Superstructure	$ 50,000	1	$ 50,000
Valves	$ 24,000	1	$ 24,000
Powerline Extension	$ 15	675	$ 10,125
Interconnection costs	$ 5,000	1	$ 5,000
Access Road	$ 60	175	$ 10,500
Subtotal			$ 467,225
Contingency		25%	$ 116,806
Construction Subtotal			$ 584,031
Permitting (FERC and SEO)			$ 100,000
Engineering Design		12%	$ 70,084
Total Cost			**$ 754,115**

SECONDARY OUTLET

	Secondary Outlet		
Item	*Unit Price*	*Quantity*	*Total Cost*
Turbine, Generator and Controls	$ 190,000	1	$ 190,000
Intake Modification	$ 20,000	1	$ 20,000
Penstock	$ 48	50	$ 2,400
Outlet lining			
Powerhouse Substructure	$ 100,000	1	$ 100,000
Powerhouse Superstructure	$ 50,000	1	$ 50,000
Valves	$ 1,000	1	$ 1,000
Powerline Extension	$ 15	600	$ 9,000
Interconnection costs	$ 5,000	1	$ 5,000
Access Road	$ 60	100	$ 6,000
Subtotal			$ 383,400
Contingency		25%	$ 95,850
Construction Subtotal			$ 479,250
Permitting (FERC and SEO)			$ 100,000
Engineering Design		12%	$ 57,510
Total Cost			**$ 636,760**

SPILLWAY

Item	Service Spillway Unit Price	Quantity	Total Cost
Turbine, Generator and Controls	$ 250,000	1	$ 250,000
Intake Modification	$ 65,000	1	$ 65,000
Penstock	$ 72	350	$ 25,200
Outlet lining	$ -	-	-
Powerhouse Substructure	$ 100,000	1	$ 100,000
Powerhouse Superstructure	$ 50,000	1	$ 50,000
Valves	$ 2,500	1	$ 2,500
Powerline Extension	$ 15	800	$ 12,000
Interconnection costs	$ 5,000	1	$ 5,000
Access Road	$ 60	300	$ 18,000
Subtotal			$ 527,700
Contingency		25%	$ 131,925
Construction Subtotal			$ 659,625
Permitting (FERC and SEO)			$ 100,000
Engineering Design		12%	$ 79,155
Total Cost			**$ 838,780**

LOWER URAD ECONOMIC ANALYSIS

There are generally two options for selling power from a small hydropower project. One is a Power Purchase Agreement (PPA), where the local utility purchases all of the power generated at an agreed upon rate. The second is a net metering agreement, where an electrical load is offset with the generated electricity. The easiest route is the PPA, but it also has the lowest value. Xcel Energy has a published rate for small hydro of 2.5 cents per kWh for any project under 100 kW. This results in annual revenue of between $4,625 and $5,100. This is not economically feasible for these projects and results in an extremely long payback period.

If an agreement could be made with the Henderson Mine to offset their electricity at a rate of 7.5 cents per kWh, revenues would increase three-fold. This decreases the payback period, but not enough to make an economically feasible or attractive project. As an example, if approximately half of the project could be funded by an outside grant, the payback periods become more attractive. Alternatively, if power prices rose significantly, the project may also become viable.

	Total Cost	Annual Generation (kWh)	Annual Revenue PPA	Simple Payback	Annual Revenue Net metering	Simple Payback	Simple Payback with 50% grant
Main Outlet	$ 754,115.00	185000	$ 4,625	163	$ 13,875	54	27
Secondary Outlet	$ 636,760.00	185000	$ 4,625	138	$ 13,875	46	23
Spillway	$ 838,780.00	204000	$ 5,100	164	$ 15,300	55	27

CONCLUSIONS

The entire City of Golden Water Supply System was considered for its hydropower potential. The City Water Supply Intake was found to be technically infeasible. The Upper Urad Reservoir will be less economically feasible (as compared to Lower Urad) because of the distance from powerlines. Very small turbines could be used at either the City PRV stations or in the Valve Chamber of Lower or Upper Urad to charge batteries needed to power remote monitoring or control systems. The small capacity and low generation at Guanella Reservoir make it unlikely to be economically feasible.

Lower Urad Reservoir site was found to be technically feasible, but economically infeasible given the cost and current energy prices. The Chute into Lower Urad Reservoir was found to be technically feasible, but would require participation from the Henderson Mine, as the infrastructure is owned by the mine. This participation is not currently likely based on initial conversations.

We hope the information provided in this report can be used at some point in the future when conditions are more favorable for small hydropower development within the City's Water Supply System.

APPENDICES

Energy Generation Estimates

SOAR Microturbine sales brochure

FERC Notice of Intent Template

Task 2 Energy Generation Estimates

ENERGY GENERATION ESTIMATES

Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Main Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Main Outlet
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	67.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Francis	
Nameplate Capacity:	38	kW

Penstock Diameter:	2.50	ft
Penstock Length	400	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

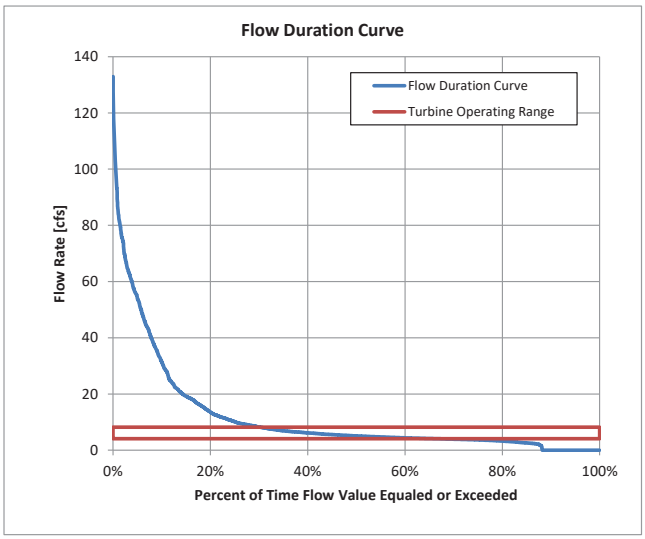
Transmission Loss:	2%

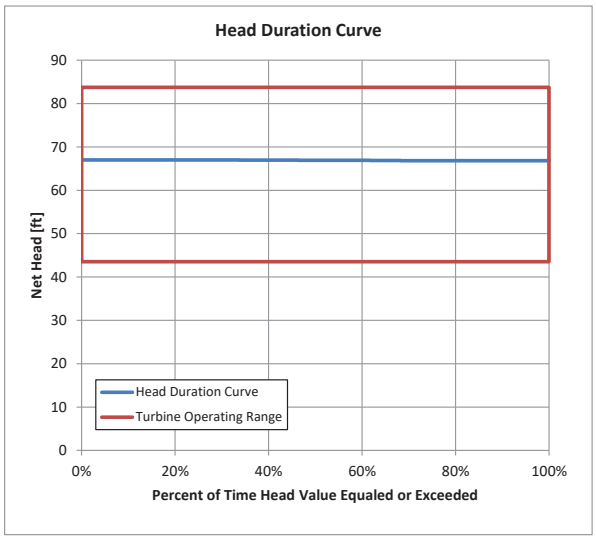
Unplanned Loss:	2%

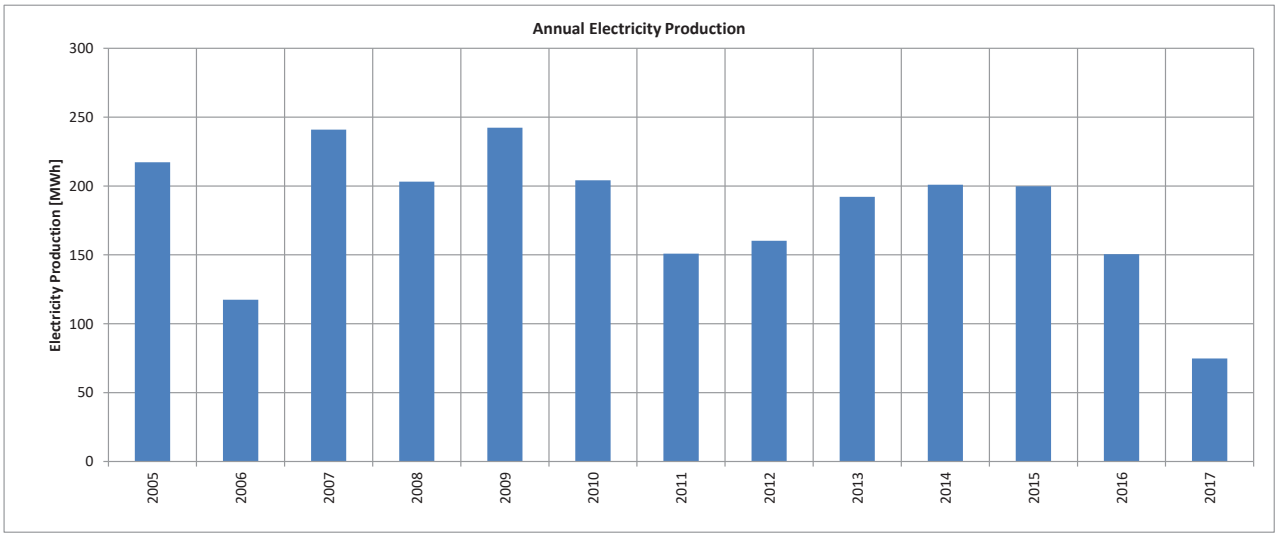
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.4	4.1	7.6	15.8	26.6	25.7	24.7	23.4	19.7	14.5	8.8	6.9	181.1
Maximum	10.1	15.2	19.8	24.4	29.6	28.6	29.6	29.6	28.6	28.6	20.5	16.1	242.4
Minimum	0.0	0.0	0.0	0.4	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.7
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	54%
Operation Days per Year:	242







Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Main Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Main Outlet - Pump-as-Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	4.5	cfs
Gross Design Head:	67.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Custom	
Nameplate Capacity:	17	kW

Penstock Diameter:	2.50	ft
Penstock Length	400	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

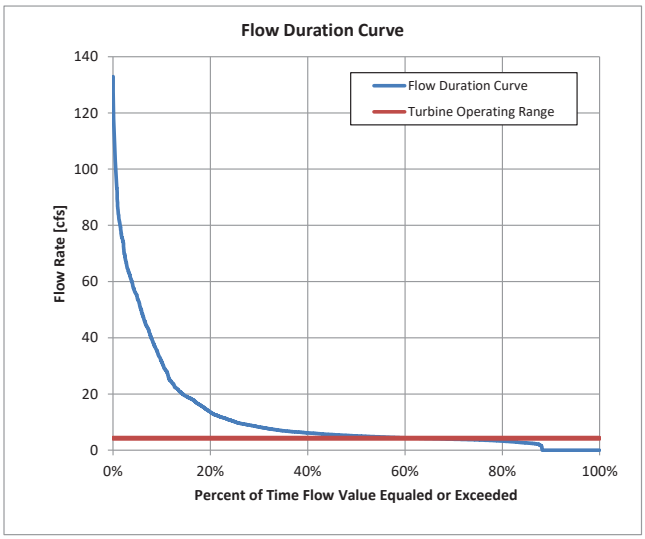
Transmission Loss:	2%

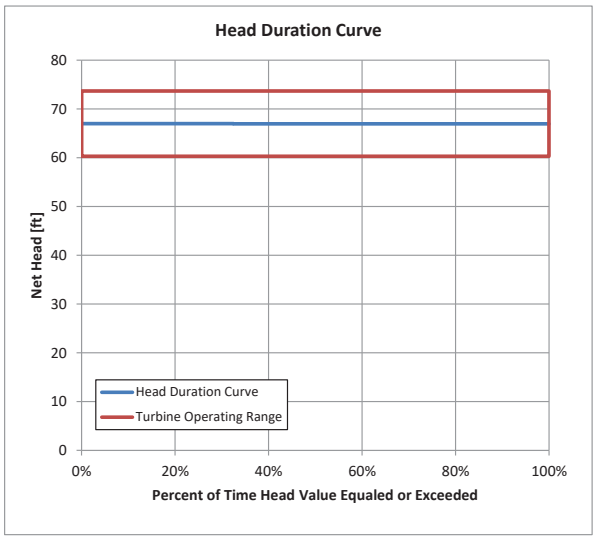
Unplanned Loss:	2%

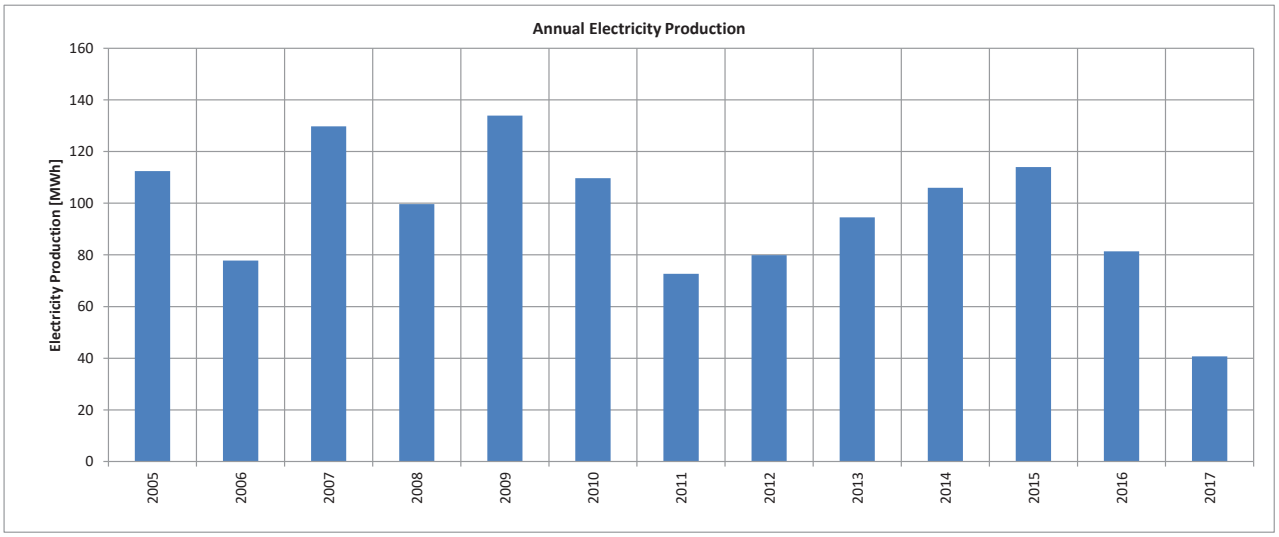
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.3	3.7	6.0	9.3	11.6	10.6	10.2	9.9	9.7	9.4	6.4	6.1	96.3
Maximum	10.1	11.1	12.2	11.8	12.2	11.8	12.2	12.2	11.8	12.2	11.8	12.2	133.9
Minimum	0.0	0.0	0.0	0.4	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.7
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	64%
Operation Days per Year:	246







Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Secondary Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Secondary Outlet
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	71.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Francis	
Nameplate Capacity:	41	kW

Penstock Diameter:	1.17	ft
Penstock Length	100	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

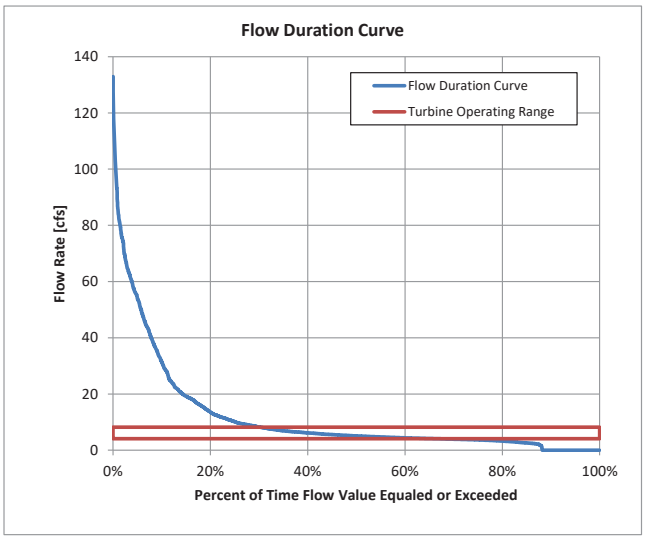
Transmission Loss:	2%

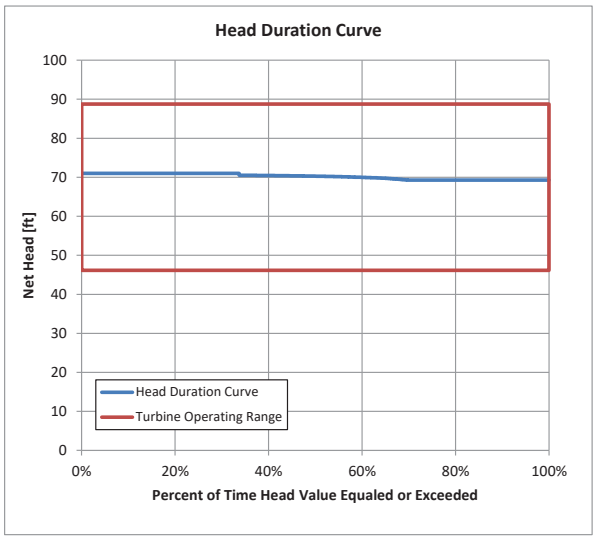
Unplanned Loss:	2%

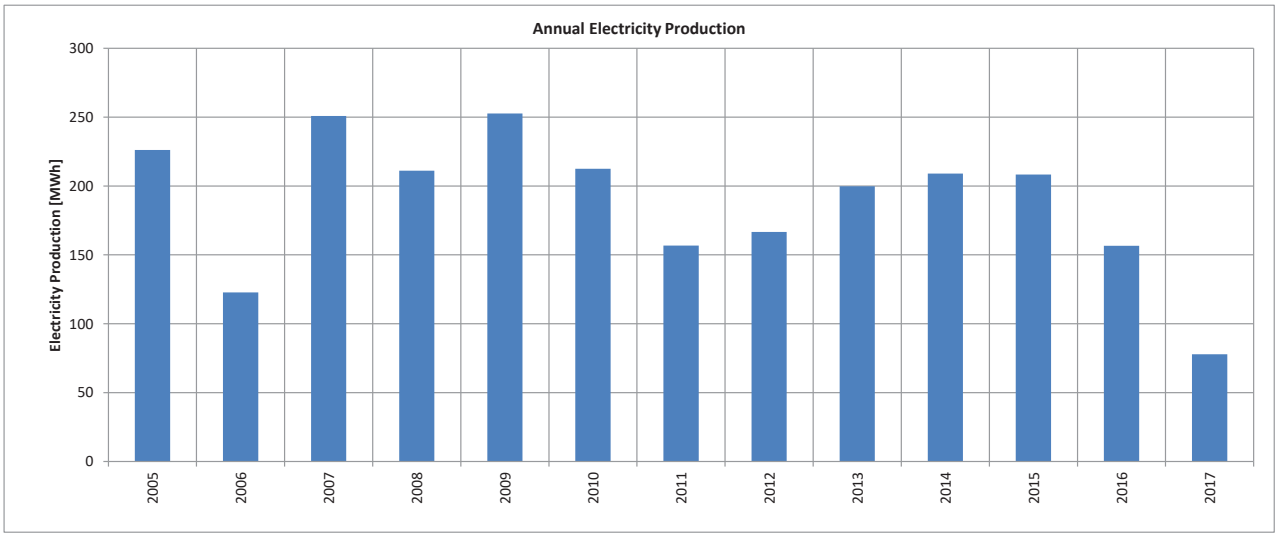
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.6	4.3	8.0	16.5	27.6	26.6	25.6	24.2	20.5	15.1	9.2	7.2	188.6
Maximum	10.7	15.9	20.7	25.4	30.7	29.7	30.7	30.7	29.7	29.7	21.4	16.9	252.6
Minimum	0.0	0.0	0.0	0.4	21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.8
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	53%
Operation Days per Year:	242







Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Secondary Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Secondary Outlet - Pump-as-Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	4.5	cfs
Gross Design Head:	71.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Custom	
Nameplate Capacity:	18	kW

Penstock Diameter:	1.17	ft
Penstock Length	100	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

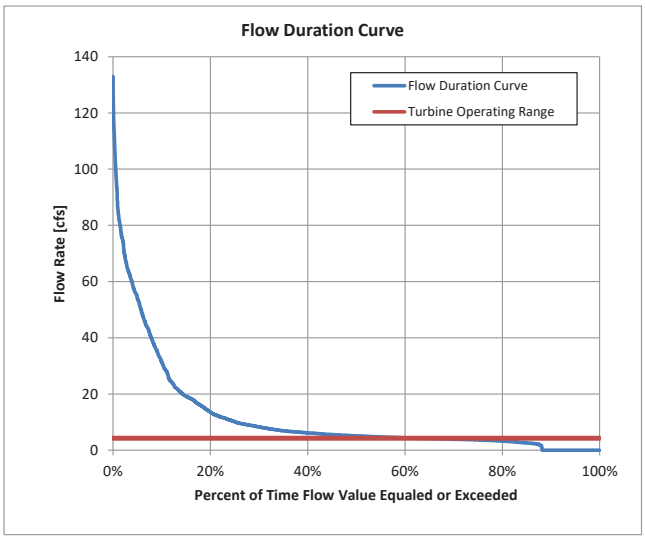
Transmission Loss:	2%

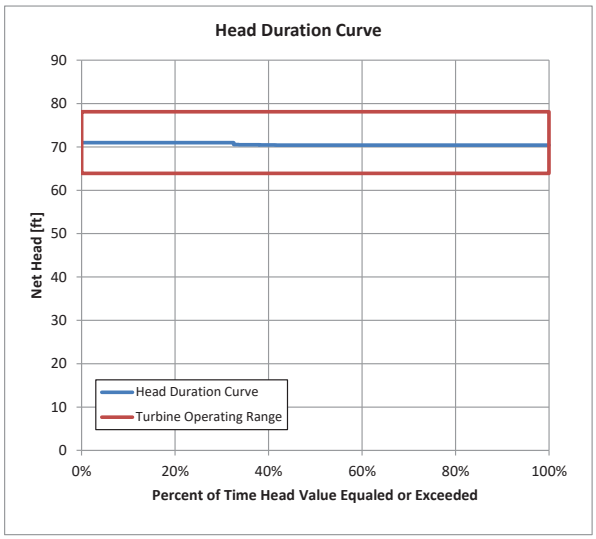
Unplanned Loss:	2%

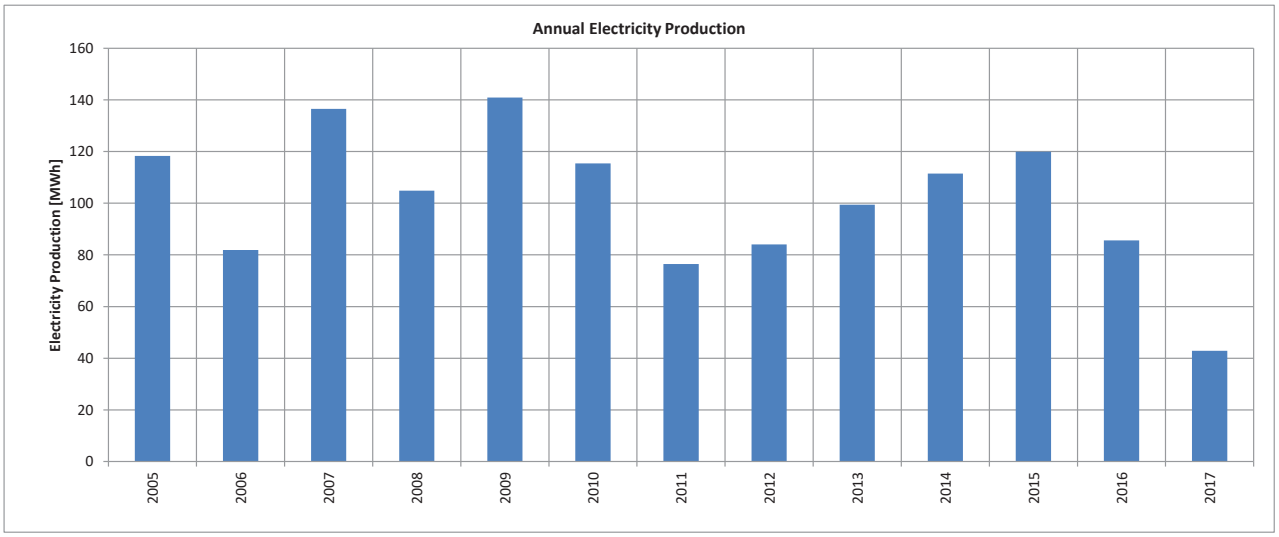
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.5	3.9	6.3	9.8	12.2	11.2	10.8	10.4	10.2	9.9	6.7	6.4	101.4
Maximum	10.7	11.6	12.9	12.5	12.9	12.5	12.9	12.9	12.5	12.9	12.5	12.9	140.9
Minimum	0.0	0.0	0.0	0.4	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.8
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	64%
Operation Days per Year:	246







Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Spillway
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Service Spillway
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	90.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir - outlet at 7+00

Turbine Type:	Francis	
Nameplate Capacity:	52	kW

Penstock Diameter:	1.50	ft
Penstock Length	500	ft
Penstock C_H Coeff.	140	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

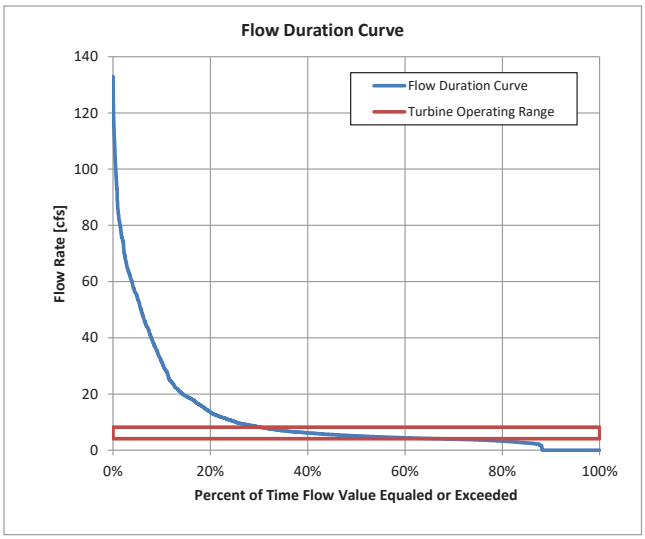
Transmission Loss:	2%

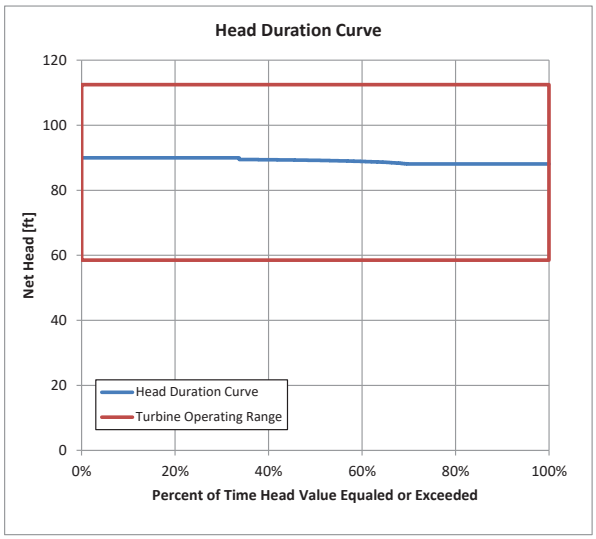
Unplanned Loss:	2%

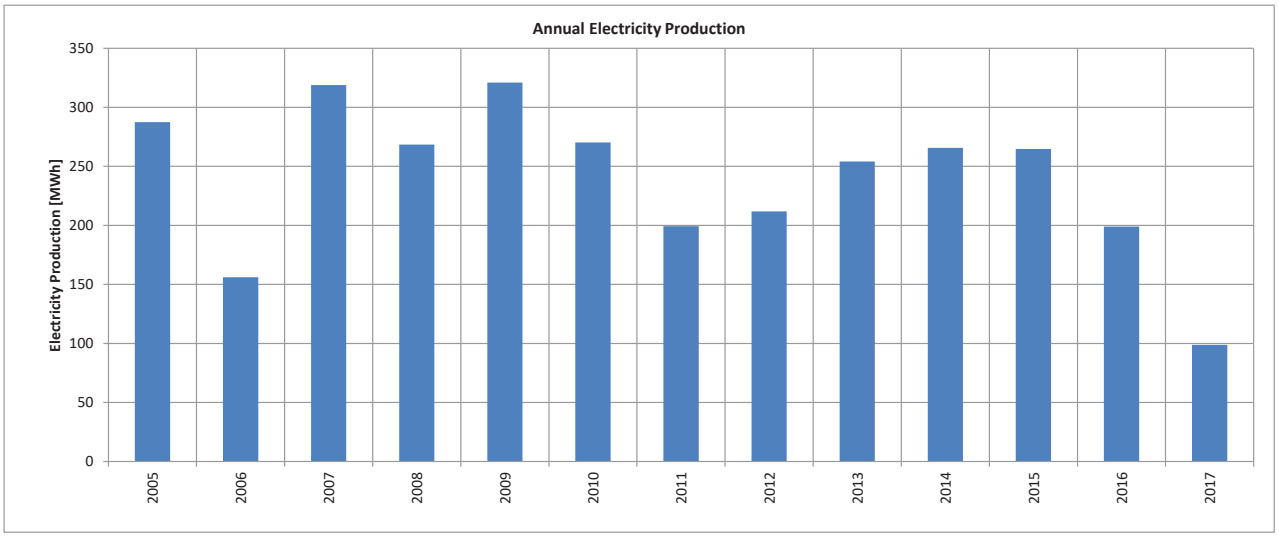
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	4.6	5.5	10.1	21.0	35.1	33.9	32.6	30.8	26.0	19.2	11.7	9.2	239.6
Maximum	13.5	20.2	26.3	32.2	39.0	37.7	39.0	39.0	37.7	37.8	27.2	21.5	321.0
Minimum	0.0	0.0	0.0	0.5	26.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.9
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	53%
Operation Days per Year:	242







Hydroelectric Generation Capacity Estimation Tool

Date: 8/30/2018

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir -Service Spillway
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Service Spillway - Pump-as-Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	4.5	cfs
Gross Design Head:	90.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir - discharge at 7+00

Turbine Type:	Custom	
Nameplate Capacity:	23	kW

Penstock Diameter:	1.00	ft
Penstock Length	500	ft
Penstock C_H Coeff.	140	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

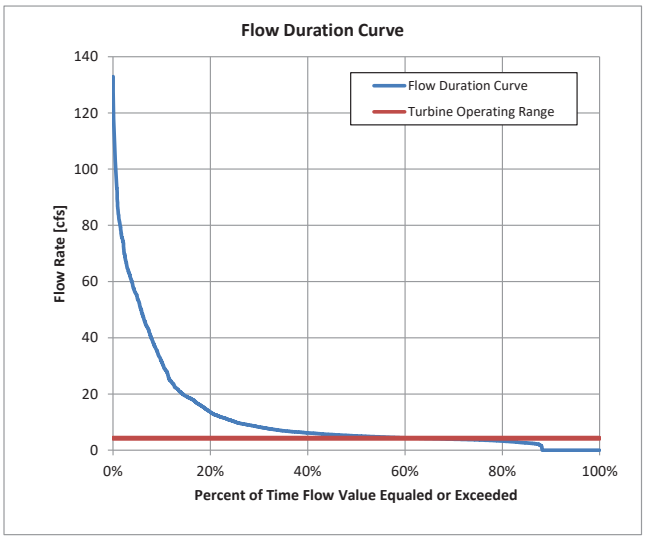
Transmission Loss:	2%

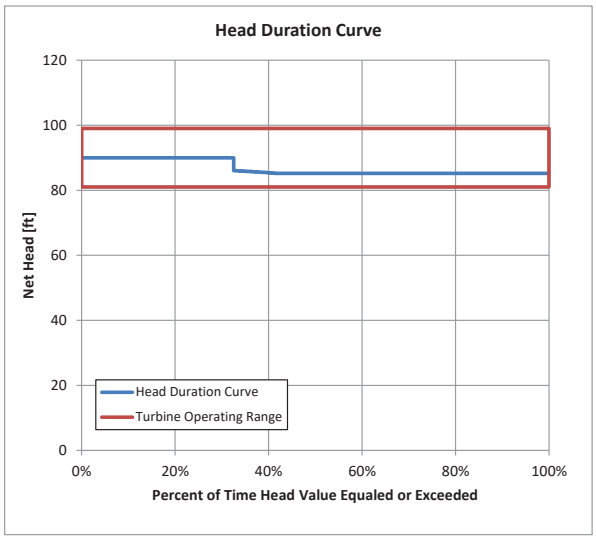
Unplanned Loss:	2%

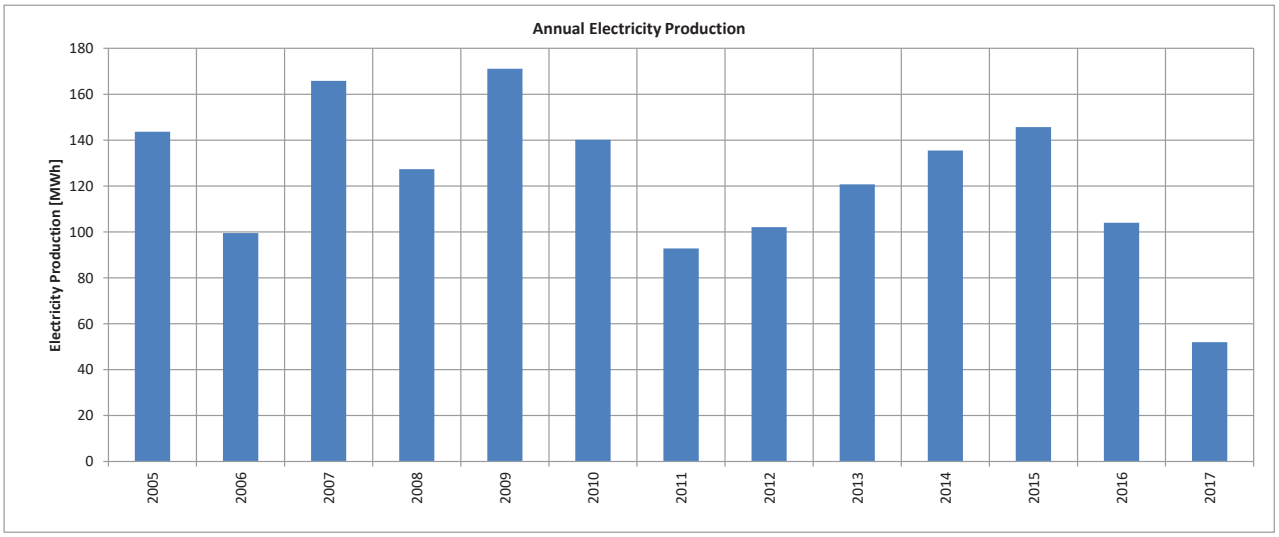
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	4.3	4.7	7.7	11.9	14.8	13.6	13.1	12.7	12.4	12.0	8.2	7.8	123.1
Maximum	13.0	14.1	15.6	15.1	15.6	15.1	15.6	15.6	15.1	15.6	15.1	15.6	171.1
Minimum	0.0	0.0	0.0	0.5	11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	61%
Operation Days per Year:	246







Hydroelectric Generation Capacity Estimation Tool

Date: 10/2/2018

Version 1.4
Summary Tab

Project:	Chute into Lower Urad
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Chute into Lower Urad
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	130.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Google Earth

Turbine Type:	Francis	
Nameplate Capacity:	74	kW

Penstock Diameter:	1.50	ft
Penstock Length	600	ft
Penstock C_H Coeff.	140	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

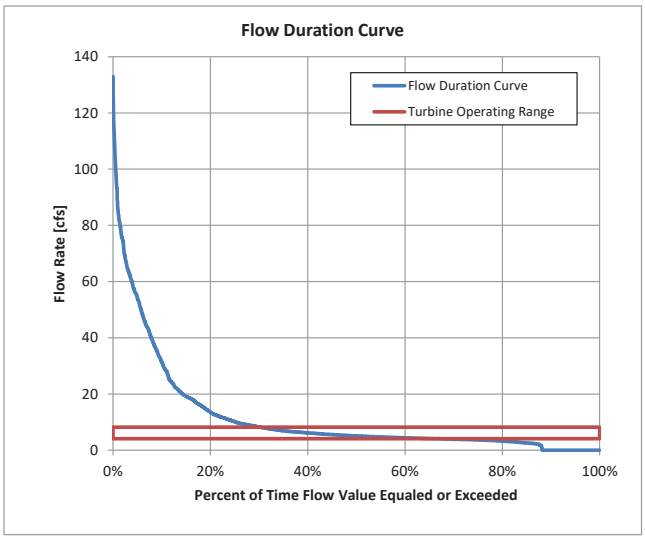
Transmission Loss:	2%

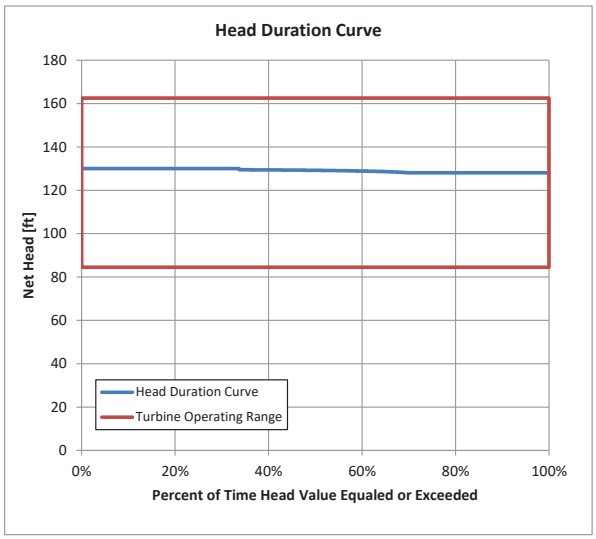
Unplanned Loss:	2%

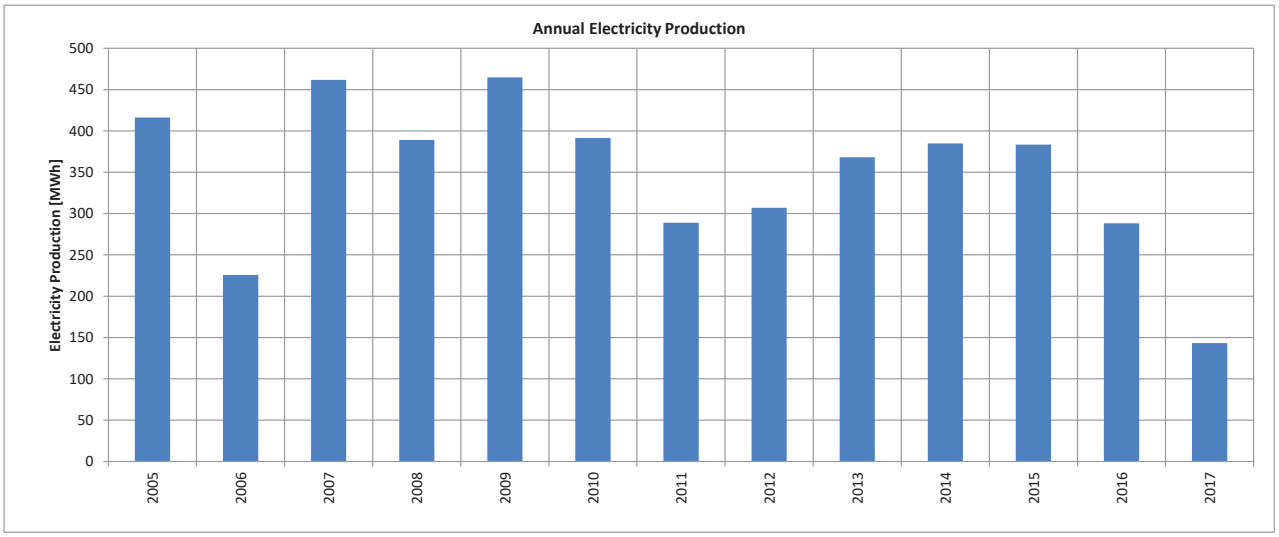
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	6.6	7.9	14.6	30.4	50.9	49.1	47.2	44.7	37.7	27.8	17.0	13.3	347.2
Maximum	19.6	29.2	38.0	46.7	56.5	54.7	56.5	56.5	54.7	54.8	39.4	31.1	464.9
Minimum	0.0	0.0	0.0	0.7	38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	143.2
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	53%
Operation Days per Year:	242







Hydroelectric Generation Capacity Estimation Tool

Date: 10/2/2018

Version 1.4
Summary Tab

Project:	Guanella Reservoir
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Guanella Reservoir
Created By:	Lindsay George

Study Period: 6/13/2005 to 6/12/2018

Design Flow:	3.5	cfs
Gross Design Head:	25.0	ft

Flow data source:	CO DWR GUANELLA RESERVOIR (OUTFLOW) (GUAOUTCO)
Head data source:	CO DWR GUANELLA RESERVOIR (GUARESCO)

Turbine Type:	Crossflow	
Nameplate Capacity:	6	kW

Penstock Diameter:	1.00	ft
Penstock Length	400	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

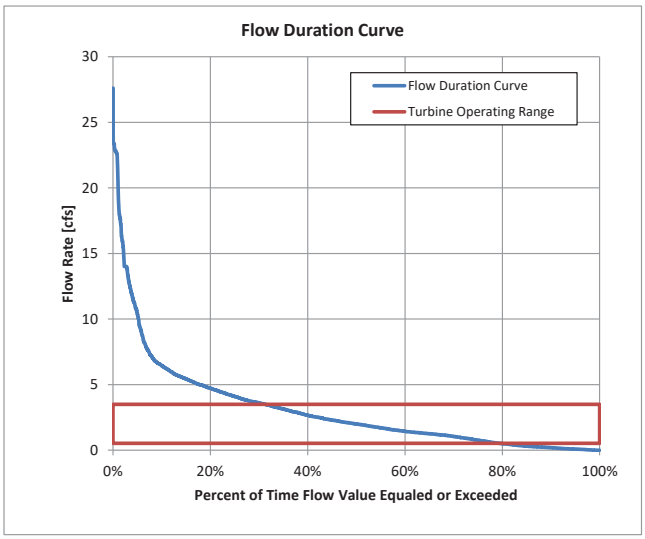
Transmission Loss:	2%

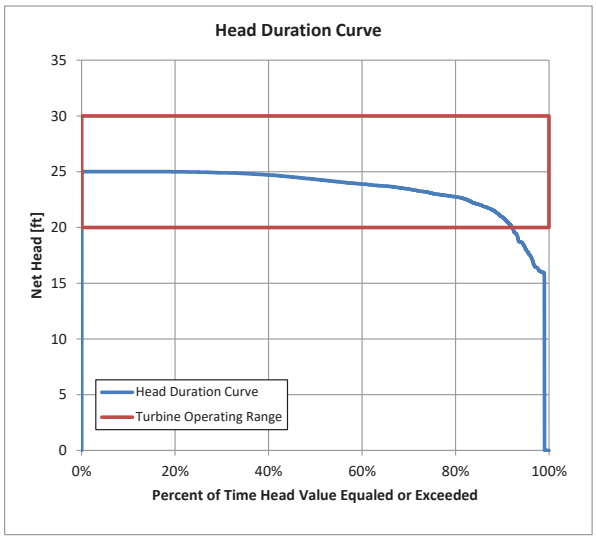
Unplanned Loss:	2%

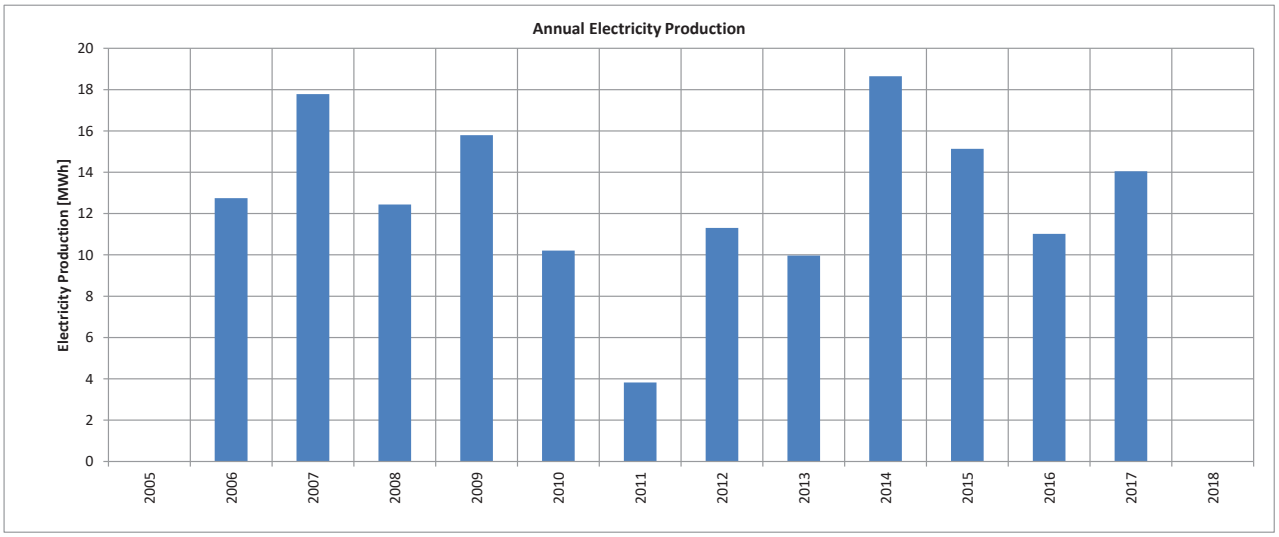
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	0.4	0.5	0.8	1.4	1.8	0.8	1.4	1.7	1.3	1.3	1.0	0.6	12.7
Maximum	1.5	1.9	3.2	2.2	2.8	3.4	2.7	3.1	2.8	2.7	2.9	2.8	18.6
Minimum	0.0	0.0	0.0	1.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	24%
Operation Days per Year:	182







SOAR MICROTURBINE SALES BROCHURE

Micro Hydro Turbine

Micro 300 Series, M300-XX
2” or Larger Pipe Sizes
300 Watt Maximum Power Output
12-24VDC/120VAC Configurations

Soar Hydropower’s Micro turbine series are designed for power generation in new or existing water networks and can be installed on any two inch or larger pipeline. Installation is simple and systems are plug-and-play. With minimal site prep requirements they are ideal for both local and off-grid applications. Common applications are installed in parallel with existing control or pressure reducing valves.

Micro Hydro turbines are ideal for running Remote terminal units (RTUs), SCADA systems, monitoring equipment, sump pumps, lighting, blowers, fans, and pressure management devices. Systems can be configured for 12-24VDC, or 120VAC, and maximum power output is 300 Watts. Generated power can be used as it is generated and excess is stored through a sophisticated battery charging system. When auxillary batteries are fully charged, the turbine automatically shuts down to prolong system life.

There are two versions of the M300 Micro Turbine. The M300-60 is engineered for higher head applications (up to 60 PSI) while the M300-30 is engineered for lower head (up to 30 PSI). Power output for both models depends on site specifics but both share the same 300W maximum potential.

For purchasing and application support contact your distributor or Soar directly

Micro Hydro Turbine

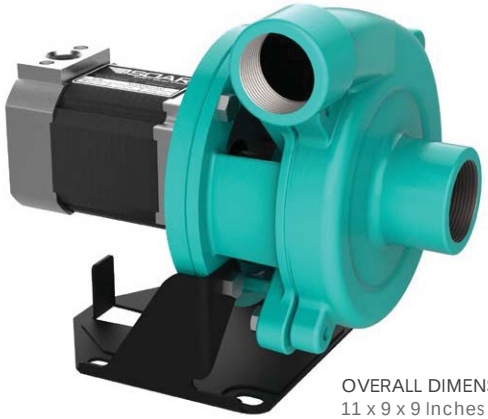
Micro 300 Series, M300-XX
2” or Larger Pipe Sizes
300 Watt Maximum Power Output

Micro Series Features

Soar’s Micro Hydro Turbines are packaged solutions with simplified installation and an extremely compact footprint. They integrate seamlessly into both new and existing water delivery networks. Typical systems include turbine, generator, and controls and come ready for drop-in generation.

M300-30
Micro Hydro 300-30

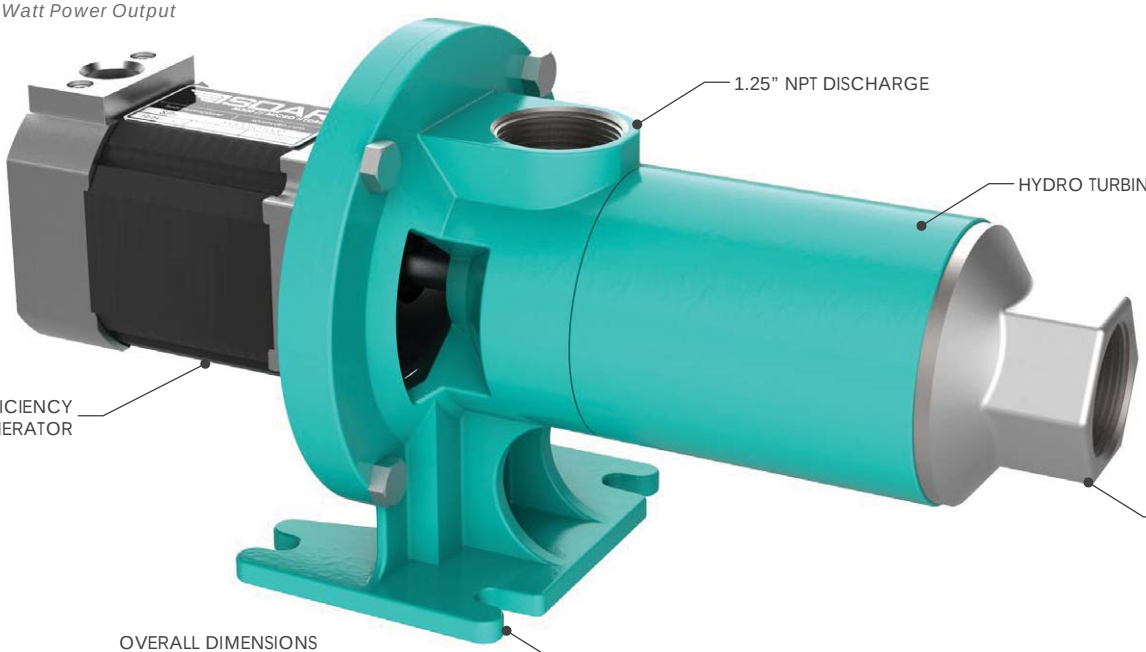
10-30 PSI, 40-60 GPM
75-300 Watt Power Output



OVERALL DIMENSIONS
11 x 9 x 9 Inches
1.25” NPT Inlet - Top
1.50” NPT Discharge - Center

M300-60
Micro Hydro 300-60

20-60 PSI, 15-25 GPM
25-300 Watt Power Output



OVERALL DIMENSIONS
15 x 8 x 7 Inches

For purchasing and application support contact your distributor or Soar directly

M300 // MICRO HYDRO

Micro Hydro Controller

Micro Controller 2500 Series, MHC2500
25A Maximum Current Capacity
12-24VDC/120VAC Configurations

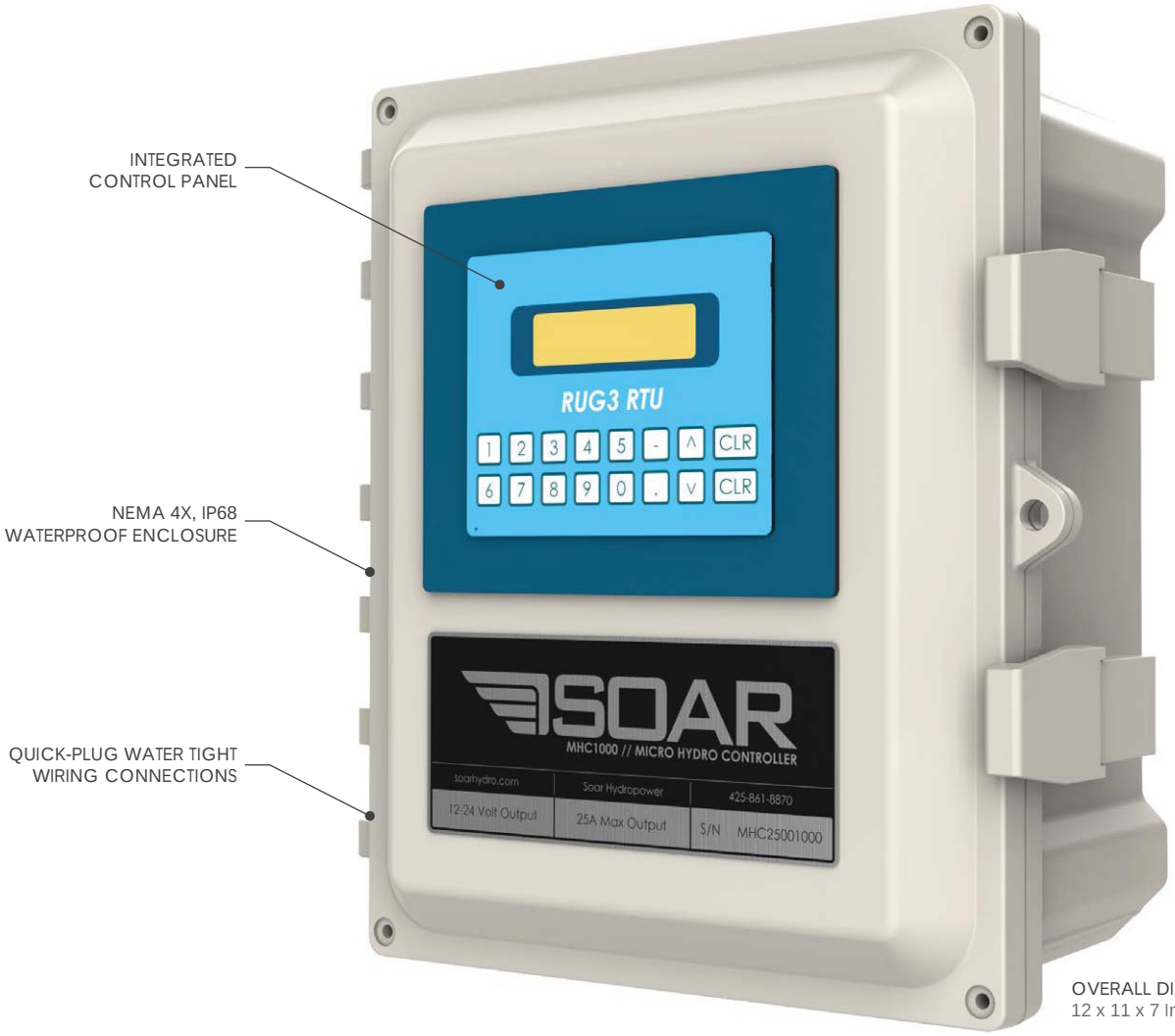
MHC2500 Controller Features

Soar's Micro Hydro Controller pairs seamlessly with the M300 series hydro turbines. With an intuitive interface and twist-lock wiring connections the MHC2500 is ready to manage power generation out of the box.

The controller automatically adapts system voltage from 12-24 Volts and can be configured for 120 Volt applications as well. The MHC2500 is compatible with turbine generation systems up to 25 Amps and charges an external battery bank that can be used actively or as needed.

MHC2500
Micro Hydro Controller

12-24/120 Volt Configurable
25A Max Battery Charge Rate
Isolated/Power Grid Applications



OVERALL DIMENSIONS
12 x 11 x 7 Inches

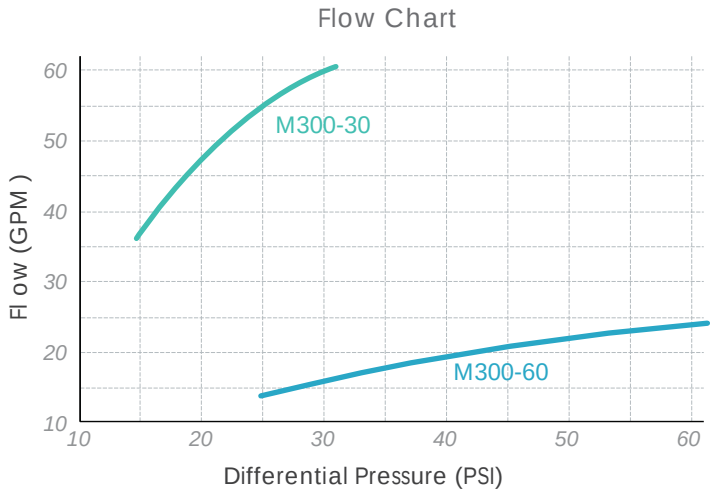
For purchasing and application support contact your distributor or Soar directly

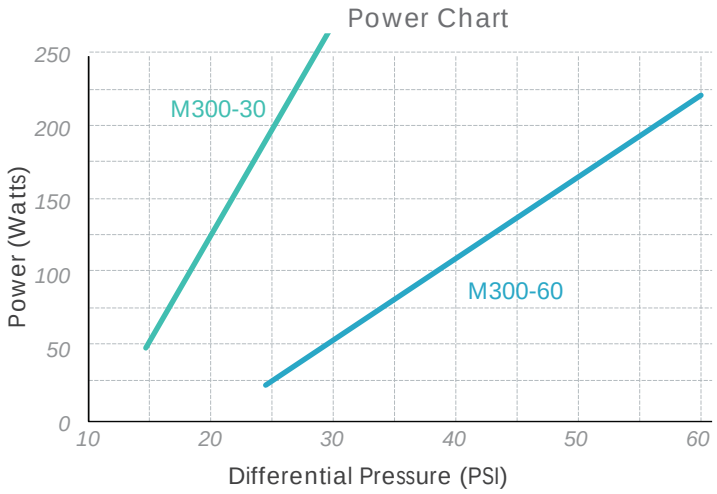
M300 // MICRO HYDRO

Micro Hydro Turbine

Technical Specifications

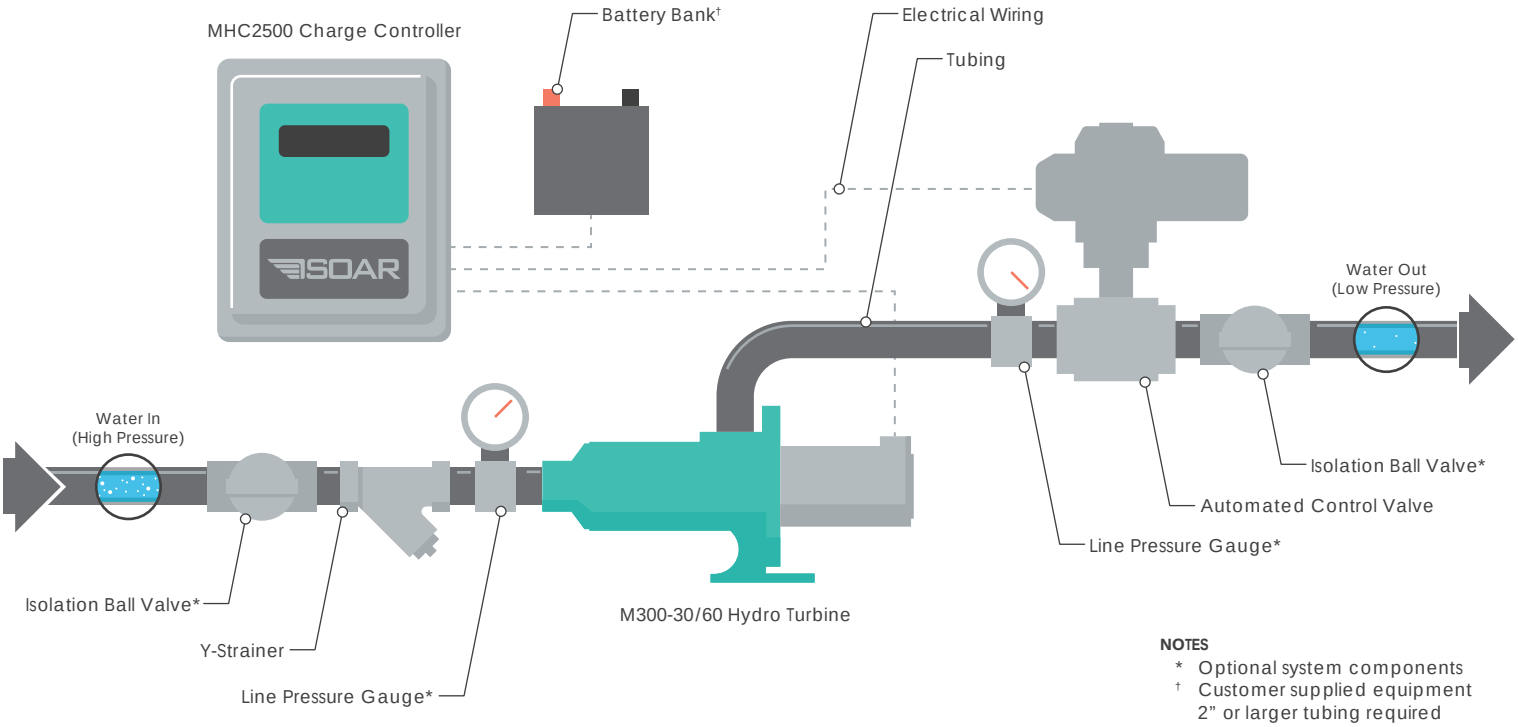
Turbine Range Charts





Flow and power output are both functions of system pressure differential. Differetial pressure must be known to determine turbine performance. To calculate the flow rate or power output, start with the differential pressure value and track upwards to where it intersects the turbine curve. From that point on the turbine curve track directly left to determine the flow or power output. Excess flow or pressure can be diverted if necessary.

Standard Installation Schematic



NOTES

* Optional system components

† Customer supplied equipment

2" or larger tubing required

For purchasing and application support contact your distributor or Soar directly

FERC NOTICE OF INTENT TEMPLATE

BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION
NOTICE OF INTENT TO CONSTRUCT QUALIFYING CONDUIT HYDROPOWER FACILITY

INTRODUCTORY STATEMENT

[*Applicant Name*] applies to the Federal Energy Regulatory Commission for a determination that the [*Facility Name*] is a Qualifying Conduit Hydropower Facility, meeting the requirements of section 30(a) of the Federal Power Act (FPA), as amended by section 4 of the Hydropower Regulatory Efficiency Act of 2013 (HREA).

The location of the facility is:

State or Territory: _____
County: _____
Township or nearby town: _____
Water source: _____

The exact name and business address of the applicant(s) is:
[Do not include the representative or consultant preparing the application.]

Applicant's Name: _____
Address: _____
_____
Telephone Number: _____
Email Address: _____

The exact name and business address of each person authorized to act as agent for the applicant(s) in this notice of intent is:

Name of Agent: _____
Address: _____
_____
Telephone Number: _____
Email Address: _____

[*Name of Applicant*] is [*a citizen of the United States, an association of citizens of the United States, a municipality, State, or a corporation incorporated under the laws of (specify the United States or the state of incorporation), as appropriate*].

NON-FEDERAL CONDUIT

The [*Facility Name*] will use the hydroelectric potential of a non-federally owned conduit.

[According to section 30(a)(3)(C)(i) of the FPA, as amended by HREA, a qualifying conduit hydropower facility may not use the hydroelectric potential of a federally owned conduit.]

ORIGINAL PROJECT

The [*Facility Name*] has not been licensed or exempted from the licensing requirements of Part I of the FPA, on or before August 9, 2013, the date of enactment of the Hydropower Regulatory Efficiency Act.

Project Information

[You must provide a detailed description of the proposed hydropower project and a detailed description of the conduit it will use, including the purpose of the existing conduit. The following information must be included:]

(1) A detailed description of any conduits and associated consumptive water supply facilities, intake facilities, powerhouses, and any other structures associated with the facility.

[Including, but not limited to: (1) the name of the conduit(s)or consumptive water supply facilities; (2)where the conduit(s)or consumptive water supply facilities begin (including the town, river, or reservoir); (3) the length and width or diameter (if enclosed) of the conduit; (4) the dimensions of the proposed hydropower structure and any other facilities needed for hydropower operation (i.e. intake pipes, powerhouse, turbine generating units, discharge pipes); and (5) how, where, and into what the water will discharge from the proposed power structure. If your project discharges into a natural water body, please explain how the hydroelectric project does not alter the primary purpose of the conduit.]

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

(2) The purposes for which the conduit is used:

[Section 30(a)(3)(C)(i) of the FPA, as amended by HREA, requires a qualifying conduit hydropower facility to use the hydroelectric potential of a non-federally owned conduit. Such a conduit means any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption and is not primarily for the generation of electricity. Specify the use of your conduit, such as irrigation, municipal water supply, or industrial uses. The primary purpose of the conduit cannot be for power production.]

_____
_____
_____
_____
_____
_____

(3) The number, type, generating capacity (kW or MW), and estimated average annual generation (kWh or MWh) of the generating units you are proposing, including plans, if any, for future units:

[*The installed generating capacity cannot exceed 5 MW.*]

_____
_____
_____
_____
_____

(4) Your project must use the hydroelectric potential conduit to generate power; however, if your project is associated with any dam or impoundment, please provide a description of the nature and extent of the dam or impoundment, including a statement of the normal maximum surface area and normal maximum surface elevation of any existing impoundment before and after the hydroelectric facilities are installed. If your project involves a dam or impoundment, you must provide a profile drawing showing that the conduit, **not the dam**, creates the hydroelectric potential for the project. You must also provide **evidence that the dam or impoundment would be constructed or continue to exist for agricultural, municipal, or industrial consumptive purposes even if the hydroelectric generating facilities were not installed**:

_____
_____
_____
_____
_____
_____

Existing Preliminary Permit or Permit Application Pending

If you have a preliminary permit for the facility or have applied for a preliminary permit, please provide the permit number below.

P-_____

Drawings, Maps, Diagrams

Include a set of drawings/maps/diagrams clearly showing the structures and equipment of the hydropower facility in relation to the existing conduit. Project drawings of the project must include:

- *A Plan View (overhead view) drawing of the proposed hydropower facilities. The drawing must include the following:*
    - *The hydropower facilities, including all intake and discharge pipes, and how those pipes connect to the conduit*
    - *The portion of the conduit in proximity to the facilities on which the hydroelectric facilities will be located*
    - *The dimensions (e.g. length, width, diameter) of all facilities, intakes, discharges, and conduits*
    - *Identification of all facilities as either existing or proposed*
    - *The flow direction labelled on intakes, discharges, and conduits*
- *A Location Map showing the facilities and their relationship to the nearest town. The map must include the following:*
    - *The powerhouse location labeled, and its latitude and longitude identified*
    - *The nearest town, if possible, or other permanent monuments or objects, such as roads or other structures, that can be easily noted on the map and identified in the field*
- *If a dam or impoundment is associated with the facility, a profile drawing showing the conduit, and not the dam or impoundment, creates the hydroelectric potential.*

VERIFICATION

You must provide Verification in one of the following forms:

Either a sworn, notarized statement, which states:

1. As to any facts alleged in the application or other materials filed, be subscribed and verified under oath in the form set forth below by the person filing, an officer thereof, or other person having knowledge of the matters sent forth. If the subscription and verification is by anyone other than the person filing or an officer thereof, it shall include a statement of the reasons therefor.

   This (notice of intent to construct, etc.) is executed in the:

   State of: _____
   County of: _____

   by: (Name) _____
   (Address)_____

   being duly sworn, depose(s) and say(s) that the contents of this (notice of intent to construct, etc.) are true to the best of (his or her) knowledge or belief. The undersigned applicant(s) has (have) signed the (notice of intent to construct, etc.) this _____ day of _____, 20____.

   By:_____

   Subscribed and sworn to before me, a _____ [*Notary Public, or title of other official authorized by the state to notarize documents, as appropriate]* of the State of _____ this day of _____, 20____.

   /SEAL/ [if any]

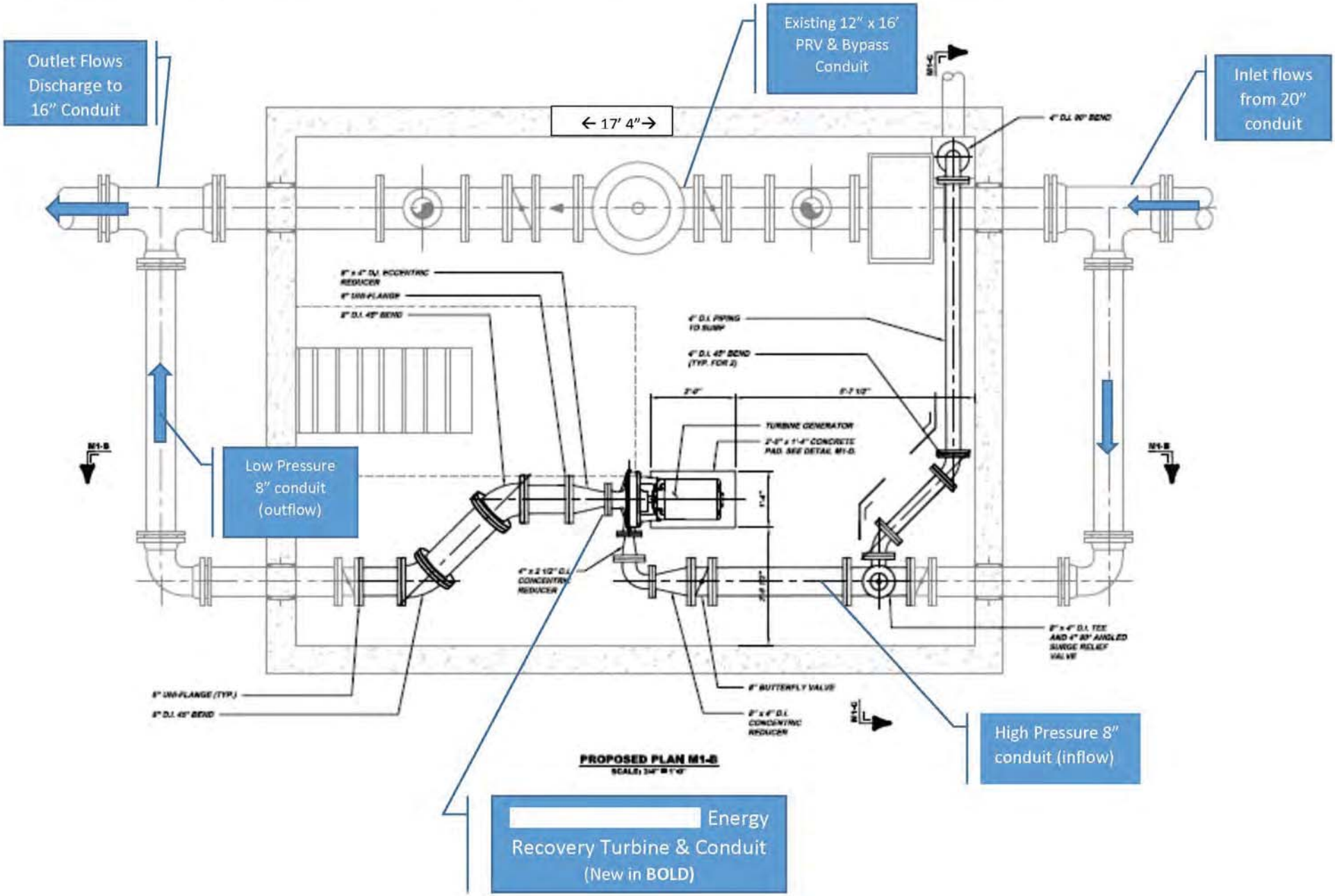
   _____
   (Notary Public, or other authorized official)

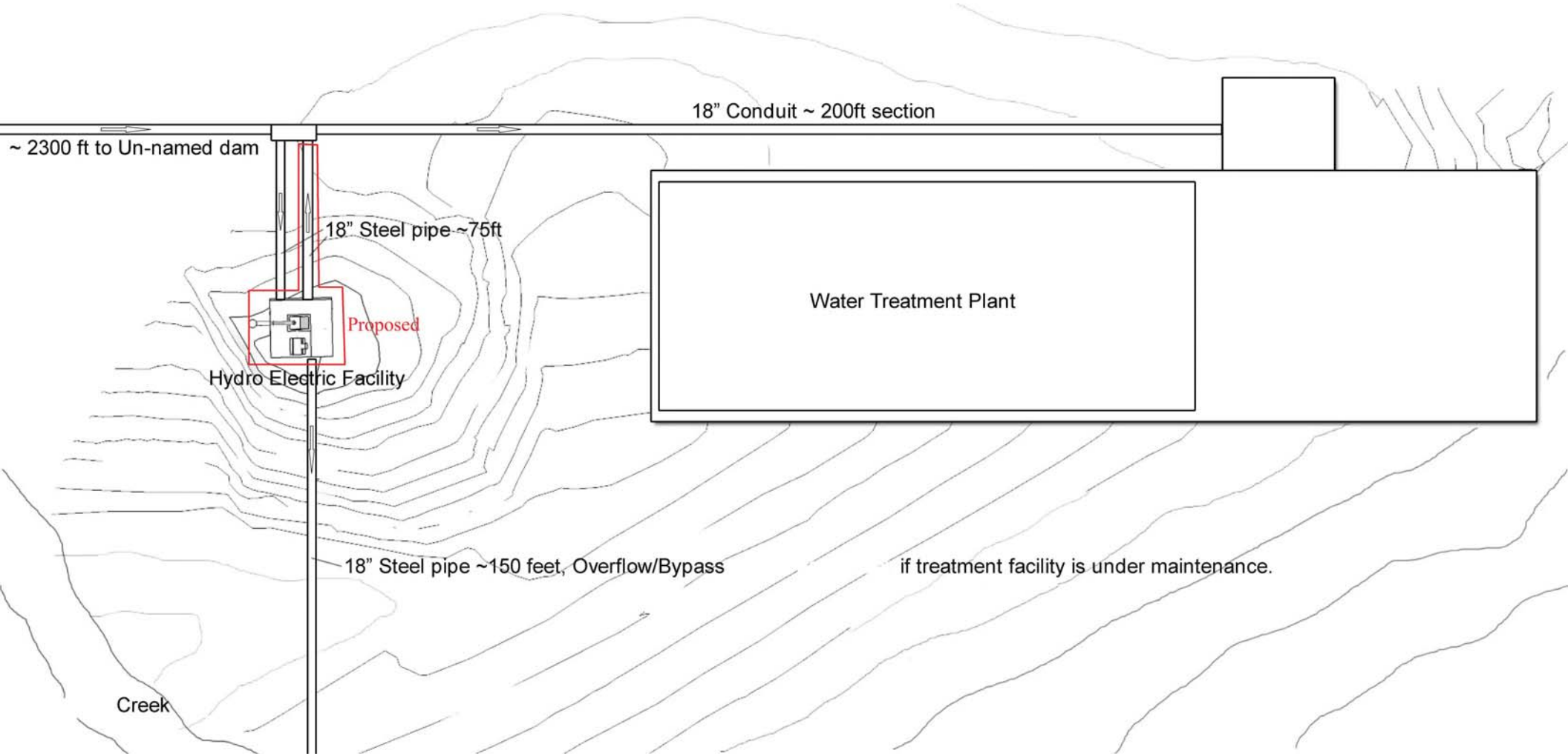
Or an unsworn declaration in the following form:

2. "I declare (or certify, verify, or state) under penalty of perjury that the foregoing is true and correct. Executed on _____ [date]."

   _____
   (Signature)

PLAN VIEW—Powerhouse PRV & New Turbine Generator – – 17 kW Hydropower Turbine System




18" Conduit ~ 200ft section
~ 2300 ft to Un-named dam
18" Steel pipe ~75ft
Proposed
Hydro Electric Facility
Water Treatment Plant
18" Steel pipe ~150 feet, Overflow/Bypass
if treatment facility is under maintenance.
Creek

TASK 2 ENERGY GENERATION ESTIMATES

Hydroelectric Generation Capacity Estimation Tool

Date: 2/19/2019

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Main Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Main Outlet - Task 2 - Cross Flow Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.0	cfs
Gross Design Head:	67.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Crossflow	
Nameplate Capacity:	35	kW

Penstock Diameter:	2.50	ft
Penstock Length	400	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

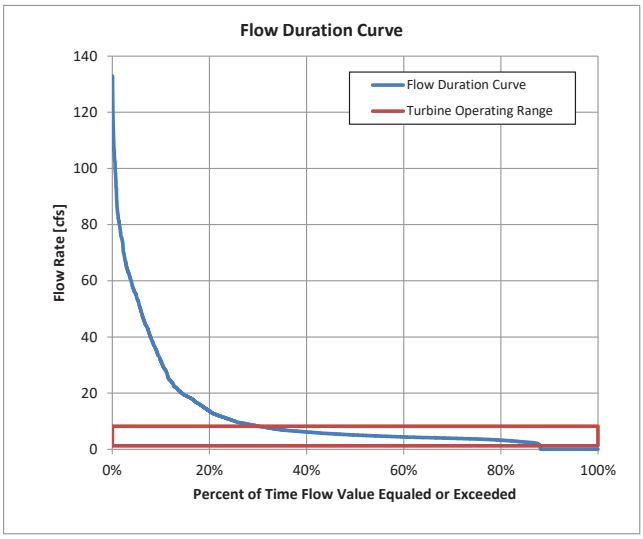
Transmission Loss:	2%

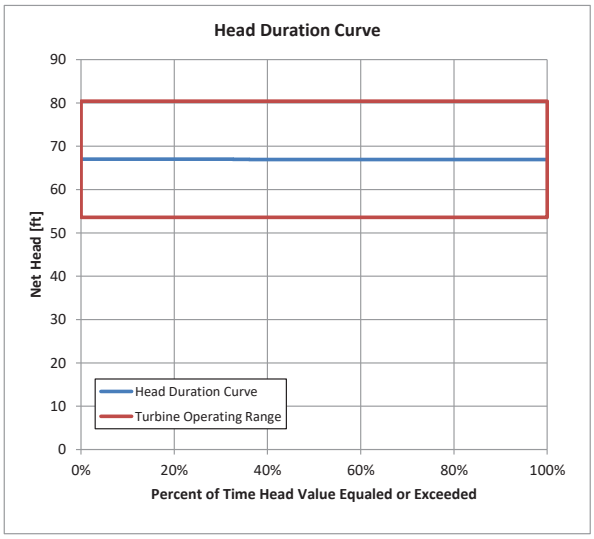
Unplanned Loss:	2%

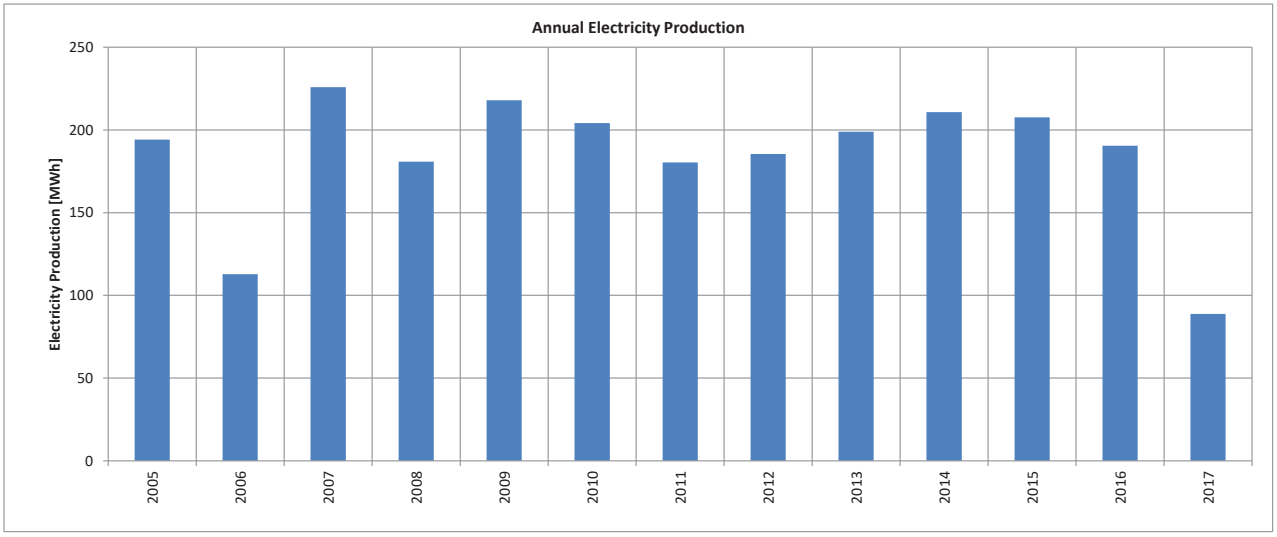
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	9.4	9.5	12.0	16.1	22.9	21.6	20.8	19.7	16.9	13.8	11.4	10.4	184.5
Maximum	12.9	14.3	17.6	20.7	24.9	24.1	24.9	24.9	24.1	24.1	17.9	15.4	225.9
Minimum	0.0	0.0	7.3	8.5	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.8
Min kW	0	0	0	10	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	60%
Operation Days per Year:	322







Hydroelectric Generation Capacity Estimation Tool

Date: 2/20/2019

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Secondary Outlet
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Secondary Outlet - Cross Flow Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	71.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir

Turbine Type:	Crossflow	
Nameplate Capacity:	37	kW

Penstock Diameter:	1.17	ft
Penstock Length	100	ft
Penstock C_H Coeff.	120	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

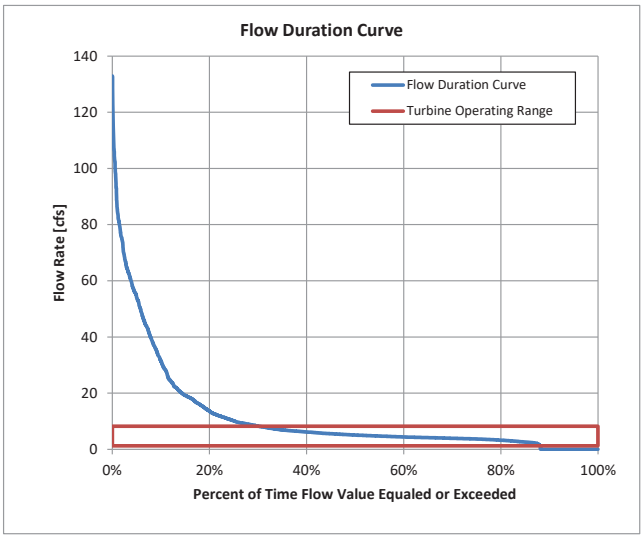
Transmission Loss:	2%

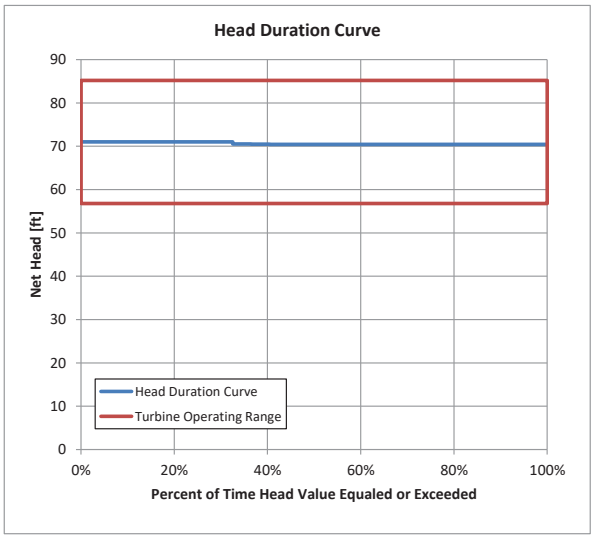
Unplanned Loss:	2%

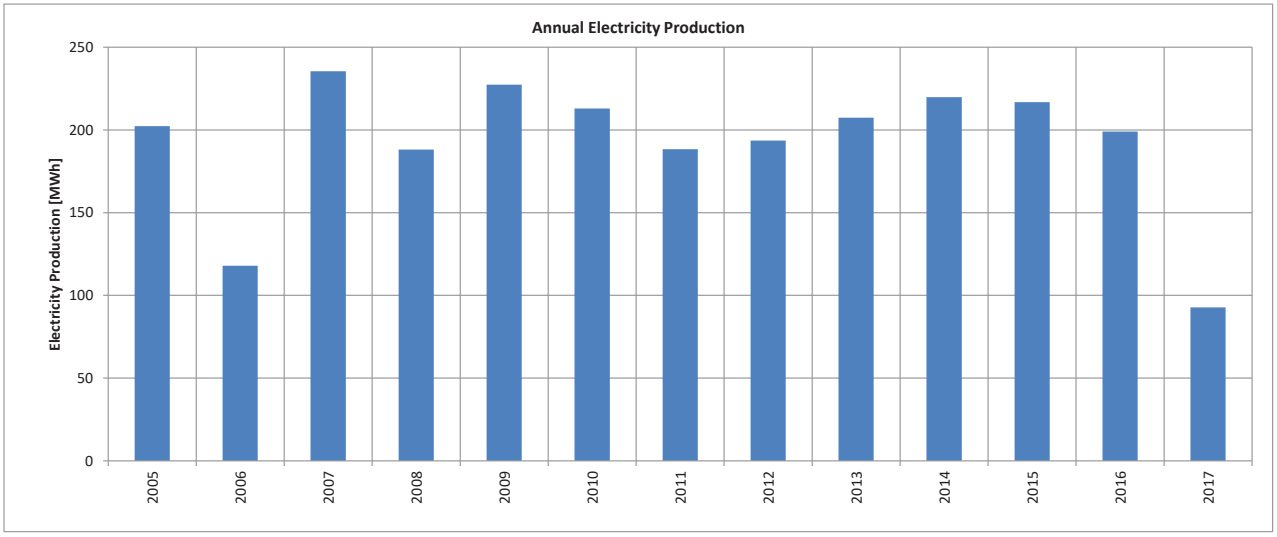
Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	9.9	10.0	12.6	16.8	23.7	22.4	21.6	20.4	17.6	14.5	12.0	10.9	192.4
Maximum	13.6	15.0	18.4	21.5	25.8	25.0	25.8	25.8	25.0	25.0	18.7	16.2	235.4
Minimum	0.0	0.0	7.7	8.9	19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.8
Min kW	0	0	0	10	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	60%
Operation Days per Year:	322







Hydroelectric Generation Capacity Estimation Tool

Date: 2/19/2019

Version 1.4
Summary Tab

Project:	Lower Urad Reservoir - Spillway
Location:	Clear Creek County

Unit System: English (cfs, ft)

Additional Info =	Green Cell
Default Variable =	Yellow Cell
User Adjusted Variable =	Orange Cell

Project Decription:	Lower Urad Reservoir - Service Spillway - Francis Turbine
Created By:	Lindsay George

Study Period: 1/1/2005 to 12/31/2017

Design Flow:	8.2	cfs
Gross Design Head:	90.0	ft

Flow data source:	Woods Creek Stream Gage
Head data source:	Full Reservoir - outlet at 7+00

Turbine Type:	Francis	
Nameplate Capacity:	42	kW

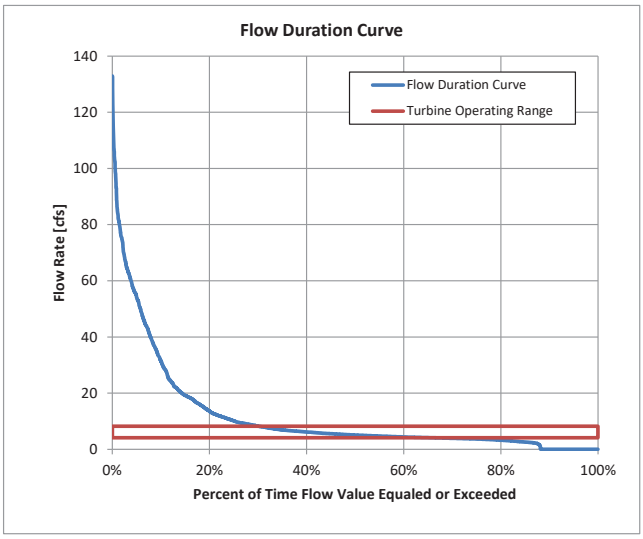
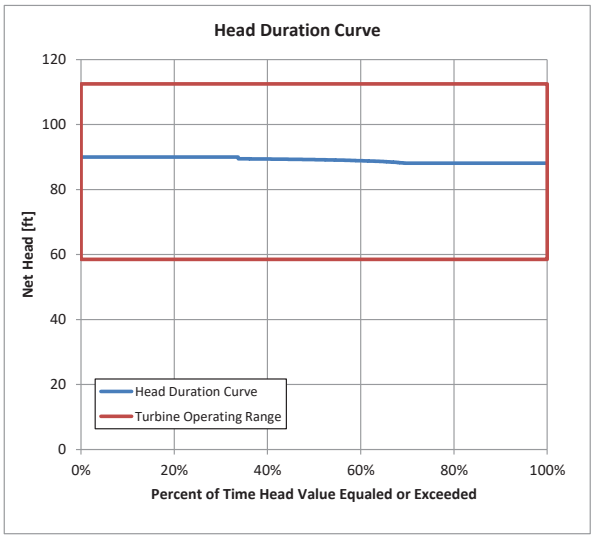
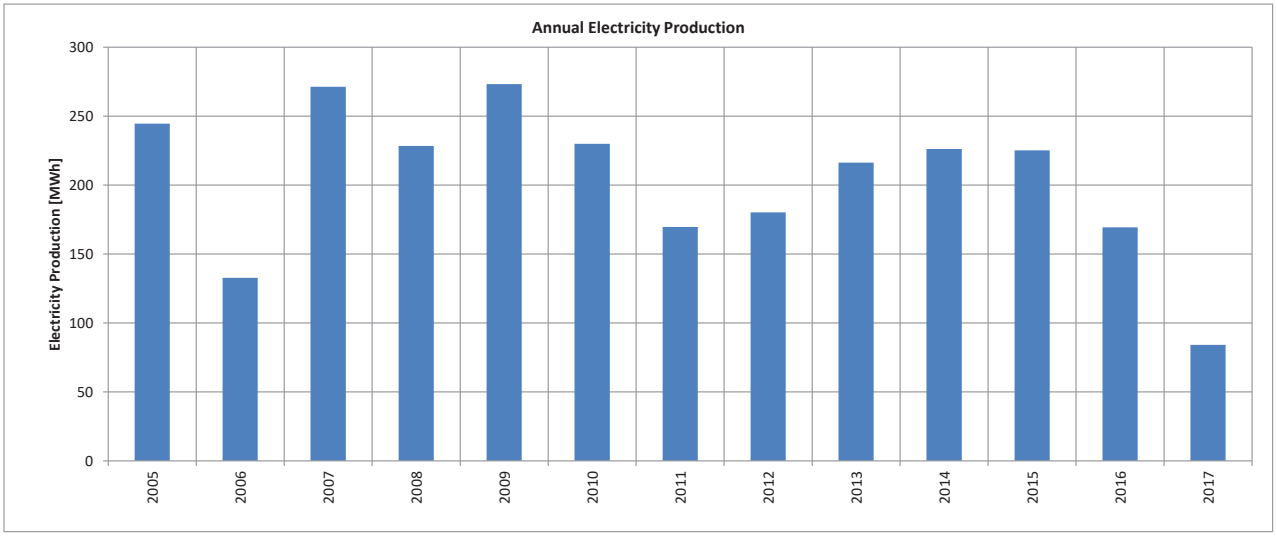
Penstock Diameter:	1.50	ft
Penstock Length	500	ft
Penstock C_H Coeff.	140	-

Minor Loss Coeff.	n/a
-or- % minor loss	10%

Transmission Loss:	2%

Unplanned Loss:	2%

Annual Electricity Production [MWh]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.9	4.6	8.6	17.9	29.9	28.8	27.7	26.2	22.2	16.4	10.0	7.8	203.9
Maximum	11.5	17.2	22.4	27.4	33.2	32.1	33.2	33.2	32.1	32.2	23.1	18.3	273.2
Minimum	0.0	0.0	0.0	0.4	22.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.2
Min kW	0	0	0	0	0	0	0	0	0	0	0	0	n/a

Annual Capacity Factor:	55%
Operation Days per Year:	242