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Hydropower on Six Mile Creek – A Feasibility Study

CEE 5910 - M. ENG. IN ENGINEERING MANAGEMENT PROJECT

Submitted by:

Lesslie John Jeyapandian (ljj36)
Arriman Makmoen (amm587)
Defeng Tao (dt476)
Garret Quist (gq29)

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Disclaimer

This project report is made for educational purposes only. Below are the scopes that this report will not cover:

1. Development of specific hardware designs. The type of project is a systems-level feasibility study, so it is not the intent to design changes to the technology to address some problem or other
2. Political or social barriers may bring into question the overall feasibility of a proposed technology or system, as the primary focus of the study is technical and economic
3. Study of emissions such as CO_2 and other greenhouse gases (methane, N_2O, etc.)

This project is only for teaching purposes and under no circumstances shall Cornell university be liable for any indirect, incidental, consequential, special, or exemplary problems arising out of this project.

Acknowledgments

This project is the final project of Engineering Management graduate students. We thank professor Francis Vanek, who is a Senior Lecturer in the School of Civil & Environmental Engineering at Cornell University, for instructing us in research of the topic and team management.

We thank Frank D. Perry for providing Fall Creek hydropower plant guidance and data of its power generation. We would also like to show our gratitude to Scott Gibson, environmental engineer in City of Ithaca, Mike Sigler, legislator in Tompkins County, John Graves, from Ithaca Community Energy Inc. and Tim Fallon for sharing their insights in local hydropower with us as well as providing valuable feedback and guidance over the course of the project. We are also immensely grateful to Loic Petillon, Project Director at Ossberger Hydro for working with us in sizing the turbine for the proposed facility and providing a quotation of the turbine.

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1. Advisor's Introduction

On behalf of team members Lesslie, Arri, Garret, and Defeng, I welcome you to this final report on the Spring 2017 Master of Engineering in Engineering Management team project on small-scale hydropower with a focus on a proposed site on Six-Mile creek in Ithaca, New York. This project constitutes another effort in a series of projects from the School of Civil & Environmental Engineering at Cornell University with a local focus on Cornell University, Ithaca, or Tompkins County, going back to the 2009-2010 academic year. Earlier reports can be found at www.lightlink.com/francis .

The four team members come from diverse engineering backgrounds and chose hydropower from a list of possible project topics offered by the engineering management program. Thereafter, the breadth of experience they brought to the project was put to good use as they were required to thing broadly about small hydropower in general and about the proposed site at First Dam on Six Mile Creek, looking from a technical, economic, and ecological perspective.

During the course of the research, the team was able to determine long-term average flow values for the proposed location and obtain a quote from a turbine vendor for an appropriately-sized 277-kW turbine that might be installed there. Using this information they projected an average production of 830,000 kWh per year at the site, total installation cost of ~$702,000, and levelized cost including both capital and non-capital cost of $0.11/kWh. The analysis protects the stream resource by assuming that plant leaves a minimum of 4 cubic feet per second of flow in the stream at all times, and not removing more than 70 cfs. The team has also compiled information on the permitting process for the project, and possible local ecological impacts of diverting some of the flow to the plant.

The work undertaken by the team also reveals two challenges for developing small hydro. First, the incentives available for small hydro are relatively modest compared to those for other renewable sources such as solar and wind. Second, there is uncertainty around the time and cost required to permit a small hydro plant that poses a risk for potential investors. As interest grows in developing small hydro as an additional renewable option, steps may be taken to improve incentives and streamline permitting.

In closing, I wish to thank the students for their contribution to our local understanding of small hydro. I also wish to thank other contributors, including Representative Mike Sigler from the Tompkins County Legislature, Frank Perry from Cornell Utilities and Energy Management, and former small hydro plant operator Tim Fallon. While their input is gratefully acknowledged, responsibility for any errors rests with the team and me as advisor.

Respectfully submitted,

Francis M Vanek

Francis M Vanek, Senior Lecturer and Research Associate
June 7, 2017

2. Abstract

Six Mile Creek is a twenty-mile-long stream that originates in the town of Dryden, from where it flows downstream and drains into the Cayuga Lake. The Six Mile Creek watershed has served as the primary source of drinking water to the surrounding communities. In the past, three reservoirs were built along the creek between the years of 1892 and 1911 to supplement the groundwater to sustain the growing population of Ithaca. The smallest of these reservoirs, the Van Natta Dam measures 20 foot across the spillway. The modern concrete dam as it exists today was constructed in 1907 after the reservoir was purchased by the Ithaca Light and Water Company to bolster water sources in the surrounding areas. A mill that was originally constructed adjacent to the dam was repurposed to serve as a pumping station. This pumping station and the dam were abandoned as the town's water demands were fulfilled by the water diverted at Third Dam further upstream from Van Natta Dam (Six Mile Creek Partners, 2007).

The dam and the abandoned pumping station located adjacent to it are an untapped water resource that could potentially serve to supplement the electricity demands of the surrounding community. The New York State Electric and Gas Company submitted a proposal in September 1984 to repurpose the dam to serve as a hydropower plant. The proposal called for installing new turbines and performing minor construction activities on the dam and the facility and estimated an annual power generation capacity of around 1.4 MWh (NYSEG, 1989). Interest in hydropower along the Six Mile Creek was subsequently lost until recently in 2016, when research looking into the feasibility of hydropower generation along the creek has renewed interest. This preliminary feasibility study will dwell into the following aspects: potential for hydropower at Six Mile Creek, Development of Small Hydro Power facilities, rehabilitation of the Van Natta Pumping Station to serve as a power generation facility, potential annual electricity generated at the revamped facility and finally, the impacts that can be expected of such a project on the surrounding environment and community.

3. Executive Summary

Hydropower is a mature technology that currently provides more than 16 % of the total global electricity demand. The Six Mile Creek located in Ithaca, New York, is an untapped water resource that could potentially be used to generate electric power that can then be used by the surrounding community.

The Six Mile Creek experiences high variability in its flow over the course of the year and is prone to sudden sharp variations over short periods such as the course of a week. A second characteristic of the creek is that the water has high silt content. Historically, three dams and a siltation trap have been constructed along the stream. The smallest of these dams, the 20-foot Van Natta Dam located adjacent to Giles Street in Ithaca, has a water pumping station that was constructed in the early 1900's. The pumping station can be repurposed to serve as a Small Hydro Plant that can generate power that can then be fed onto the grid to serve the local community.

In estimating the annual power generation capability for the hydropower plant at Van Natta Dam, the flow characteristics of the Six Mill Creek were studied and analyzed. The proposed plant is designed to operate as a run-of-the-river plant, meaning that water will not be stored in the dam and the aesthetic aspects of the stream and the dam will be preserved. The proposed facility will include a powerhouse that will house a single crossflow turbine, rated at 277 kW. The crossflow turbine was selected as it exhibits a high tolerance to debris and silt in the water and secondly, it is designed in a such a manner that it operates on a smooth high efficiency curve over varying loads. The second aspect of the turbine is what makes it appropriate for Six Mile Creek because of its high volatility in the average flow that is experienced. This turbine will allow the plant to operate at peak efficiencies over the varying loads that will be available over the course of the year. Water will be fed to the turbine through a steel penstock that is 4 feet in diameter and 122 feet in length. It is also theoretically possible to build a penstock that will serve as an intake for water from the 30-foot or 60-foot dam, which are located further upstream, and transport it downstream to the Van Natta Dam where it could potentially generate more power. However, given time and resource constraints, this option was not looked into in this project and it is the recommendation of our team that it be researched in the future. However, based on the available water resource using only the penstock feeding the turbine from the Van Natta Dam, it is estimated that with a single turbine configuration, the plant can generate up to 830 MWh of energy annually with a capacity factor of 35 %.

The facility will have to be repurposed and the dam requires minor maintenance and repair work. Based on estimates based on previous reports and quotations from the industry, the project will have a total direct cost of 400,000 USD associated with it along with indirect costs including legal and regulatory fees estimated at 260,000 USD. In total, the proposed Van Natta Dam Hydropower facility will cost 700,000 USD. The levelized cost of the electricity generated here, if fed into the grid will be 11 cents per kilowatt-hour. Assuming a project lifetime of 25 years and accounting for subsidies obtained in the form of Renewable Energy Credits (RECs), the project has a net present value of 400,000 USD over its lifetime and the project breaks even in 15 years.

There are several key regulations that pertain to distributed generation and renewable energy sources. In 1978, the federal government passed the Public Utility Regulatory Policy Act, which required local utilities to allow small distributed generation interconnection to the grid. In response to this, New York’s Public Service Commission created Public Service Law 66-J, defining what types of generation are allowed to connect and how. Recently, on March 9, 2017, the New York PSC issued an order amending PSL 66-J, changing how distributed generation sources get compensated for their electric generation. Any new distributed energy resource built after March 9 will get compensated based on the hourly market value of electricity. This monetary value gets applied to the Owner’s electric bill along with an environmental component that pays the Owner for any RECs generated by their facility. If the Owner chooses, they may opt to retain their renewable energy credit and claim to use renewable energy for their own carbon reduction goals. However, if they do this the Owner will not get compensated for the REC by the utility.

If an Owner chooses to construct a hydropower station in New York, they are required to receive an operating license from the Federal Energy Regulatory Commission (FERC). Although the process is lengthy, installations less than 5 MW can apply for an exemption to the final licensing requirement, speeding up the process. Once approved, the Owner is required to follow the Standard Interconnection Requirements to connect the generating station to the grid.

Although hydropower is regarded as a green energy source, the construction and operation of a hydropower plant still has potential negative impacts to the surrounding community and environment. The environment of the surrounding area will be affected during the hydropower plant construction and operation. There are three expected environmental impacts of the hydropower plant on Six Mile Creek: effects on species habitat, fish mortality, and morphological change. The impacts on species habitat caused by periodic ponding (i.e., reduction in flow to the point where flow in and out of a location is not continuous and temporary, isolated "ponds" are formed) is unknown but could be significant. In order to eliminate the occurrence of ponding, a minimum bypass flow of 9 CFS is required. This will also allow salmon to pass the dam safely. In addition, a fish screen needs to be installed to prevent fish from getting caught in the intake stream of the turbine, so as to reduce turbine-related mortalities. Outside of migration months, to keep aesthetic value of the Van Natta Falls, the minimum flow should be 4 CFS.

4. Team Biography

4.1. Garret Quist

Garret Quist graduated from the Ohio State University in 2012 with a Bachelor's degree in mechanical engineering, focusing on power generation and nuclear engineering. He has worked for Cornell University as a Utilities Engineer in the central heating plant for the past four and a half years, providing project management for capital improvement projects, inspecting equipment, scheduling repairs, and undertaking various initiatives to improve plant reliability and efficiency. Recent projects he has been involved in include the boilers 3 and 4 installation, Lake Source Cooling intake screen cleaning, and CHP water conservation program. Garret is currently registered as an EIT in the state of New York and is a certified Project Management Professional.

4.2. Arriman Maulana Makmoen

Arriman Maulana Makmoen (Arri) earned his Bachelor's degree in Chemical Engineering from Institut Teknologi Bandung (ITB), Bandung, Indonesia in 2012. Following graduation, he was recruited to work alongside his academic advisors in a project feasibility study for bioethanol plant, with PT. Rekayasa Industri, Indonesia's state-owned Engineering, Procurement, and Construction (EPC) company as the client. He continued his career by working with Halliburton for three years as a drilling fluid engineer. There, he worked in various oil/gas fields and the last half of his journey was dedicated for one of Indonesia's major geothermal project, Sarulla Operations, Ltd. Later on, he continued to explore the renewable energy industry by becoming an intern in Tamaris Hydro, one of Indonesia's emerging hydropower companies. As for now, Arri is pursuing his study in the final semester as an M.Eng candidate in Engineering Management, Cornell University.

4.3. Lesslie John Jeyapandian

Lesslie John Jeyapandian is a final semester student in the Engineering Management program at Cornell. Lesslie is a mechanical engineer by training and having received his bachelor's degree in mechanical engineering from Anna University, Chennai, in 2013, went on to work as a project engineer with Qatar Engineering and Construction Co., an EPC company headquartered in Doha, Qatar. In his capacity as a mechanical engineer, Lesslie has worked on oil and gas construction and maintenance projects, both offshore and onshore. His career interests lie primarily in contracts services and execution of engineering projects in the energy sector.

4.4. Defeng Tao

Defeng Tao began his undergraduate study major in Material Processing and Control at Huazhong University of Science and Technology (HUST), Wuhan, Hubei, China in 2008 and specialized in Electronic Packaging in 2010. He transferred to Arizona State University (ASU) in 2011. In 2011 fall, he became one member of dean's list, which was a reward to the students whose GPA is higher than 3.5. In 2012 spring, he won the second prize in the Material's Bowl held by ASU and University of Arizona. In 2012, he received his Bachelor of Engineering in Material Processing and Control from HUST. Then he continued his graduate study at Arizona State University (ASU) and joined Nathan Newman's research group to study superconductors. In 2016, he got his Master of Science in Material Science and Engineering. Now, he is working on his second master's degree in Engineering Management at Cornell University.

5. Motivation

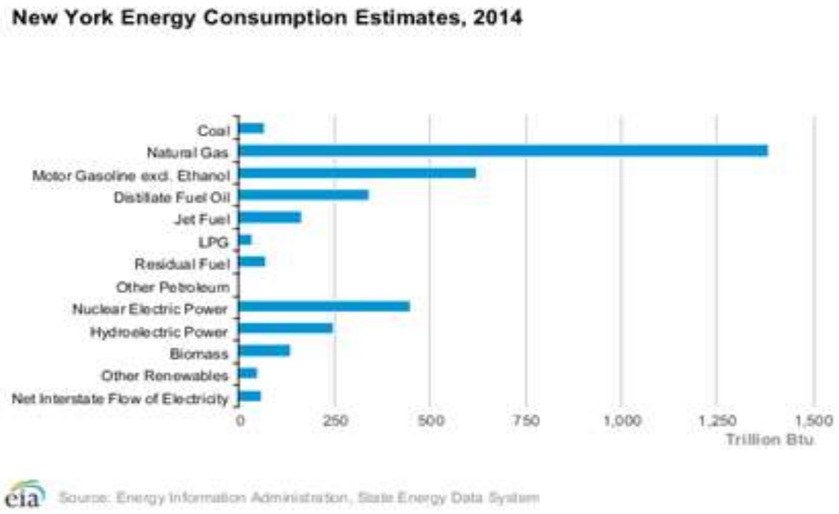
Climate change, caused by greenhouse gases is becoming ever more alarming in the 21st century and has been an important concern among all nations. This, coupled with depleting fossil fuel reserves highlights an imperative need to invest in the development of renewable energy production. Developing renewable energy sources can substitute conventional energy sources, such as oil, gas, and coal. Recently, hydropower as one form of renewable energy has received increased attention. Not only can it meet the demand on basic electricity generation, but it also produces near-zero greenhouse gas emissions.

The hydropower potential at Six Mile Creek could be realized at minimal to no cost to the surrounding environment and the local community (Bosack, 2007). In 2016, Tompkins County Legislature requested to update a study of Six Mile Creek hydropower, which is the impetus for this project. Establishing a functional Small Hydro Power Facility at Six Mile Creek to augment the electricity production will be a firm step directed towards reducing emissions and developing a more sustainable and environment-friendly community. With this project, the team examined the feasibility of developing a hydropower facility at Van Natta Dam and estimated the costs of establishing such a plant and the economic payback associated with it.

6. Modern Hydropower

6.1. General Trends

Hydropower is a mature technology and one which is used world over. It plays an essential role in satisfying today's electricity demand. Overall, hydropower contributes to more than 16% of the global electricity generation and about 85% of worldwide renewable electricity (IEA, 2015). In the United States alone, hydropower had a total capacity of 79.64 gigawatts (GW) in 2014 and the net capacity has increased by 1.48 GW from 2005 to 2013 (U.S. Department of Energy, 2015). The state of New York ranks fourth in the nation in terms of electricity generation from hydropower. There are more than 300 hydroelectric generating stations connected to New York's electric grid. The energy consumption estimates for the year 2014 by source is shown in ***Fig. 6.1***. Hydropower is the fifth largest source with about 250 trillion BTU, equivalent to 73.3 billion kWh.



Source: Energy Information Administration, State Energy Data System

Fig. 6.1. *Energy consumption estimates by source in 2014*

6.2. Hydropower in Ithaca

Ithaca has a long history with hydropower. In fact, local hydropower itself was founded in 1830, when a channel was built to direct water from the Fall Creek to mills and factories, providing the power make paper, farm equipment, boats, guns and other manufactured goods that put Ithaca on the map (Bosack, 2007). The first electricity facility in Fall Creek gorge was built in the early 1880's. The original plant was powered by water from a dam that was historically situated just above the present dam. In 1904, the present dam was built on Fall Creek Gorge. The Cornell Hydro Power Plant operates with water that is sourced from this dam. The water is transported downstream through a five-foot diameter underground penstock that feeds the water into two turbines. This hydroelectric plant is also run-of-river type. The average production of this plant ranges from 4.5M to 5.5M kWh. The electricity generated at the plant is fed into the grid and is primarily used by Cornell University. Apart from this, historically, as mentioned earlier in the report, the Van Natta Dam was used as a pumping station and was used to transport water to the water treatment facility

The Hydropower facility currently functional at Beebe lake in Fall Creek serves as a model for the proposed hydropower facility at Six Mile Creek. The annual power output can be used to understand the general trend in water resource availability over the course of the year in watersheds similar to the Six Mile Creek. Comparing the average flow of the two streams, it can be concluded that given the much smaller size of the Six Mile Creek, a hydropower facility powered by the stream will be small in size and as such the following sections will dwell into the aspects of Small Hydro Power Projects.

6.3. Small Hydro Project Development

Small hydro implies hydroelectric production facilities built on a scale that is suitable for local communities or to contribute to distributed generation in a regional electric grid. Small hydro projects typically have an average generating capacity that ranges between 50 kW and 20 MW. Facilities that have a capacity of more than 20 MW are not commonly considered as small hydro plants. Small hydropower (SHP) provides electricity with a high-energy payback ratio and, generally, with lower production costs than other renewable energy technologies (RETs), aside from large hydropower. SHP can be combined within multipurpose infrastructures such as drinking water and irrigation networks (Crettenand, 2015).

Given the above constraints of small hydro, the project design of a SHP facility is unique and there are several companies that exclusively cater to the development of such projects in the USA. Some of the industry leaders in this niche sector are Hydropower International Services LLC., National Hydropower Association, New England Hydropower Inc., Hydropower Turbine Systems Inc., Nautilus LLC and Ossberger Hydro.

6.4. Small Hydro Power Project Design

Most companies supplying equipment for small hydro projects adopt a policy to offer only equipment that fits the site conditions best, requires a minimum of civil works costs and still provides a maximum in annual generation. In fact, companies usually offer to design and develop the project in addition to supplying the equipment and complete the integration with the existing grid. These "water to wire packages" simplify the planning and development of the site because one vendor looks after most of the equipment supply. Since non-recurring engineering costs are minimized and development cost is spread over multiple units, the cost of such package systems is reduced.

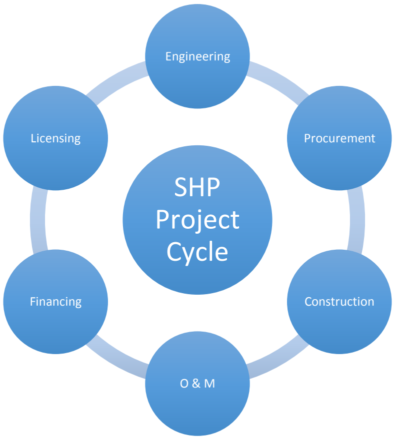


Fig. 6.2. *A Process Flow Diagram of a Typical SHP Project*

Small hydro projects also typically have faster environmental and licensing procedures, and since the equipment is usually in serial production, standardized and simplified, and since the civil works construction is also reduced, small hydro projects can potentially be developed very rapidly. The following sections will dwell into the details of the EPC aspect of the project cycle.

6.4.1. Engineering

The broad scope of engineering involved in the development of SHP facilities include the following:

- Feasibility Studies
- Hydropower Engineering
- Environmental Impact Assessments and Reports
- Site Investigations
- Civil, Structural and Mechanical Design
- Cost Estimates
- Contract Documents
- Tender Evaluations
- Project Management
- Project Planning
- Construction supervision
- On-site Inspections

6.4.2. Procurement and Construction

In line with the scope of this document, this will be a high-level overview of the essential components of a SHP facility. The fundamental components of a SHP facility are as follows (Shreyasi):

- Forebay and Intake Structures:

A forebay is an enlarged body of water in front of the intake. It is ideal to have a forebay to essentially act as a buffer for water intake especially in the case of run of the river hydro plants where there are no dams or reservoirs to store water (as in the case of Cornell Hydro Power Plant). The forebay temporarily stores water for supplying the same to the turbines. The water cannot be allowed to pass as it comes in the reservoir or the canal. Intake gates are provided with hoist to control the entry of water. In front of the gates trash racks are provided to prevent debris, trees, etc., from entering into the penstock. Rakes are also provided to clean the trash racks at intervals.

- Head race or Intake conduits (penstocks):

The head race or intake conduits carry water to the turbines from the reservoir. The choice of open channel or a pressure conduit (Penstock) depends upon site conditions. The pressure conduit may be in the form of a flared intake passage in the body of the dam or it may be a long conduit of steel or concrete or sometimes a tunnel extending for few kilometers between the reservoir and the power house. The pressure conduit does not follow the ground contours and any gradient is given to suit the site conditions. The velocity of water in the power conduit is also higher than in the open channel. For up to about 60 meters' head, the velocity may range between 2.5 to 3 0 m/sec.

- Surge Tanks

Surge tanks essentially act as a pressure release valve (PRV) for the system on the whole. Its function is to receive the rejected flow from the conduits when the flow is stopped by closing a valve to control or stop the flow of water into the turbines.

When there is a sudden reduction of load on the turbine, it becomes necessary for the governor at the turbine end to close the turbine gates for adjusting the flow of water to keep the speed of the turbine constant. However, the water is already on its way to the turbine. When the turbine gates are closed, the moving water has to go back. A surge tank would then act as a receptacle to store the rejected water and thus avoids water hammers.

- Turbines and Generators

This is the major component of a SHP facility usually having the heaviest cost impact_(Bansal, 2010) . Penstock construction is the other major cost impact in SHP projects. The cost analysis is discussed in the next section of this report.

Water turbines may be classified under two types, namely:

- Impulse or velocity turbines
- Reaction or pressure turbines

Impulse Turbines:

In the impulse turbine, the energy available at the inlet of the turbine is purely kinetic energy. As the water flows through the vanes, the pressure is atmospheric from inlet to outlet. An impulse turbine is essentially a low-speed wheel and is used for relatively high heads.

Reaction Turbines:

If at the inlet of the turbine, the water possesses both kinetic and pressure energy, the turbine is a reaction turbine. As the water flows through the runner, the water is under pressure and the pressure energy keeps on changing into kinetic energy. The runner is completely enclosed in an air-tight casing and the runner and the casing is completely full of water. Reaction turbines are essentially high speed wheels and are used for relatively low heads. The turbines may also be classified as follows with reference to type of power plant:

Low head turbine (less than 30 m);
Medium head turbine (30 to 160 m);
High head turbine (160m up to and over 1000 m);

Low head turbines are Propeller turbine and Kaplan turbine. These turbines use large quantities of water. Medium head turbines are modern Francis turbines. Impulse turbines are high head turbines. These turbines require relatively lower quantities of water.

If the water flows through the runner in the radial direction but leaves in the direction parallel to axis of rotation of the runner, the turbine is a mixed flow turbine. Most modern turbines are mixed flow turbines (cross flow turbines).

In the design of a plant, the above constraints play a critical role in helping choose the most optimal turbine and generator combination that would be ideal for the site under consideration.

- Power House

The purpose of the power house is to support and house the hydraulic and electrical equipment.

- Tail race and draft tube

It is essentially a channel which carries water away from the turbines after the water has worked on the turbines. The surface of water in the tail race channel is also known as the tail race.

6.5. Industry Standard Turbines

This section briefly lists and describes the most popular turbines that are employed in SHP facilities.

6.5.1. Original OSSBERGER® Crossflow Turbines

Original OSSBERGER® Crossflow Turbines are optimal within a power range between some few kilowatts and a present maximum of 5 MW per machine. They are tolerant of debris in the water and adjust perfectly to accept varying flows; that is why they are extremely well suited for use in run-of-river locations. Thanks to their cavitation-free operation even at minimal flows these turbines are ideal for stand-alone units. Original OSSBERGER® Crossflow Turbines are entirely steel-welded and built from standardized individual components. This modular system facilitates low-cost manufacture while meeting the individual design criteria to suit any specific project. Thus, a tailor-made plant is configured precisely according to individual site requirements.

6.5.2. Kaplan Turbines

Based on the Francis Turbine the Kaplan Turbine was developed by the Austrian Engineer Victor Kaplan towards the beginning of the 20th century. Due to its adjustable runner blades, this turbine system is the most adaptive. Apart from the original version with vertical shaft and inlet spiral the bulb turbine variant has spread widely over the world.

The Kaplan Turbine is of the reaction type: The swirled water flows in parallel with the shaft to the fully admitted runner, where the pressure for energy conversion is realized. Special construction and design are used to prevent cavitation. The water flow is regulated by adjustable wicket gates and runner blades

It is an axial flow reaction turbine; water flows parallel to the axis of rotation of the shaft. Kaplan turbine is a special type of axial flow reaction turbine, wherein the vanes of the hub are adjustable. Kaplan turbines are ideal for plants where there is a large quantity of water available at low heads.

6.5.3. Pelton Wheel Turbines

The Pelton Wheel is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The energy available at the inlet of the turbine is only kinetic energy. The pressure at the inlet and the outlet is atmospheric. This turbine is ideal for high heads (Bansal, 2010).

In this type of system, water from the river or reservoir flows through the penstocks at the outlet of which a nozzle is fitted. The nozzle increases the kinetic energy of the water from the penstock. At the outlet of the nozzle, the water comes out in the form of a jet and strikes the buckets (vanes) of the runner.

Nozzles direct forceful, high-speed streams of water against a rotary series of spoon-shaped buckets, also known as impulse blades, which are mounted around the circumferential rim of the runner. As the water jet impinges upon the contoured bucket-blades, the direction of water velocity is changed to follow the contours of the bucket. Water impulse energy exerts torque on the bucket-and-wheel system, spinning the wheel; the water stream itself does a "U-turn" and exits at the outer sides of the bucket, decelerated to a low velocity. In the process, the water jet's momentum is transferred to the wheel and thence to a turbine. Thus, "impulse" energy does work on the turbine.

Because water and most liquids are nearly incompressible, almost all of the available energy is extracted in the first stage of the hydraulic turbine. Therefore, Pelton wheels have only one turbine stage, unlike gas turbines that operate with compressible fluid.

6.6. Cost Estimation

In designing a SHP facility at Six Mile Creek, we use data from industry standard quotations as well as models that have been developed for analyzing cost parameters involved in the development of small hydro facilities (Mishra, 2012).

Detailed cost analysis of the project including estimation of annual revenue generated are included in further sections of this report.

7. Hydropower Generation at Six Mile Creek

In designing a feasible hydropower generation facility at Six Mile Creek, the following studies and analyses will have to be carried out (European Small Hydropower Association, 2004):

- Topographical analysis of the site and water resource
- Evaluation of the water resource and its generating potential
- Site location and design of basic layout of a plant
- Hydraulic turbine and generator selection
- Mechanical and Electrical design and integration
- Civil and Structural Design
- Environmental Impact assessment and mitigation strategies
- Economic Evaluation and iteration of design to meet financial constraints
- Institutional framework and Policy regulation

Given the scope of the project and the resources available, the core engineering design aspects of this feasibility study will not be carried out as required for the Engineering and Construction of a facility. The basic operating concept and economics of a feasible hydropower generation facility will be studied and reported upon. The economic analysis will also be carried out with several assumptions to simplify the calculations for this basic feasibility study.

7.1. An overview of the Six Mile Creek

Six Mile Creek which is located in Tompkins County, New York, is about 20 miles long. It originates in the Yellow Barn State Forest, which is located in the central area of Tompkins County, and drains into Cayuga Lake. The meandering creek flows southerly into Town of Caroline and then crossing Slaterville Springs, where it then flows west in Brooktondale. Then, it turns northwest through the City of Ithaca and passes a series of dams to its confluence. It covers an area of about 46.5 square miles shown in ***Fig. 7.1***, in which it is marked as the light color area with the line in green marking its boundary. Its watershed is the principal source of drinking water for the City of Ithaca and has been managed by the city for over 100 years. Before the creek flows into Cayuga Lake, it is interrupted by four dams, which are the Van Natta Dam, the

Thirty Foot Dam, the Sixty Foot Dam and the Silt Dam. All of them are located on the downstream of Six Mile Creek. There is a pumping station located along Giles Street in Ithaca, which was called the Van Natta Pumping Station and was constructed by Ithaca Light & Water Company.

Fig. 7.1. The Six Mile Creek Watershed

Due to the lack of groundwater in the late 19th century, three reservoirs were built on Six Mile Creek during 1892 and 1911 to meet the need of the growing city. Firstly, Ithaca Light & Water Company purchased the Van Natta Dam to bolster the water resource in 1892. The pumping station was constructed one year later. The total length of the dam is 142 feet with a 115-foot length spillway. The average height is 12 feet. In 1901, the Thirty Foot Dam was built upstream of Van Natta Dam to meet the increasing water demand. On December 27, 1911, work was completed on the Sixty Foot Dam to supply additional water to the city, which formed Potters Fall Reservoir. Since sediment began to fill in Sixty Foot Dam, the Silt Dam was built in 1925 as a pre-settling basin, located upstream of Burns Road (Harris, 1952)

7.2. Topographical Study

There are a total of 3 dams and 1 siltation dam that were built over the last century along the waterway. Below ***Fig 7.2*** shows elevation and location of the dams along the creek.

Fig 7.2. Six Mile Creek, Ithaca, New York.

The Van Natta Dam is situated at the lowest elevation among the dams, and the power house for the old facility is situated adjacent to the spillway of the dam. It was constructed in 1892. It is located at 42.43°N and -76.48°W at an elevation of 186.2 m above sea level.

The second dam called the 30 ft. dam was constructed in 1902 and is located at 42.42°N and -76.47°W at an elevation of 188.2 m above sea level. The third dam called the 60 ft. dam was constructed in 1911 and is located at 42.41°N and -76.46°W at an elevation of 220.8 m above sea level.

Sediment began to fill the 60 ft. dam and as a result, a fourth dam, a siltation dam was constructed in 1925 to act as a pre-settling basin for sediment.

7.3. An Evaluation of the Water Resource Available at Six Mile Creek

7.3.1. Stream Characteristics

Six Mile Creek is a stream channel that transports both sediment and water from higher to lower elevations. The flow characteristics of the stream are dictated by the amounts and relationships between the water and sediment quantities that are being transported by the stream (Six Mile Creek Partners, 2007). The flow that is observed at the creek follows trends over the year that are within reasonable variations limits, thus we can use an average of previous years' flow data to arrive a reasonable base line estimate of flow characteristics that can be used to design the system.

One of the major problems that is particular to this creek is the relatively heavy concentration of the sediment in the water. This will affect the performance characteristics of any turbine that uses its water as a prime mover. The silt dam was built exclusively to tackle this problem. As a result there is a buffer well before the 60 ft. dam that essentially acts as a sediment trap and thus the concentration of sediment downstream is significantly reduced. However, this concentration of sediment in the water will play a significant role in the selection of turbine for the proposed hydropower facility as will be discussed in later sections of this report.

7.3.2. Seasonal Flow Analysis

Figure 7.3. on the following page shows the approved discharge information of Six Mile Creek as was gathered by the United State Geological Survey (USGS) in 2015, which is the most recent available information on the resource. The period recorded here is from November 2002 to current year. In this table, the yellow dots are the median daily statistic from 13-year collection. Average monthly discharge data from 2003 to 2015 is used to plot the general flow trend, as shown in ***Fig.7.4***. According to the flow chart, it is easy to observe that the average discharge rate reaches the peak during March and April and decreases to the bottom during August, September, and October. Due to the seasonal precipitation, temperature and other environmental effects, flow discharge differs from year to year. For example, the maximum monthly discharge rate of April could be 184.6 cubic per second (CFS) in one year, but it could reach the minimum

rate, 32.4 CFS, in another year. This chart essentially helps in understanding the discharge rate and seasonal flow pattern trends of Six Mile Creek.

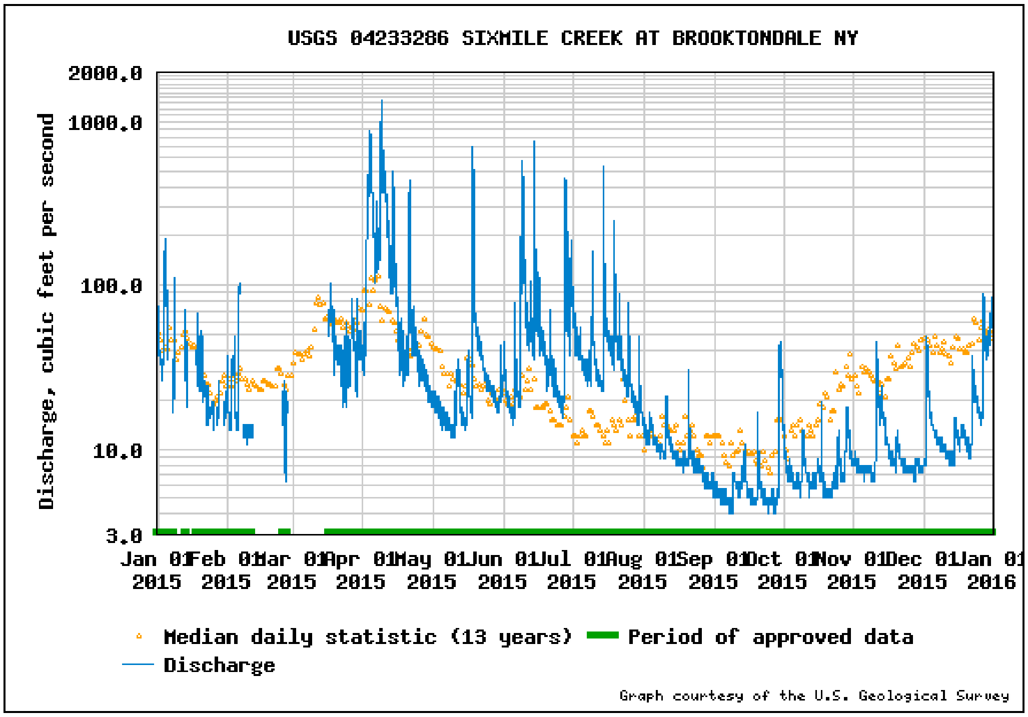


Fig. 7.3. Plot of discharge from Six Mile Creek in 2015

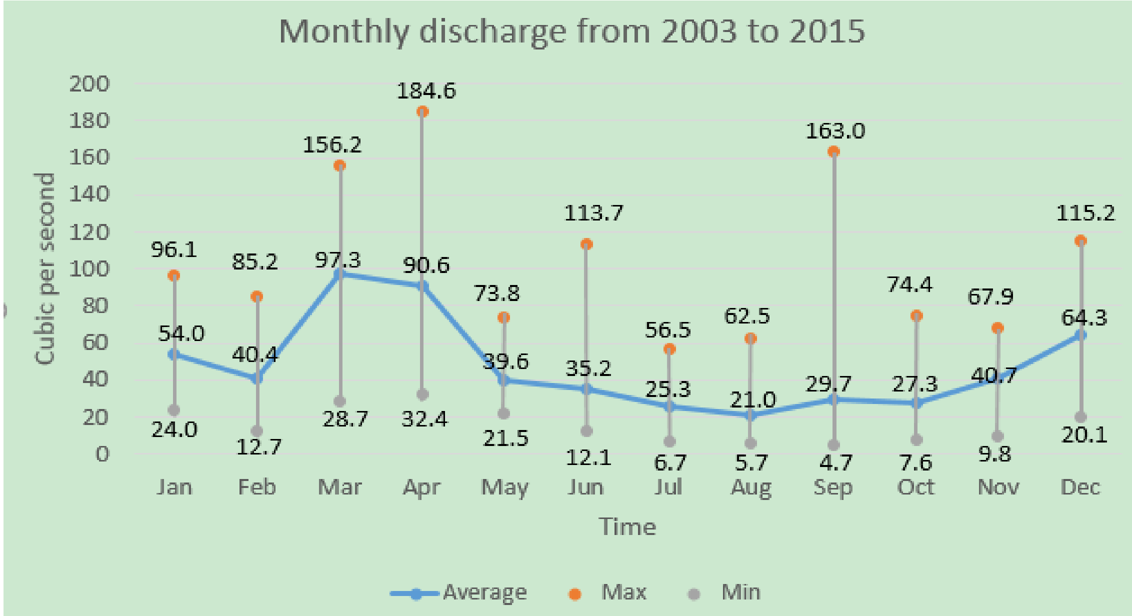


Fig.7.4 Average Monthly discharge from 2003 to 2015

In order to meet the requirement of proposed equipment operation, the flow range is from 20 to 100 CFS. If the flow is less than 20 CFS, the hydropower plant will not operate and all of the flow will pass over the spillway. If the flow is larger than 100 CFS, the additional flow will pass through the spillway. More detail about operation will be discussed in the turbine sizing and environmental impact sections.

7.3.3. Precipitation in Ithaca

Aside from Six Mile Creek’s flow rate, precipitation/rainfall patterns were studied in the hopes of finding a correlation that might help better analyze and study the flow availability at the creek. The Van Natta Dam is located in Ithaca, NY, thus it will require the average precipitation data for that specific area. ***Fig. 7.5***. shows the annual average precipitation chart in Ithaca, NY.

From the graph, we can observe that precipitation is higher in the summer months, due to the hot weather and high humidity. The highest average precipitation is recorded in June, which is 3.8 inches in 90°F condition. On the other hand, there is less rainfall in the winter because of the cold and dry weather. February has the lowest precipitation, viz. 1.97 inches in 40°F.

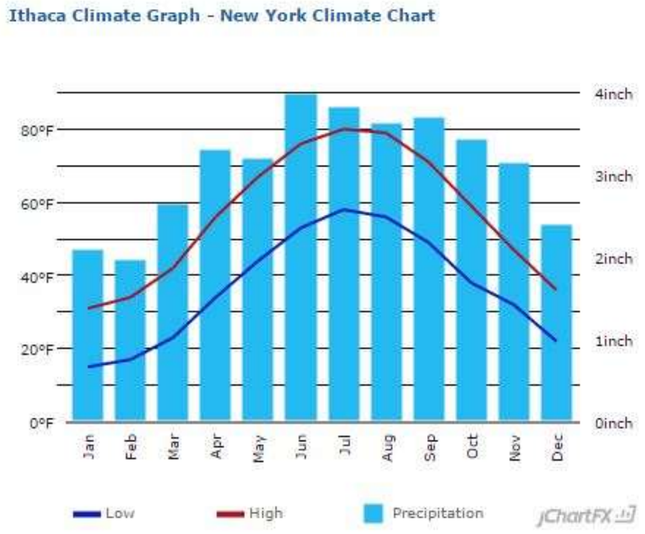
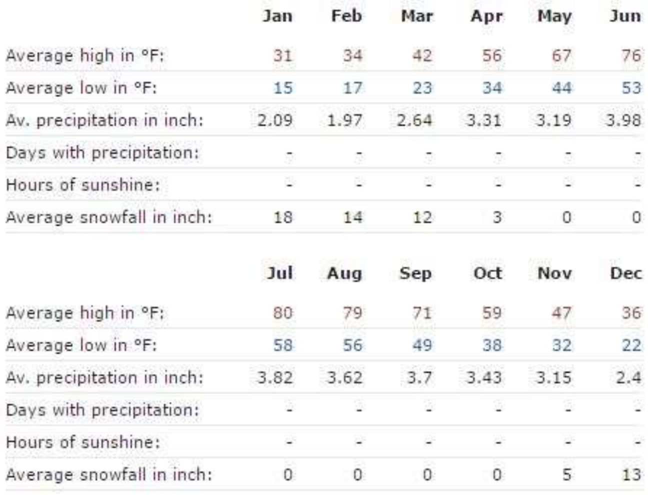


Fig. 7.5. Annual average precipitation chart in Ithaca, NY

Table 7.1 in the following page provides a brief overview at the average climatic trends observed in Ithaca over the course of a year. The sudden and rather sporadic variation in the flow available at the creek dictates the selection of the turbine as well as the sizing of the turbine unit as will be detailed in later sections of this report.

Table 7.1. *Climate data of Ithaca, NY*



	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	31	34	42	56	67	76
Average low in °F:	15	17	23	34	44	53
Av. precipitation in inch:	2.09	1.97	2.64	3.31	3.19	3.98
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	18	14	12	3	0	0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	80	79	71	59	47	36
Average low in °F:	58	56	49	38	32	22
Av. precipitation in inch:	3.82	3.62	3.7	3.43	3.15	2.4
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	0	0	0	0	5	13

As mentioned above, precipitation also plays an important role for flow availability. The monthly data collected from 2011 to 2015 was shown in ***Fig.7.5***. It always snows during the winter months in Ithaca. In order to make the precipitation more accurate, we use the equation that 10-inch snow equals to 1-inch rainfall. According to the chart, we can observe that in one certain year, precipitation is higher in the summer months because of the high temperature and is lower in winter months due to the dry and cold weather. The correlation between precipitation and flow discharge from 2011 to 2015 is also obtained in ***Table 7.2***. The correlation value is about 0.5, which is not very strong.

A more detailed breakdown for the climate data and analysis showed that no reliable correlation could be established between precipitation and average flow in the creek. It was observed, however, that immediately after periods of heavy rainfall, the flow available in the creek would increase to levels much higher than the average flow recorded at the creek. For instance, between the late evening hours of May 1st 2017 and early morning hours May 2nd 2017, the county experienced heavy rains, with the town of Ithaca recording precipitation of over 1 inch, a 600 % increase from the monthly average of just 0.15 inches. In the same period, the USGS flowmeter gauge for the stream recorded discharge at the creek jump up from the usual average for this period of just around 40 cfs to flows as high as 650 cfs over the course of a few hours (USGS, 2017).

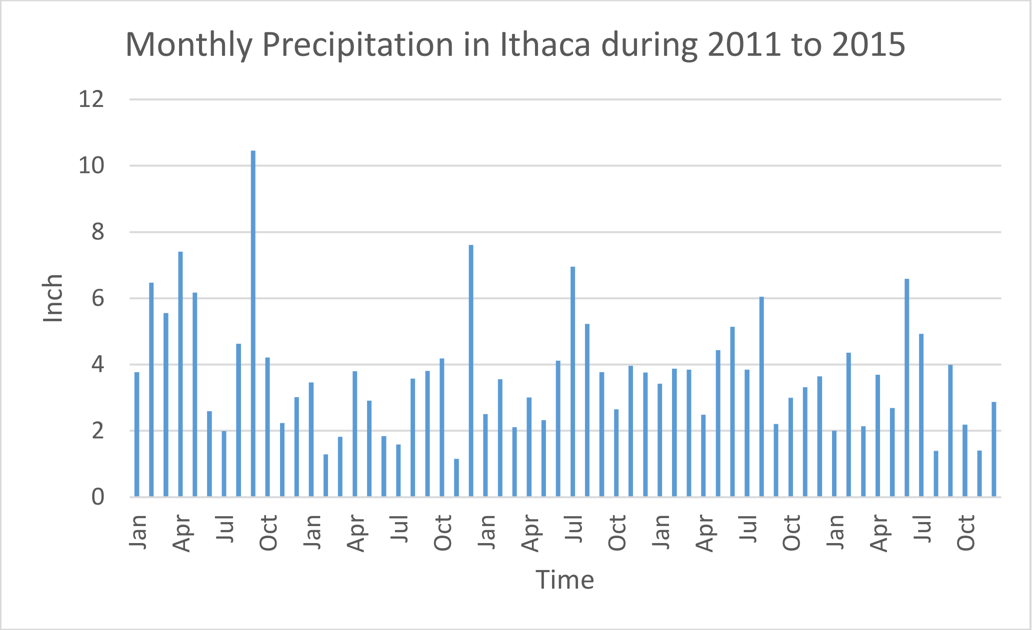


Fig. 7.5 *Monthly precipitation during 2011 to 2015*

Table 7.2 *Correlation between Precipitation and Flow Discharge*

	Precipitation	*Flow Discharge*
Precipitation	1	
Flow Discharge	0.495161427	1

7.3.4. Creek Flow Forecasting

As mentioned earlier in the report, the feasibility of forecasting flow on an average was looked into. The findings of the team are reported as follows:

For the purpose of better sizing the turbine and estimating the annual, forecasting the available flow in the creek seemed to be a good idea. In the beginning, Holt-Winter's method was used to forecast by using the monthly data and Monte Carlo Uncertainty analysis was carried out by applying the daily flow data. However, both proved incapable of making an accurate estimation.

Eventually, the team used the flow duration curve in sizing the turbine and estimating annual power generated at the facility.

Holt-Winter's method is a forecasting technique from the exponential-smoothing family. We can apply it to time series exhibiting trend and seasonality. It is easy to understand that the flow discharge has the seasonality, and we can see a downward trend showing in the annual discharge plot, ***Fig.7.5***. Because the seasonal effects may be additive or multiplicative, we will use both methods to make the forecasting.

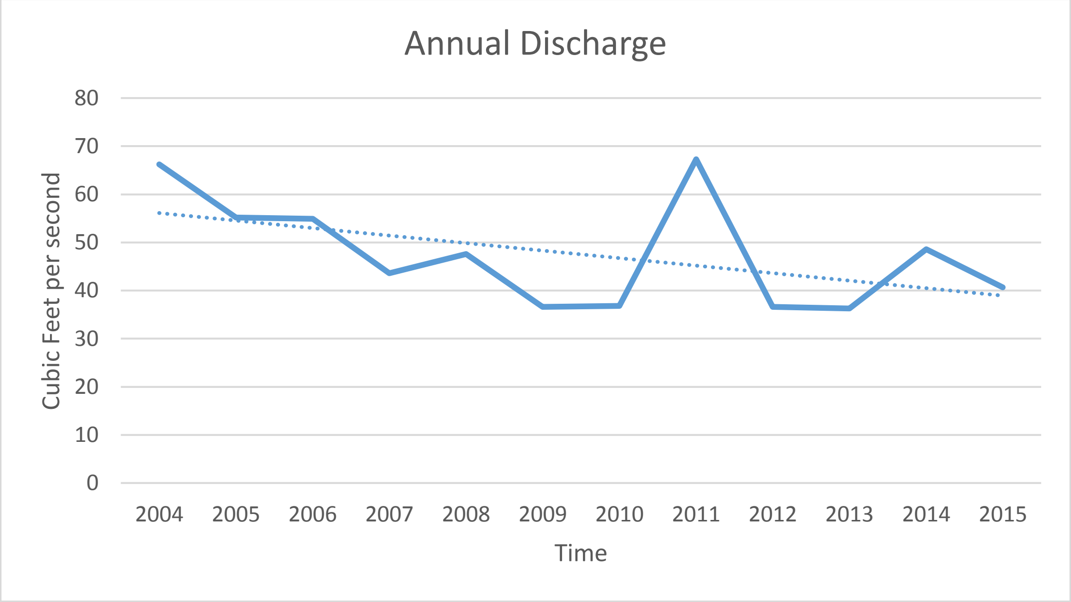


Fig. 7.5. Annual discharge from 2004 to 2015

The monthly data in 2003 is used for initiation to calculate the additive and multiplicative seasonal factors. The data from 2004 to 2014 are used to calibrate the smoothing parameters and the data in 2015 are used to the validation. According to the smoothing parameters, the forecasting can be made for 2016. The results of the two methods are illustrated in ***Fig.7.5*** and ***Fig.7.6***.

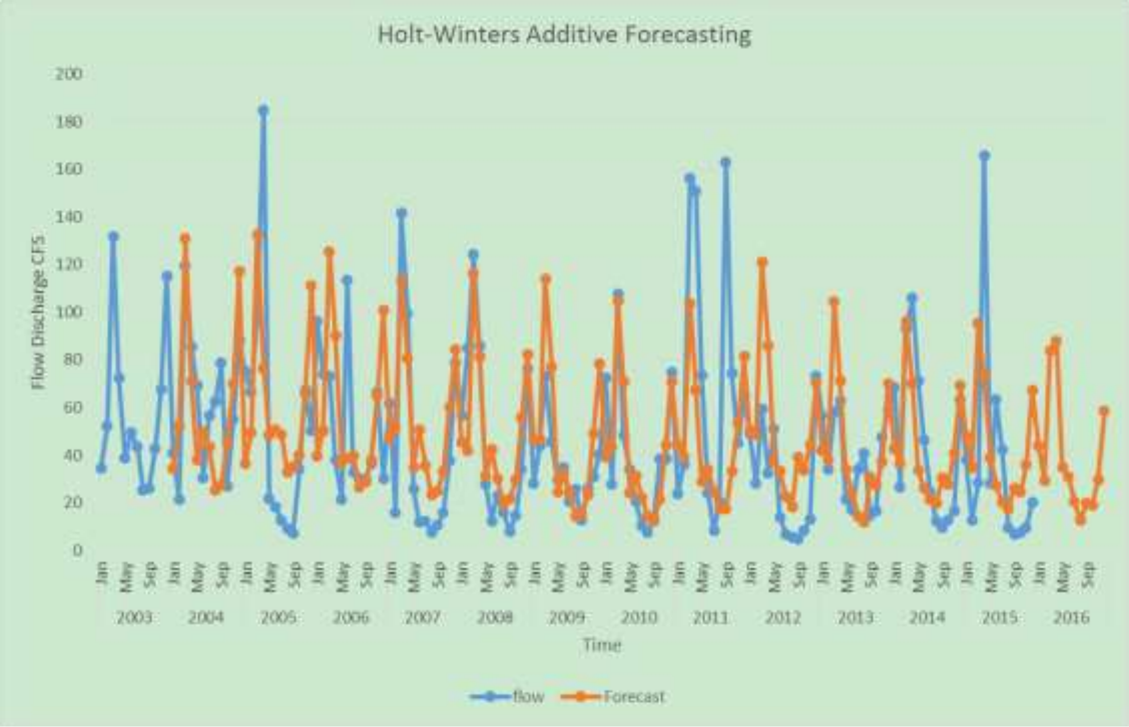


Fig. 7.5 Holt-Winters' Method for additive seasonal effects

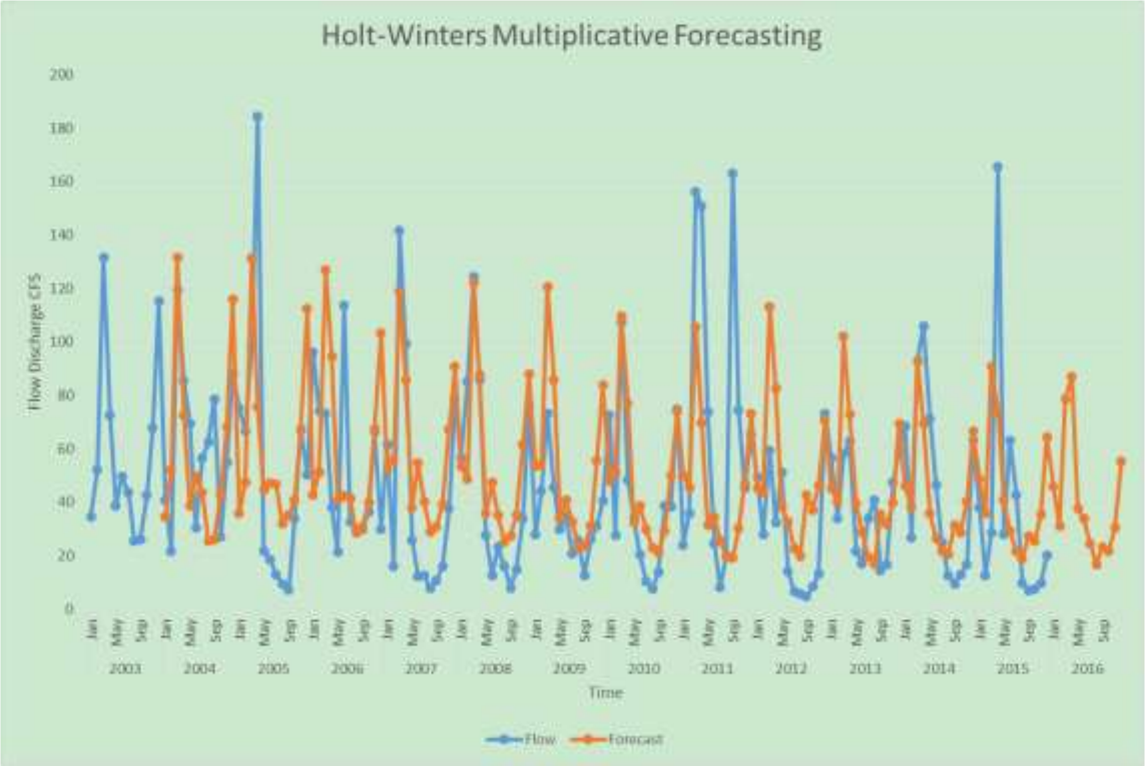


Fig. 7.6 Holt-Winters' Method for multiplicative seasonal effects

However, in the both methods, the mean squared error's (MSE) values are relatively large. The MSE value for additive seasonal effect is 948.1 and that of multiplicative seasonal effect is 969.0. According to the correlation between years and months, we can figure out that, the correlation value is close to zero. It means the data is more likely randomly distributed, which makes the Holt-Winters method not suitable for this situation. As a result, the Monte Caro method is applied in next step. The correlation results are shown in ***Table 7.2*** and ***Table 7.3***.

Table 7.2. Correlation between year to year

	Flow	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Flow	1													
2003	0.088885	1												
2004	0.111725	-0.08333	1											
2005	0.053046	-0.08333	-0.08333	1										
2006	0.050775	-0.08333	-0.08333	-0.08333	1									
2007	-0.02987	-0.08333	-0.08333	-0.08333	-0.08333	1								
2008	-0.00075	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1							
2009	-0.10081	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1						
2010	-0.04707	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1					
2011	0.18177	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1				
2012	-0.14422	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1			
2013	-0.06744	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1		
2014	-0.009	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1	
2015	-0.08704	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	-0.08333	1

Table 7.3 Correlation between monthly flows

	Flow	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Flow	1												
Jan	0.024998	1											
Feb	-0.03412	-0.08807	1										
Mar	0.221892	-0.09267	-0.08819	1									
Apr	0.189419	-0.09102	-0.08662	-0.09115	1								
May	-0.02928	-0.09267	-0.08819	-0.09279	-0.09115	1							
Jun	-0.06374	-0.09102	-0.08662	-0.09115	-0.08953	-0.09115	1						
Jul	-0.09302	-0.09267	-0.08819	-0.09279	-0.09115	-0.09279	-0.09115	1					
Aug	-0.11119	-0.09267	-0.08819	-0.09279	-0.09115	-0.09279	-0.09115	-0.09279	1				
Sep	-0.07325	-0.09102	-0.08662	-0.09115	-0.08953	-0.09115	-0.08953	-0.09115	-0.09115	1			
Oct	-0.08438	-0.09267	-0.08819	-0.09279	-0.09115	-0.09279	-0.09115	-0.09279	-0.09279	-0.09115	1		
Nov	-0.02944	-0.09102	-0.08662	-0.09115	-0.08953	-0.09115	-0.08953	-0.09115	-0.09115	-0.08953	-0.09115	1	
Dec	0.081142	-0.09254	-0.08807	-0.09267	-0.09102	-0.09267	-0.09102	-0.09267	-0.09267	-0.09102	-0.09267	-0.09102	1

7.3.5. Monte Carlo Uncertainty Analysis

Creek flows do not appear to correlate well with the month of the year. Rather than model the creek flow based on expected monthly values, it can make sense to assume all months behave equally. With this assumption, each month of the year would have a flow probability distribution that is the same as the yearly flow probability distribution. A creek flow probability distribution for all 13 years of data was created to represent the actual distribution of flows in Six Mile Creek. This distribution is shown below in ***Fig. 7.7***.

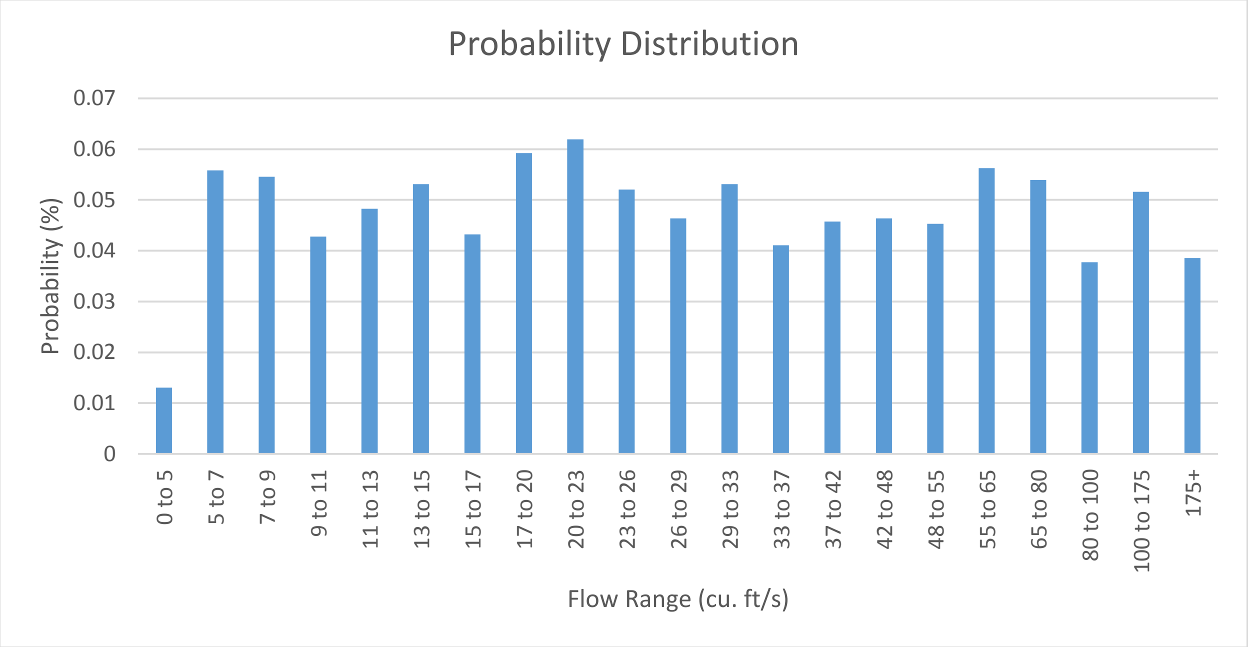


Fig. 7.7: Probability distribution of flow rates in Six Mile Creek.

The distribution of flow rates may also be represented as a cumulative probability distribution, shown in ***Fig. 7.8***.

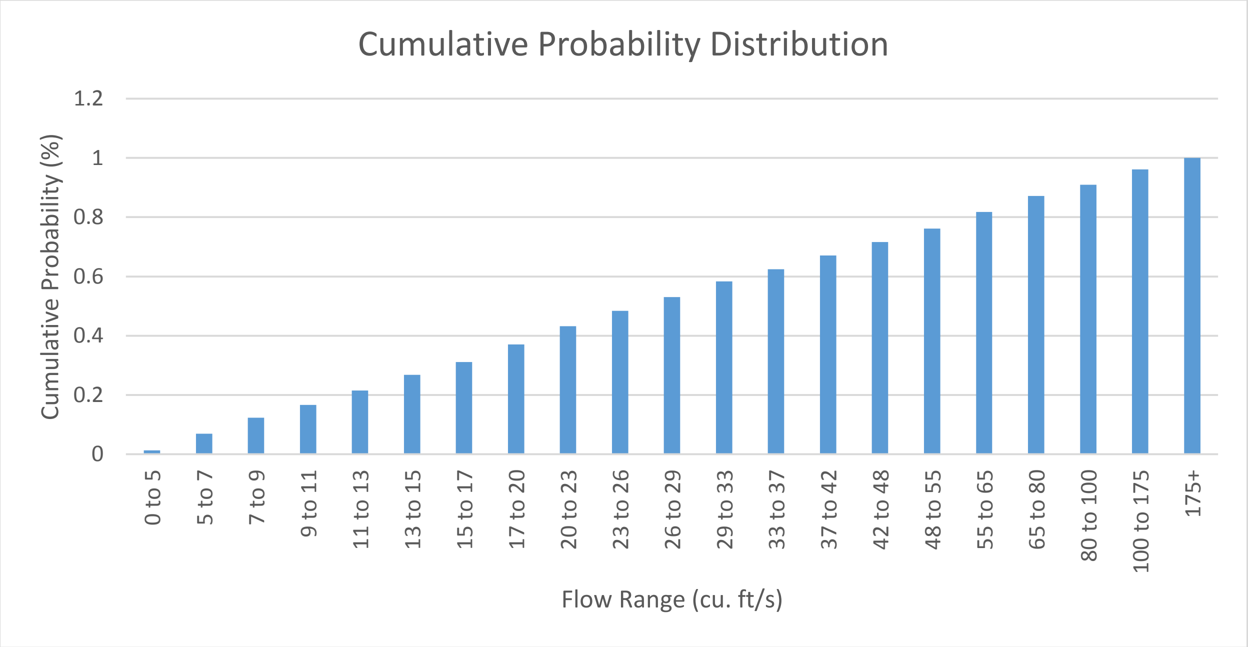


Fig. 7.8: Cumulative probability distribution of flow rates in six mile creek.

Based on this flow distribution, a Monte Carlo simulation was set up. This simulation generated a random number between 0 and 1 which represented the cumulative probability in the above distribution. The random number was assigned a flow rate based on the average cumulative probability distribution to create one year's worth of simulated flow rates. The Monte Carlo simulation was run ten times to simulate ten years of daily flow rates. These yearly data sets were made into load duration curves and plotted together in ***Fig. 7.9***.

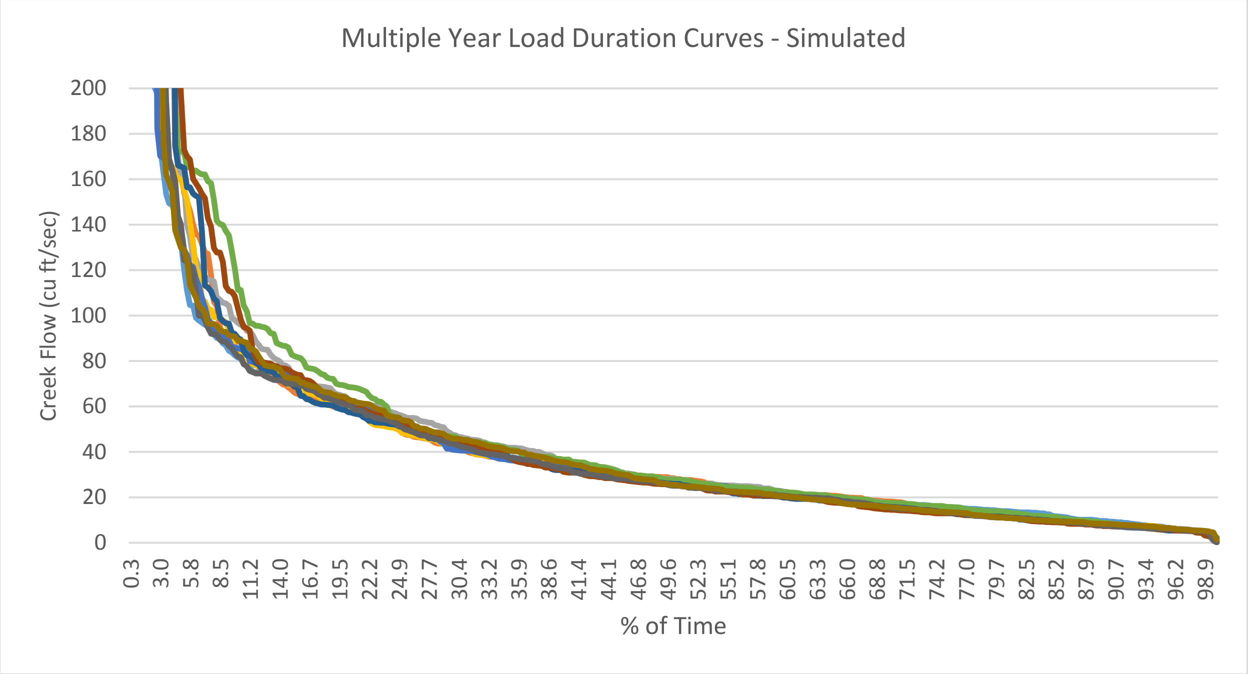


Fig.7.9: Load duration curves derived from Monte Carlo simulations.

Fig.7.9 provides a visual representation of the yearly differences that result from random variation in the 13-year average flow distribution. However, they do not vary as much as one would expect. The actual yearly flow distributions are shown plotted together in ***Fig. 7.10***.

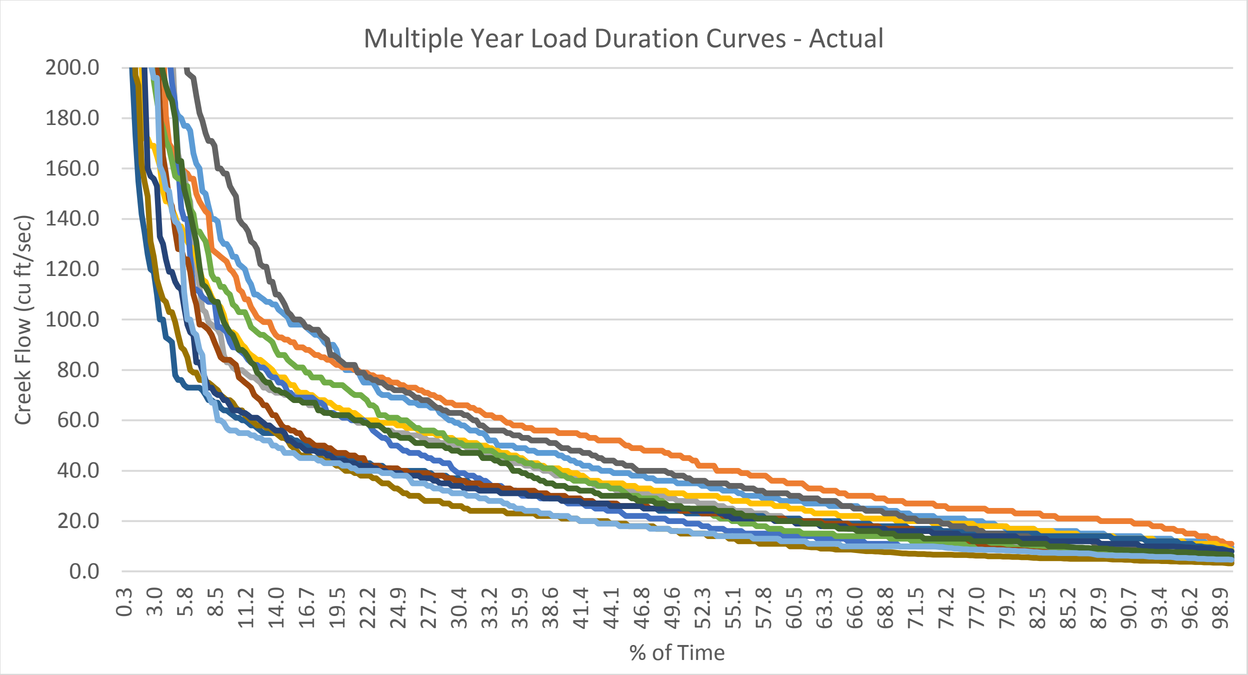


Fig. 7.10: Yearly load duration curves for actual creek flows.

It is apparent from comparing ***Fig.7.9*** and ***Fig.7.10*** that the 13-year average probability distribution does not produce as much variability as what is observed. Clearly flow rate probability distributions can vary from year to year more than random variation in the average distribution can account for. Simply put, some years are wetter than others. For the purposes of this study, it is nevertheless assumed that a 13-year averaged flow distribution is representative of the creek's flow characteristics. This is a reasonable assumption because the hydroelectric installation is designed to last several decades and one wet or dry year will have an insignificant impact on the economics of the project. Though it may produce less electricity one year compared to the next, over time the average is expected to stay constant and turbines should be selected based on the average flow distribution.

7.4. Site Selection

As mentioned earlier in the report, given that the foundational structure already exists along with a penstock that feeds water into the facility, the Van Natta Dam proves to be the most feasible site for a pilot Small Hydro Plant at Six Mile Creek. Further, NYSEG has already carried out a feasibility study in 1989 that essentially proposed to repurpose the water pumping facility to serve as a hydropower generation facility (NYSEG, 1989). Structural analysis is to be carried out to establish the feasibility of renovating the structure, given the dilapidated structure is nearly a century old. If the facility proves to be structurally sound, then only minor construction work will be required to have the hydropower facility begin operations and become fully functional.

The dam will require minor maintenance. Currently, the penstock that transports water from the dam is constructed as two separate sections, one is a brick lined concrete capped penstock, 8 feet in diameter and 58 feet in length that transports water from the intake conduit at the dam side and feeds it into the secondary section of the penstock, which is 6 feet in diameter and 67 feet in length that eventually connects to the turbine level at the proposed powerhouse which will house the turbine. For the scope of this project, it is proposed to revamp the penstock and essentially construct a single steel penstock 122 feet in length and 4 feet in diameter that will transport water from the dam and feed it directly into the turbine. This setup will reduce losses in head that is generated when water is transported along the length of the penstock. The salient features of this site are as follows (NYSEG, 1989):

- Estimated Average Head : 55.84 feet
- Penstock Length : 122 feet
- Diameter of Penstock : 4 feet
- Penstock Material : Steel
- Average Flow : 47.12 cfs

Note that the average head as indicated here is measured from the top of the water level at the intake into the penstock to the lowest water level at the tail race of the turbine. The average flow represented here is to give us an idea of the sizing of the turbine. It is essentially the average of 13-year monthly flow data.

7.5. Turbine Selection and Sizing

The turbine and the associated mechanical and electrical components are the major components of any Small Hydro Power facility and represent the bulk of the capital expenditure associated with the development of a facility besides the civil works such as the construction of a penstock.

For the scope of this project, having not carried out nay structural integrity tests on the Van Natta pumping station, this feasibility study will assume that the facility can be used as is and only minor maintenance work will be required. As a consequence, for this project, the turbine and the associated machinery will represent the bulk of the capital investment. As discussed in earlier sections of this report, there are primarily two types of turbines: Impulse turbines such as the Pelton Wheel Turbine and the Crossflow Turbine are designed to operate in high head and low flow conditions whereas reaction turbines such as the Kaplan or Francis Turbines are designed to operate in a low head - high flow combination. So, in general, the turbine is primarily selected based on the head and flow available at the proposed site. Secondary factors that influence the selection of the turbine are the nature of the stream flow and the consistency in observed average flow.

7.5.1. General Design Parameters

We have selected the Ossberger Cross-flow Turbine to be the optimum turbine that can be employed at the Six Mile Creek water resource. This turbine proves to be the ideal choice due to the following factors:

Water Composition:

The water at Six Mile Creek is rich in sediment and debris, given the nature of the surrounding environment. Traditional turbines like Pelton, Kaplan and Francis turbines have a higher efficiency but their performance is highly affected by debris in the water and drops off exponentially. Cross-flow turbines are designed in such a manner that they clean themselves with the water flow that occurs while the turbine is being operated. Thus, even though the efficiency is lower, crossflow turbines have a higher reliability and hence a higher overall efficiency especially at Six Mile Creek.

Available Head:

In general, heads lower than 30 meters are considered to be low heads. Cross-flow turbines are ideal for low heads such as our case at Six Mile Creek because it is a low speed turbine that relies heavily on flow rather than head in optimizing its performance.

Flow Characteristics:

As discussed earlier, the flow at Six Mile Creek is very seasonal and highly variable. The peak efficiency of a cross-flow turbine is somewhat less than Pelton, Kaplan or Francis turbines. However, the cross-flow turbine has a flat efficiency curve under varying loads. With a split runner and turbine chamber, the turbine maintains its efficiency while the flow and load vary from 1/6 to the maximum. This is ideal for our facility as can be seen from the flow data, that the river flow is variable and varies from as low as 4 cfs to as high as 180 cfs. Due to its excellent performance under partial loads, the cross-flow turbines are ideal for run-of-the-river hydro power installations.

Maintenance:

Taking into account the fact that debris accumulation will be prevented with cross-flow turbines as well as the fact that cross-flow turbines are ideal for unattended power production, it is ideal for the installation at Van Natta Dam. Also, the simple mechanical design of the turbine means there are very few moving parts that require periodic maintenance. This will go a long way in optimizing maintenance and operating costs of the installed facility.

7.5.2. Turbine Sizing

As mentioned earlier in the report, most companies supplying turbines commercially provide a water-to-wire service, which means that the supplier will provide the turbine, the generator and all associated equipment as a single package that is sized according to the flow duration curve and annual flow pattern at any given site.

For the purposes of this project, the turbine sizing was carried out by Ossberger Hydro and a proposal was submitted to supply a 277 kW turbine priced at 250,000 USD. This also included the required speed increaser and the generator unit. Contact information of the manufacturer and the Project Director who worked on this proposal are provided in the acknowledgments section of this report. The turbine was sized based on the load duration curve generated for Six Mile Creek as shown in ***Fig. 7.7.***

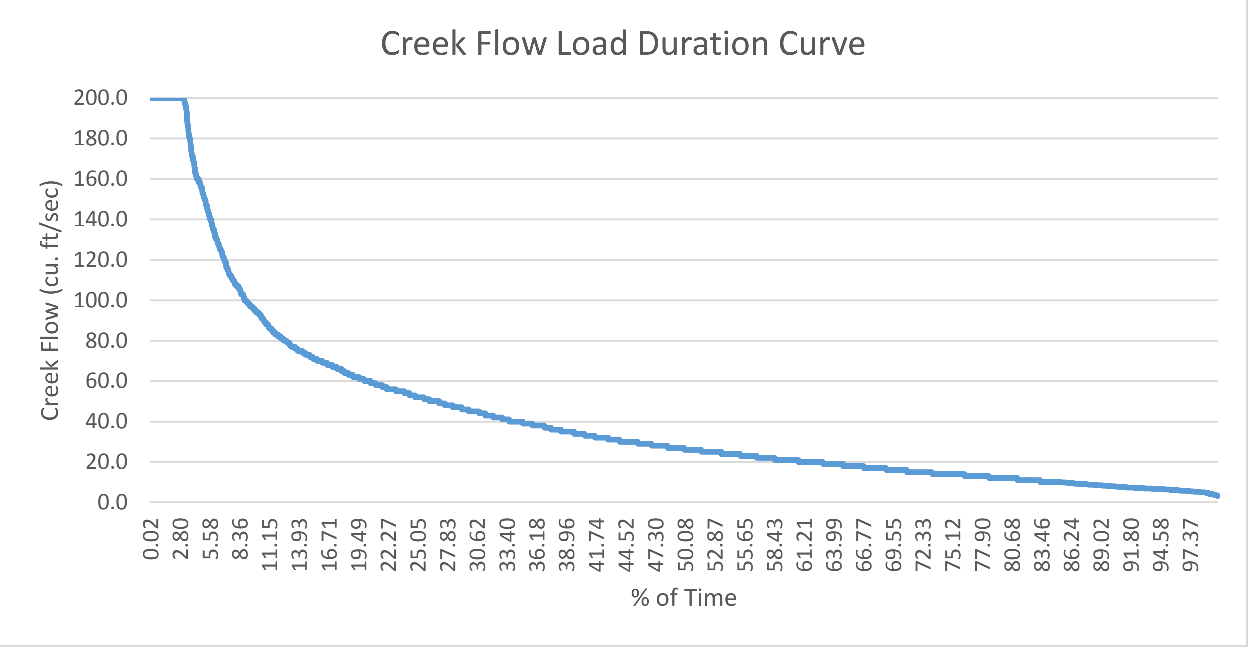


Fig. 7.7. Flow Duration Curve (Flow in cfs), Six Mile Creek.

The salient features of the proposed turbine are as follows:

- Net Head : 55.84 feet
- Maximum flow (cfs) : 70 cfs
- Minimum flow (cfs) : 7 cfs
- Turbine Maximum Output : 277 kW
- Generator Maximum Output : 256 kW

The specification sheet of the proposed turbine and power generation assembly are available in the appendix. The Budget proposal submitted by Ossberger Hydro for this project are also available in the appendix.

8. Evaluation of Energy Generating Potential

In order to evaluate the annual available power of the water resource at Six Mile Creek, flow data was averaged and a 13-year average of monthly flows from 2003 to 2015 was used in the final calculation. ***Table 8.1.*** lists the average, maximum and minimum flows on a monthly basis. ***Fig. 8.1***. plots these data points so the trends in river water flow can be visualized.

Table 8.1. Monthly Flow data (cfs) for Six Mile Creek, 13-Year Average (2003-2015)

Month	Average flow	Max	Min
Jan	54.00	96.10	24.00
Feb	40.39	85.20	12.70
Mar	97.31	156.20	28.70
Apr	90.58	184.60	32.40
May	39.60	73.80	21.50
Jun	35.21	113.70	12.10
Jul	25.31	56.50	6.74
Aug	21.03	62.50	5.68
Sep	29.65	163.00	4.70
Oct	27.37	74.40	7.64
Nov	40.73	67.90	9.75
Dec	64.26	115.20	20.10

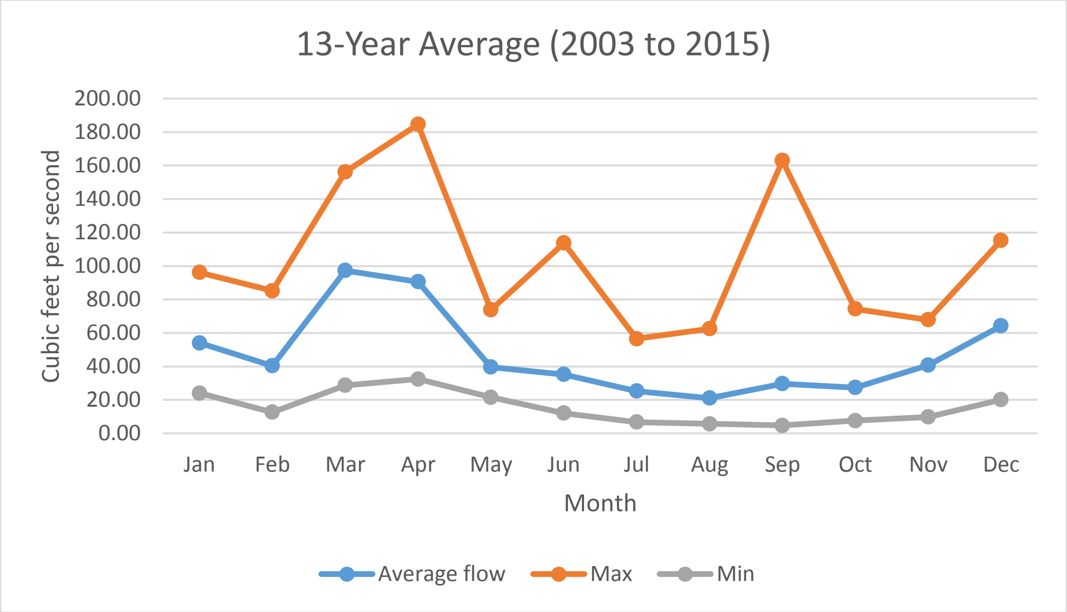


Figure 8.1. Monthly Flow of Six Mile Creek, 13-year Average (2003-2015)

As the plant is run-of-the-river, it is required that a minimum bypass flow be allowed at all times to maintain the aesthetic value of the falls as well as protect and sustain aquatic life of the stream. This minimum bypass flow as dictated by regulations is 10 cfs. So, the flow available for power generation will be less than the actual flow available at the creek. Also, the turbine is effective only when the flow through the turbine falls between 7 cfs and 70 cfs. If the flow is any lower or higher, and the turbine cannot operate as it is not designed to operate under those conditions. The turbine also has varying efficiencies over these different flows.

In order to calculate the potential energy that can be generated at the facility, the average daily flow from the past 13 years were segmented into bins, each bin having a range of 7 cfs and spread evenly from 7 cfs all the way up to 70 cfs. So, the bins used in the calculation of the energy are graphed in ***Fig. 8.2***. Now, as can be observed from this plot, more than 33 % of the time, the flow available in the creek is too low, far below the operating range of the turbine. The turbine cannot produce power under these conditions. Also to be noted here is that more than 12% of the time, the average flow observed in the creek is above the 70 cfs operating range limit of the turbine and the turbine cannot produce power from the additional flow above 70 cfs in this scenario.

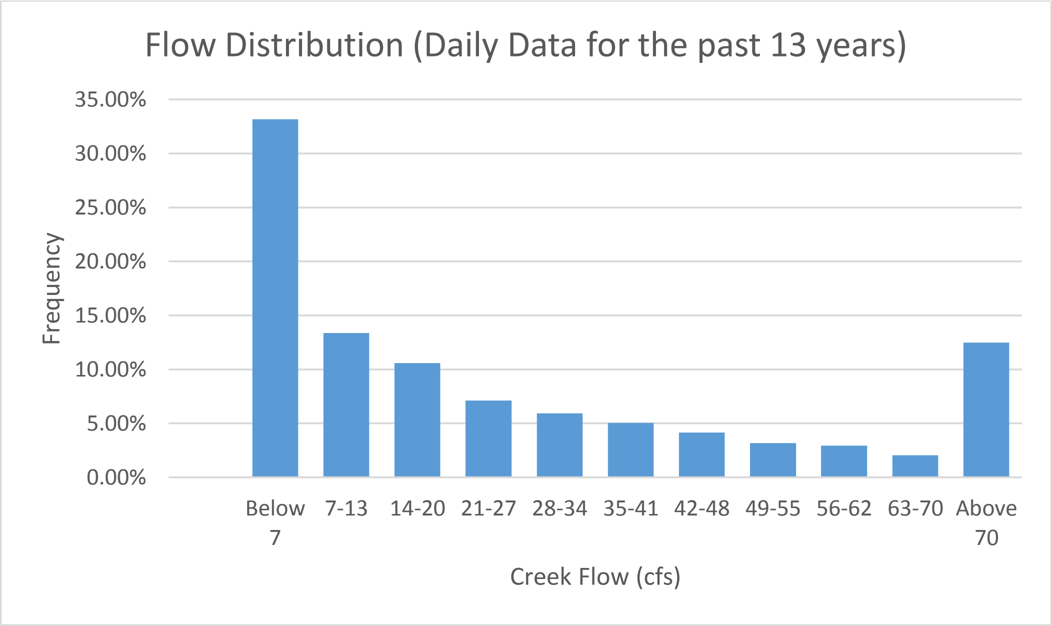


Fig. 8.2. Flow Distribution of Six Mile Creek (Based on Daily flow 2003 – 2015)

Accounting for the varying efficiencies, we are able to calculate the energy that can potentially be generated at the facility, if the proposed configuration is implemented, over the course of one year based on daily flow data of the past 13 years. The net energy generated over this period works out to be about 830,000 kWh. ***Fig. 8.3.*** details the amount of energy generated in each bin of flow distribution.

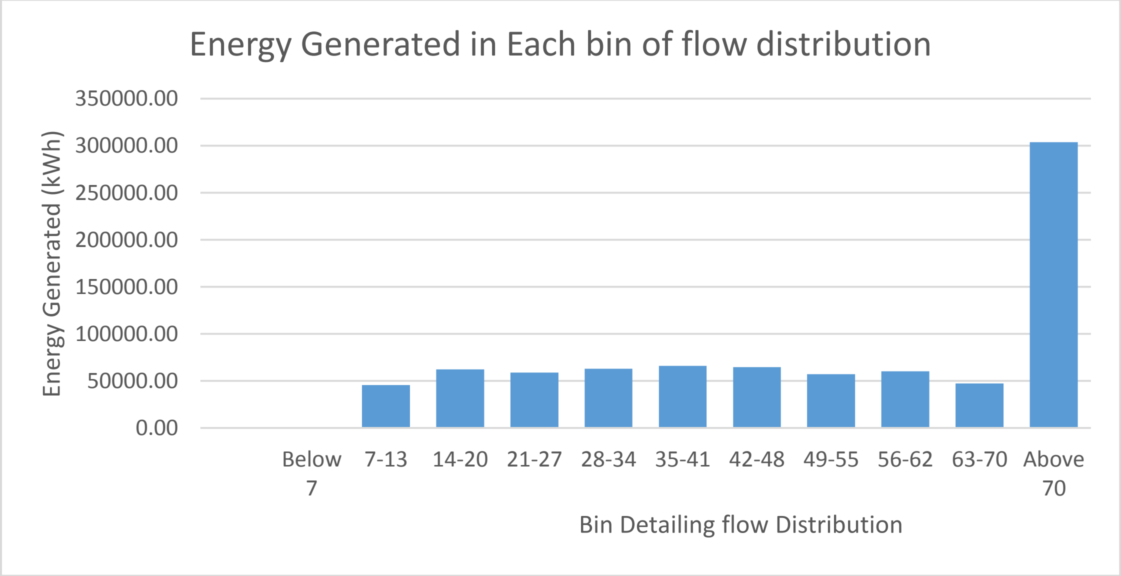


Fig. 8.3 Energy Generated in each bin of flow distribution, Six Mile Creek

The bulk of the energy is generated when flows at the creek exceed the design limit of 70 cfs because when flow available is higher than 70 cfs, the penstock is deigned to let in only 70 cfs of flow into the turbine and hence, the turbine operates at design capacity and produces the most energy. Based on these calculations, the plant has a capacity factor of 37 %. (Calculation: CF = (830,000 kWh)/(256 kW X 8,760 hr/yr) = ~0.37.)

9. Economic Analysis

Prior to conducting the analysis, finance-related data were collected and several assumptions were made for the purpose of this report. From the U.S. Energy Information Administration (U.S. EIA), the average electricity retail price for New York state is $ 0.15/kWh as per year 2015 (EIA, 2017). Then, the discount rate used for further net present value (NPV) calculation is 3% as per New York State Department of Taxation and Finance (NY State Department of Taxation and Finanace, 2017). Next, the inflation factor changes over time, but in this case it is assumed as 1.5% (U.S. Inflation Calculator, 2017). By referring to the Cornell University Hydropower Plant, the capital cost is assumed as $ 50,000/year because the operations and maintenance will not require high labor (Perry, 2017).

9.1. Capital Costs and Levelized Cost of Electricity (LCOE) Calculation

Having the Ossberger turbine quoted to cost $ 250,000, this value will be the project's Inside Battery Limit (ISBL), meaning the cost of the project up to its physical boundaries. Engineering cost will be assumed as 30% of ISBL. The depreciation is assumed to be straight-line and no salvage value after 25 years of the project lifetime. Although, the implication of depreciation will not be that significant to the cash flow since the project is government-based – we do not apply tax in the calculations.

One factor that will impact the cash flow of this project is Renewable Energy Credits (RECs), an incentive for renewable electricity producers. As per year 2017, New York State Energy Research and Development Authority (NYSERDA) set the RECs of New York State to be $ 0.021/kWh (NYSERDA, 2017). This will significantly bring more revenue to help cover the high capital expenses and the low electricity generation.

Lastly, land cost is not included since this project will use an existing facility. Other capital costs such as dam repair, start-up, and indirect cost are future-valued from the 1989 Van Natta report for simplification purposes (NYSEG, 1989). Working capital is assumed as 5% of fixed capital investment. The full breakdown of capital expenses (CAPEX) is shown in detail in ***Table 9.1.***

Table 9.1. Breakdown of Capital Costs involved with the proposed project

	1989	2017	Remarks
Inside Battery Limit (ISBL)			
Ossberger turbines		$ 250,000.00	Quotation from Ossberger Canada
Direct Cost			
Engineering cost		$ 75,000.00	30% ISBL for small projects
Dam repair	$ 21,000.00	$ 48,046.48	Future-valued
Start-up/test	$ 15,500.00	$ 35,462.88	Future-valued
TOTAL DIRECT COST		**$ 408,509.36**	
Indirect Cost			
Contingency	$ 83,700.00	$ 191,499.55	Future-valued
Legal and permitting	$ 30,000.00	$ 68,637.83	Future-valued
TOTAL INDIRECT COST		**$ 260,137.38**	
Fixed Capital Investment		$ 668,646.74	Total Direct Cost + Total Indirect Cost
Working Capital		$ 33,432.34	Assumed 5% of FCI
Land		-	Not included. Use existing facility
TOTAL CAPITAL INVESTMENT		**$ 702,079.07**	

One of the most important part for the NPV calculation is the calculation of Levelized Cost of Electricity (LCOE). It is the electricity cost determined by dividing annualized cost with annual electricity output. The formula for calculating LCOE is shown below:

$$LCOE = \frac{Annualized\ CAPEX + Operations\ \&\ Maintenance\ Cost + Fuel\ Cost}{Annual\ Electricity\ Output}$$

Annualized CAPEX is determined by dividing CAPEX with the annuity factor, as shown below:

$$Annualized\ CAPEX = \frac{CAPEX}{\left(\frac{(1+r)^n - 1}{r\ (1+r)^n}\right)}$$

where r is the annual interest rate and n is the project lifetime. Operations and maintenance cost is considered non-capital, which is $ 50,000 as assumed previously. Fuel cost is negligible, since this is a hydropower plant which does not require fuel combustion process. Thus, having the CAPEX of $ 702,079.07 and annual electricity output of 830,000 kWh, the annualized capital cost for 25 years at 3% is \$40,319, the total annual cost including O&M is \$90,319, and the LCOE for this project is (\$90,319)/(830,000 kWh) = \$ 0.11/kWh.

9.2. NPV of the proposed Project

The NPV of this project is calculated by summing up the annual cash flows (CF$_n$) as shown in in the following relation, while internal rate of return (IRR) is determined from the interest rate when the NPV is equal to zero.

$$NPV = \sum_{i=0}^{n} \frac{CF_n}{(1+r)^n}$$

In order to determine the significance of RECs, NPV was calculated for two scenarios:

1. Project with RECs, using figure of \$0.021/kWh introduced above
2. Project without RECs

Fig. 9.1. and 9.2. in the following page show the comparison of those two scenarios.

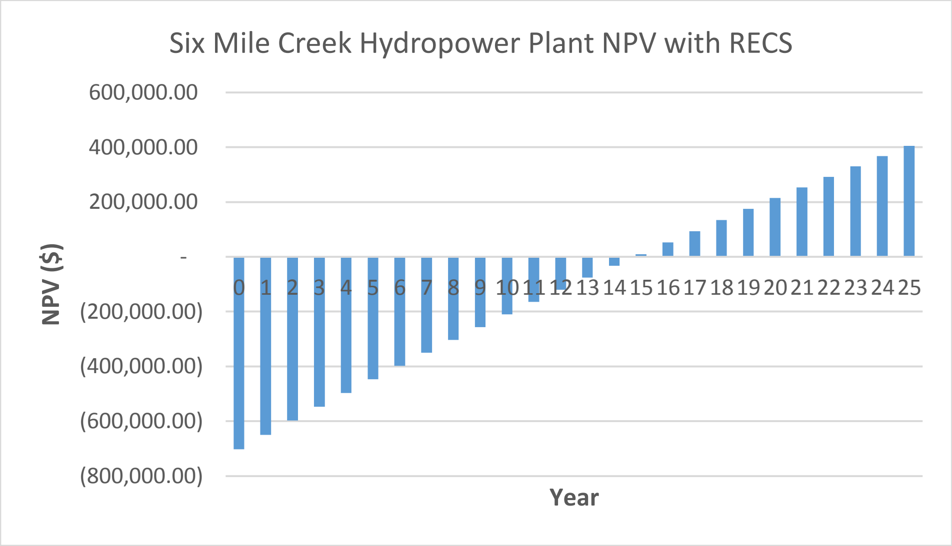


Fig. 9.1 Six Mile Creek Hydropower Plant NPV with RECS

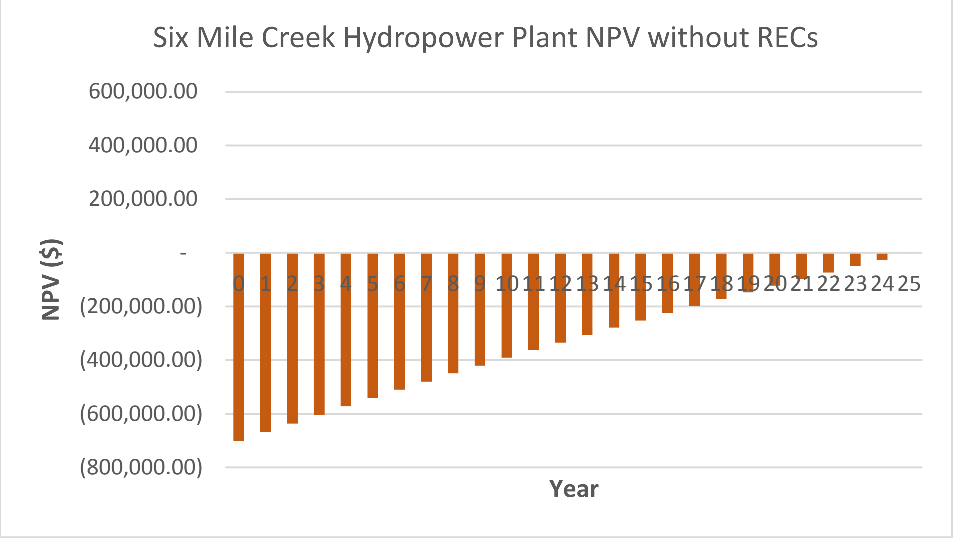


Fig. 9.2. *Six Mile Creek Hydropower Plant NPV without RECS*

The results of NPV and IRR calculations are shown as follows:

	Project with RECs	Project without RECs
NPV	$ 404,548.08	$ (122,643.37)
IRR	5%	2.9%

From the NPV and IRR analysis, it is obvious that RECs significantly contribute to the increase of revenue, hence leading to positive NPV. With RECs, the NPV is $ 404,548.08 and the IRR is 5%, which is greater than the interest rate used in this calculation. Compared to the other scenario, RECs can get the project to break even financially at the 15th year. Hence, with the support of RECs this project is viable, though it may still be subject to the change of previous assumptions.

On the other hand, without the support of RECs this project will result in negative NPV even after 25 years of lifetime. The IRR is also less than the annual interest rate. Without RECs, this project will not be viable unless there are some major reduction in CAPEX or O&M cost.

10. Environmental Impact and Analysis

Hydropower is regarded as a green energy source, because it does not emit carbon dioxide and will not pollute the air we breathe. The water is driven by gravity, which is regarded as non-destructive. The water resource is relatively inexhaustible when compared with the fossil fuels. However, hydropower plant still has negative impacts. The environment of the surrounding area will be affected during the hydropower plant construction and operation. Some strong identified impacts are shown in in the pie chart ***Fig. 10.1***. The percentage value indicates how often the impacts have been mentioned. Based on this chart, we can see that species habitat, fish morality and morphological change are the most common impacts.

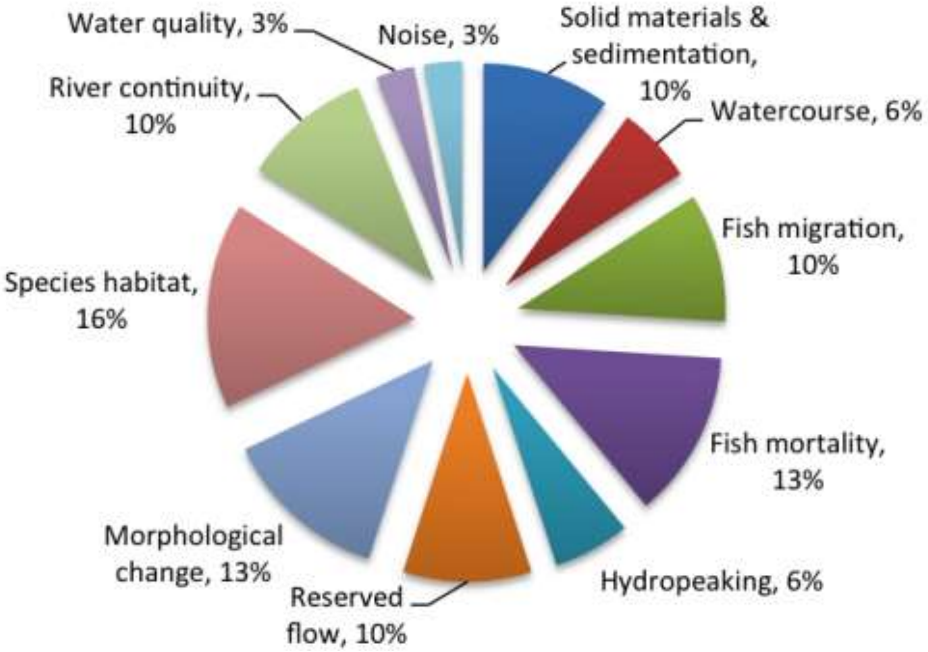


Fig. 10.1 *Strongly identified impacts from hydropower plants*

According to Bergkamp et al. (2000), the impact could be classified under three categories: first-order impact, second-order impact, and the third-order impact. These impacts can be divided into those that are observed downstream and upstream. For example, the first-order impacts that are located upstream include water quality alteration and sediment accumulation. Impacts happening downstream could be changes in water flow and morphology.

The second-order impacts are the effects caused by the first-order impacts and the abiotic and biotic changes in ecosystem structure. The difference between with first- and second-order impacts is that it may take several years to identify occurrence of second-order impacts. However, the first-order impact happens immediately after the reservoir is built. The examples for second-order impacts are the influence on vegetation grown near the river and the plankton in the stream.

The third-order impacts are the results of the first- and second-order impacts. This impact can take place over many years and in the end, a new ecological equilibrium will be reached. Examples are the impacts on invertebrates, mammals, fish, and birds in the ecosystem or marine and estuarine change.

As to the expected environmental impacts of the hydropower plant, the first one is the periodic ponding. When a dam is built, the water can be regulated, which means that in some cases, the amount of water released through the dam is small. As a result, the water in the downstream area of the dam is not sufficient. Some places may be even extremely dry. In the summer month, due to the reduced flows and increasing water demands of Ithaca City, the lower reaches of the Six Mile Creek are periodically ponded. The habitat for all species living in and around the river will be affected significantly by ponding. However, the specific impacts should be studied because it is reported to be unknown.

The second one is fish mortality. The landlocked salmon fry stocking program is launched by New York State Department of Environment Conservation (DEC) and these salmon grow to the smolt stage in upstream and migrate to Cayuga Lake during March, April, and May. During the migration month, salmons could be injured if the flow is not sufficient for them to pass the dam. In order to solve this problem, the recommended minimum flow for fish migration is 9 CFS, 24 hours a day during the migration months.

In addition, the fishes in their younger stage will be trapped into the intake structures and turbine related mortalities will happen. For the purpose of preventing the entrainment of fish through the turbine, a fish screen should be installed at the penstock intake. The mesh size should be 2 inches’ maximum. The DEC also decided to reduce the size from 2 inches to 1 inch. In addition, According to European Small Hydropower Association (ESHA) (2004a) the injury and mortality of fish depends on turbine type. Due to the different construction of turbines, the Kaplan turbine is more fish friendly than a Francis turbine. It is interested that the survival is related to the efficiency a Kaplan turbine. The more efficiently it runs, the larger amount of fish can survival.

Lastly, as to the morphological change, besides the periodical ponding mentioned above, the other one is the impact to the aesthetic value of falls. Enough water should be provided to keep falls flowing. Except for the migration month, the minimum flow should be 4 CFS to maintain the aesthetic value of the Van Natta Falls in the remaining months.

11. Licensing and Regulation

11.1. Regulations Governing Distributed Generation

The regulations information provided in this section of the report is intended to provide a general scope of rules and regulations applicable to distributed generation in New York State. All information is publicly available online. For additional details and clarification, the reader may refer to the links provided at the end of each subsection.

11.2. PURPA – Public Utility Regulatory Policy Act of 1978

PURPA is a federal law passed in 1978 to serve three purposes: conserve energy, optimize efficiency of electric generating resources, and provide equitable rates to consumers (section 101). The law provides the basis for today's electric utility billing. This includes mandatory conditions such as requiring electricity costs to reflect the cost of generation and requiring the utility's bill to reflect the cost of generation at different times of the day (section 111).

In addition to providing ground rules for billing consumers, PURPA also requires electric utilities to sell power to and buy power from qualifying small production facilities. The utilities are required to purchase electricity at a cost that is "just and reasonable to the electric consumers of the electric utility and the public interest". Furthermore, the utility may not "discriminate against qualifying … small power producers" by offering lower prices than market value for the electricity produced. Similarly, the utility has to offer a fair rate for electricity sold to the small power producer and cannot artificially raise prices to make power generation no longer cost effective for the generator.

PURPA does not set regulations for electric utilities or the market. Rather, it is a set of rules on which state regulators are to base their own regulations. For further information regarding PURPA, the full text of the Act is available online through the following link:

https://www.usbr.gov/power/legislation/purpa.pdf

11.3. New York public service law 66-J

The New York Public Service Law, part 66-j is New York State's law defining who can connect electric generating equipment to the grid and under what conditions. For distributed generation, PSL 66-j limits the total rated capacity of the power generator to 2 MW.

PSL 66-j requires all electric corporations in the state of New York (or NYSEG, in central NY) to provide interconnection of distributed generation to the grid. This is essentially the state law aligning with the federal PURPA act. However, PSL 66-j also allows the electric corporation to deny interconnection to the grid if total rated generating capacity in the service area impacts more than 2% of the Utility's incremental net annual revenue. At this point, the amount of distributed generation in the area would presumably have a negative impact on the cost of electricity for other consumers. It is important to note that the 2% limit is not a cap.

Along with interconnection rules, PSL 66-j requires the generator to install certain safety equipment such as automatic isolation from the utility system based on voltage and frequency deviations and lockable disconnect switches that are externally accessible. Finally, PSL 66-j allows remote net metering and community net metering in New York state.

11.4. Remote Net Metering

Remote net metering is a method of billing where the customer-generator is allowed to offset cost of kWh's used at one or more of their metered locations with the value of kWh's created at the generator. There are two subsets of remote net metering: volumetric and monetary. Volumetric metering applies kWh's from the generator meter directly to the customer's meter, whereas monetary metering applies the value of kWh's exported through the generator's meter to the customer's bill.

Regardless of whether volumetric or monetary metering is used, the generation is only permitted to offset the customer's electric consumption. If the customer generates more than they produce, they do not receive money from the utility. Instead, they may receive a credit that can be applied to future bills. There is no time limit on how long credits can last—they carry over indefinitely.

On March 9, 2017, the NYS public service commission issued an order amending PSL 66-j. This amendment states that all new distributed energy projects using remote net metering are to be billed on a monetary basis according to a new Value of Distributed Energy Resources (VDER) tariff.

Additional information on remote net metering is available at the following link:
http://programs.dsireusa.org/system/program/detail/453

11.5. Value of Distributed Energy Resources Tariff

The VDER tariff was introduced to compensate the customer generator for electricity in a way that more closely reflects the market value of the generated electricity. One of the main reasons NY state switched to the new compensation system was because "volumetric crediting, on which net energy metering is based, fails to reflect the full and accurate value that distributed energy resources provide to the grid". The idea is that accurate pricing for the value of the distributed energy resources will increase the amount of distributed resources in the state, leading to lower costs and cleaner energy.

There are two parts to the tariff. The first part states that all existing distributed energy generation projects are to be compensated based on the old (existing) tariffs. Furthermore, all new generation projects that already have an interconnection contract with the utility may elect to follow the old net metering rules for up to twenty years. The second part of the VDER tariff states that all new distributed energy generation must be compensated according to what is referred to as a "value stack".

The value stack method of compensation provides a monetary credit to the generator based on day ahead hourly electric prices in the load zone. On top of this, the electricity price factors in the capacity value of the distributed energy resources, the environmental value (based on renewable energy certificates or RECs), the demand reduction value, and the locational system relief value. The capacity value is determined by the amount of generation provided during the peak hour of the previous year. More generation leads to a higher capacity value. The demand reduction value is the amount of electricity the customer can take off the grid during a given period of time, and the locational system relief value is the value of decongesting the grid, based on marginal cost of service studies performed by the NYISO. The environmental component of compensation is an option that the owner may elect to receive or forego. If the customer elects to retain their renewable energy credits, no environmental value will be attributed to their generation.

The value stack method of compensation may only be used for customers that have hourly metering. Customer-generators that wish to install distributed generation and use net metering must have these hourly meters. However, there are exceptions for community distributed generation as detailed in the next section of this report.

The VDER order may be read in its entirety at the following link:
http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={5B69628E-2928-44A9-B83E-65CEA7326428}

11.6. Community Net Metering

Community distributed generation is similar to remote net metering in that one generator, up to 2 MW, may provide a customer with monetary credit against their electric bill. The difference is that community net metering allows multiple customers (minimum of 10) to claim portions of generation from one or more generators. Furthermore, the customers may use the monetary credit against their electric bills even if their meter is in a different service classification. This allows residential customers to purchase renewable energy from the grid via an agreement with the generator.

New community distributed generation projects compensated under the value stack tariff are subject to a market transition credit (MTC). The MTC is the difference between the base retail rate of electricity for small or residential customers and the estimated value-stack value. This MTC is provided because the service classification of residential customers does not take into account hourly pricing or demand response. This essentially keeps community net metering on volumetric metering until phase two of the VDER is implemented. There appears to be a great deal of uncertainty over how community net metering should be handled, though the overall goal of providing renewable energy to low income residents is likely to be maintained in the future. Community net metering can allow low-income residents to reduce their electricity bills, since the project owner can choose to sell some of the electricity produced to low-income residents at prices per kWh that are below what they would otherwise pay.

It is important to note that the Public Service Commission does not consider community distributed generation as subject to PURPA. This is because it is a state program that an owner-generator can elect to participate in. The PSC has commented that if the owner-generator wishes to be compensated for excess renewable energy credits due to excess generation, they may participate in remote net metering instead. This commentary can be referenced in the value of distributed energy resources tariff document in the previous section.

11.7. Standardized Interconnection Requirements and Application Process

The standardized interconnection requirements are set by the State of New York and define the process through which customers may interconnect to the electric utility's infrastructure. The interconnection requirements also set deadlines and responsibilities for the utility to follow. There are eleven steps to interconnect to the grid as described below.

Steps for Interconnection:

1. Reach out to the local utility to indicate interest in connecting to the grid (NYSEG).
2. Request a pre-application report from the utility. This is a non-binding set of information on local the electrical system and some readily available data. Pre-application report costs $750 unless the owner formally requests an interconnection within 15 days of receiving the pre-application report.
3. Submit an interconnection application. Costs $750, but that cost gets credited toward the utilities interconnection cost at the end of the project if an interconnection does indeed happen. Applicant's application gets put in the utility's interconnection inventory.
4. Utility performs supplemental screening and provides a rough cost estimate. The Owner has to make a decision to accept costs and move on with the project or abandon it.
5. Assuming step 4 is approved, the Owner submits a coordinated electric system interconnection review (CESIR). A complete design has to be provided to the utility as part of the CESIR application. The Owner has one year to submit the CESIR after getting on the utility's interconnection inventory.
6. Utility reviews proposed CESIR design. If approved, the utility will provide a +/-25% cost estimate for doing interconnection work.
7. Applicant commits to the utility performing the interconnection work by paying full estimated cost to the Utility.
8. Project is constructed.
9. Project installation is tested.
10. IF project passes step 9, it is allowed to officially interconnect to the grid.
11. Utility issues Owner formal letter of acceptance and cost of interconnection is reconciled with original cost estimate.

The full interconnection requirements document may be viewed at the following link:

http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/dcf68efca391ad6085257687006f396b/$FILE/SIR%20Final%203-17.pdf

Interconnection costs can be highly variable depending on capacities of existing infrastructure at the proposed interconnection location. There is a "but for" clause in the state laws which requires the customer to pay for any upgrades necessary for installation of their proposed distributed generation project. The average cost of interconnections in New York State is $100,000 per MW, while the average in Tompkins County is $220,000 per MW. Interconnections for Cornell's solar farms have ranged from $150,000 to over $1,000,000.

11.8. New York's Plan for Increasing Renewable Energy Generation

11.8.1. Clean Energy Standard

The New York Public Service Commission implemented the Clean Energy Standard (CES) on August 1, 2016. The CES mandates that the State produce 50% of its electricity with renewable resources by 2030. The CES order states that the load serving entities (electric utility suppliers that bid load purchases to the NYISO) must follow the renewable energy standard (RES).

The Renewable Energy Standard requires Load Serving Entities, or LSE's, to provide 50% renewable energy by 2030 through the purchase of renewable energy credits (RECs). The CES order further specifies incremental increases in renewable energy requirements from 2017 through 2030 to reach the 50% renewable goal. Overall, to reach 50% renewables, more renewable generation must get installed in the state. If this does not happen and the LSE cannot purchase enough renewable energy credits, the CES mandates that the LSE must purchase alternative compliance payments (ACPs) from the State, which cost 10% more than a renewable energy credit. In this way, the energy market is incentivized to install more renewable energy resources. As ACPs drive up the cost of electricity, renewable energy projects will become more cost effective and economically attractive.

The REC and ACP prices are set by the New York State Energy Research and Development Authority (NYSERDA) and change on a yearly basis.

11.8.2. RECs and NYGATS

One REC is equal to one MWh of generation from a recognized renewable energy resource. The New York Public Services Commission determined that all renewable energy credits shall be issued by the New York Generation Attribute Tracking System (NYGATS), which is overseen by the New York State Energy Research and Development Authority (NYSERDA). The NYGATS system is set up to allow the LSEs to purchase RECs from renewable energy generators in a process called Renewable Energy Standard Tier 1 solicitations. Tier 1 is a classification for any renewable generator brought online after January 1, 2015. Tier 2 is a classification for a generator that was existing prior to January 1, 2003, and allows existing renewable energy generators to obtain subsidies for maintenance. Due to the difference in dates between Tiers 1 and 2, there are some renewable energy generators that simply have no tier. RECs are only given to renewable generators that meet Tier 1 criteria.

Complete eligibility and certification guidelines for Tier 1 compliance may be read at the link below:
https://www.nyserda.ny.gov/-/media/Files/Programs/Clean-Energy-Standard/Eligibility-Certification-Guidelines.pdf

New distributed generation projects in New York are required to follow the March 9, 2017, VDER order. As part of this order, distributed generation projects have two options that they can choose from. The first option is called the "default interconnection – LSE – Option". This transfers all of the RECs from the generator to the Load Serving Entity. The customer does not receive RECs and cannot claim use of renewable energy for carbon neutrality or reduction goals. However, they do receive the environmental value component in the value stack, or the "E" value. The E value is the price of one REC as set by NYSERDA, the current price of which is $21.16.

The second option available is the "Customer Retention Option", under which the customer receives non-transferrable RECs from NYGATS for clean energy generation but forfeits the "E"

value in the value stack. The customer may retire their RECs and claim use of renewable energy generation, but this their only option if they choose to retain their RECs.
The VDER order is written so that the customer must choose one option or the other at the time of interconnection. If the customer generator selects the default option first, they may make a one-time, irreversible decision to switch to the customer-retention-option. However, they may never change from the customer retention option to the default option. Regardless of the option that is chosen, the customer is not permitted to participate in RES Tier 1 solicitations under the current order.

More detailed information on renewable energy credits and their application to distributed generation projects is provided by NYSERDA at the link below:
https://www.nyserda.ny.gov/-/media/Files/Programs/NYGATS/2017-04-13-StakeholderMTG.pdf

11.8.3. Ongoing legislation and industry challenges to regulations

The March 9, 2017, order on "net energy metering transition, phase one of value of distributed energy resources, and related matters" was a significant change to the power industry. As such, there are many comments and requests for amendments.

One of the major concerns with the recent order is the restrictions on RECs and how the Owner-Generator is not able to participate in the Tier 1 solicitation. This greatly reduces the ability of an Owner-Generator to utilize credits obtained with excess generation. A petition for re-hearing has been filed with the PSC to redress these issues, and can be read in full at the link below.
http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={709FFD12-1A5B-4C43-8D17-EE41987B8256}

A separate piece of legislation has been proposed to the New York Senate, which requires LSEs to surrender RECs to the Owner-Generator. However, the legislature is likely to defer to the PSC and we don't expect that the proposed bill will be voted on. Details on the proposed amendment are at the link below.

https://www.nysenate.gov/legislation/bills/2017/a6682/amendment/original

11.9. FERC

The federal energy regulatory commission is the agency responsible for permitting all hydroelectric facilities in the United States. All hydropower installations on a federal waterway or sited at a government owned dam are required to obtain an operating permit from FERC.

There are three permitting options for hydroelectric facilities: traditional, integrated and alternative. The permitting options are discussed in length in the FERC licensing handbook which can be accessed through the link shown below:
https://www.ferc.gov/industries/hydropower/gen-info/handbooks/licensing_handbook.pdf

For the purposes of this report, it should be noted that regardless of the permitting process, the Owner/Operator of the hydroelectric facility is required to go through the same pre-filing procedure which includes a public notice of intent, comment period, environmental analysis, development of drawings and review by the fish and wildlife agency.

Another point of interest for this project is the "5 MW or Less Exemption". The Owner may apply for this exemption if the hydro project is less than 5 MW. Applying for an exemption still requires the Owner to go through the pre-filing process according to any one of the three permitting procedures and the Owner must still file an application including an introductory statement, description of the project, general map of the location, environmental analysis and drawings. However, if the exemption is granted, the application will not be subjected to further public reviews and comment periods, which may save significant amounts of time and cost in the permitting procedure.

12. Conclusions

Given the technical aspects from flow availability and the equipment specifications, as well as assumptions made for the economic analysis, this hydropower project is financially viable. This viability is still subject to the implementation of RECS, life cycle assumptions, construction quotations, assumptions for discount rate, and the investment lifetime. If the project can progress further to be more detailed, it is encouraged to re-justify the abovementioned assumptions in order to ensure its feasibility.

In terms of environmental impacts, there are some impacts related to the ecosystem, particularly fish. However, the impacts are not significant for a small hydropower plant. Despite that, it is still better to do further study about the impacts of periodic ponding.

13. Recommendations for Future Work

In order to get more accurate calculation for flow availability, we would recommend putting any measuring device for on-site flow measurement. Because the current gage data is positioned quite far from the actual site, hence in this report we can only do estimates.

As for the technical aspects, we would recommend conducting a feasibility study looking into the possibility of constructing a penstock from the 60 ft. dam to Van Natta dam. Theoretically, this could potentially increase the available average head at the intake to the turbine. Furthermore, the study can also include the scenario where the facility uses two turbines instead of one. Again, this will depend on the flow availability.

The figure of $68,638 for permitting the project given in the cost modeling section of the report is subject to change. In recent years there have been virtually no new small hydro systems permitted in our region, only upgrades to existing small hydro. Therefore, the time and cost required to push the project through the permitting process is relatively unknown and subject to wide variability in cost. As part of future research, it would be beneficial to study the estimation of permitting cost more closely to estimate a range of possible cost outcomes.

Environmental impacts exist but they are not significant for running a small hydropower plant. Impacts of periodic ponding are recommended to be studied.

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