Stream Height and Precipitation Modeling for Flood Event Preparedness on the Landsman Kill

Rhinebeck Village, NY

2022

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Acknowledgements: We would like to acknowledge Professor Richard Feldman, our mentor on this project, and Professor Chris Algozzine who aided us in the process and provided his extensive knowledge and advice. We would also like to thank the 2021 Computer Science Capping group for their work on the Asher Dam Alert System and for setting up and configuring the monitoring equipment in the Fall. Dr. Zion Klos also provided suggestions regarding hydrology measurements and provided his knowledge in the field. Thank you to the 2019, 2020, and 2021 environmental science and computer science capping groups who paved the way for this semester's work, and thank you to Mayor Bassett and Vanessa Bertozzi and everyone involved in the village for giving us the opportunity to continue this project.

Introduction

With climate change effects becoming an increasing issue in the Hudson Valley, the Village of Rhinebeck has experienced increased amounts of flooding, specifically near and around the Landsman Kill and Crystal Lake residential areas. Flooding is one of many examples of climate change disruption that is predicted to worsen significantly, especially without intervention. In the past, residents of the Village of Rhinebeck have expressed upset from the flooding, as it is common and frequent for some residents on the shores of both the Landsman Kill and Crystal Lake. Currently, the Asher Dam serves as the primary flood mitigation method for Crystal Lake, and allows excess water to flow downstream into the Landsman Kill from the lake, lowering flood risk for surrounding residents. However, it is difficult to predict when to open the valves, it is a dangerous task, and flood relief is not guaranteed as shown by Rhinebeck's experiences with Hurricane Irene in 2011 and Sandy in 2012. This semester we witnessed a strong storm event that also caused about 5ft of flooding at the equipment site near the Rhinebeck Highway Department.

This project was a continuation of our studies at Marist College in the Environmental Science Department, using the work of the 2019, 2020, and 2021 capping classes. We used our compilation of knowledge and experience to continue their work and the investigation of modeling and monitoring flooding in the Landsman Kill.

As a continuation of the Fall 2021 Computer Science Capping group's project and the previous Environmental Science capping groups, we found and analyzed local precipitation data, monitored and analyzed stream level data from the LevelVent Logger, started a ratings curve measurement process, re-installed and re-configured the LevelVent Logger, installed and configured the Tipping Bucket, and developed efficient methods to analyze and work with the incoming data from the equipment. All of these achievements, along with the Asher Dam Alert System, will assist the Village of Rhinebeck in predicting flood and stream level patterns with the goal of preventing and mitigating flooding in this area and along the Landsman Kill.

Equipment Installation and Monitoring

The monitoring equipment is located at the Rhinebeck Highway Department behind the building, on a bridge that runs over the Landsman Kill and connects the two Highway Department lots.

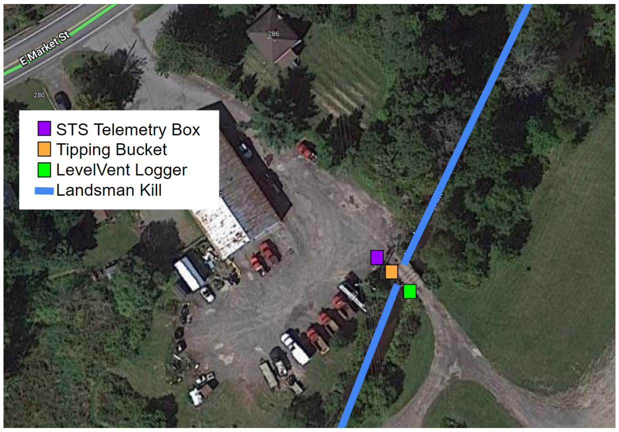

Figure 1. Equipment placement on the Landsman Kill at the Rhinebeck Highway Department.

Figure 2: The equipment installation site during the March 25 site visit, with the tipping bucket (left) and the LevelVent Logger (right).

a. *Solinst LevelVent Logger*

The Solinst LevelVent Logger (Fig. 2) is the primary piece of monitoring equipment established in the Landsman Kill system for this project, gauging stage height of the Landsman Kill based on barometric pressure readings. The LevelVent Logger was installed by the 2021 environmental sciences capping group, as described in subsection

3 of their report *Flood Mitigation and Monitoring on the Landsman Kill and Crystal Lake*. The LevelVent Logger has collected a continuous set of stage height and temperature data with few major interruptions since October 12, 2021. The accuracy of this data, however, was a point of uncertainty up until this capping group's reinstallation of the instrument. Between October 12, 2021 and March 25, 2022 the LevelVent Logger was installed at an unknown height from the stream bed, and the software calculating stage height was compensated with a 6" offset from the bed for every reading. Following reinstallation, the LevelVent Logger was installed <1" from the bed of the stream, eliminating any offset. The LevelVent Logger is also now configured to record stage height in meters, to match the data reporting done by the Asher Dam Alert System.

Figure 3: The Solinst LevelVent Logger taken out of the stream during the March 25 site visit.

b. Tipping Bucket

The collection of precipitation data for the Landsman Kill project has been varied up until the work of this year's capping group, as the Spring 2021 environmental science capping group did not yet have access to the tipping bucket precipitation logger. This logger was installed by the Fall 2021 computer science capping group, but was removed shortly thereafter given that, as an unheated tipping bucket system, readings in freezing conditions are not possible and installation over a period of freezing temperatures risks damage to the components. This year's capping group installed the tipping bucket on March 25, 2022 alongside the LevelVent Logger and programmed the system to record precipitation in centimeters to match the data reporting done by the Asher Dam Alert System. This installation was performed to follow through with the recommendation made by the 2021 environmental science capping group.

Figure 4: The interior mechanism of the tipping bucket during assembly

c. *STS Telemetry Box*

The Solinst Telemetry System (Fig. 5) is located near the tipping bucket on a pole about 5ft from the river edge. The STS sends the water level, temperature, and rainfall data from the field to a Home Station PC, in our case a server in (the basement of) Hancock building at Marist College. Inside the telemetry box itself is the STS system, a Digi Modem that contains a SIM card for data transport, and a battery.

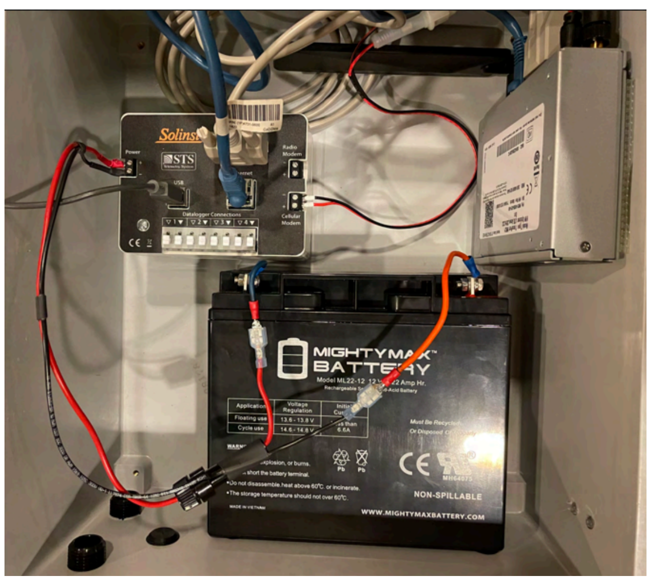

Figure 5: The Telemetry Box

Asher Dam Alert System

The Asher Dam Alert System (ADAS) is a public, online resource reporting the data collected by the monitoring equipment in an accessible manner. The website was put into place by the Fall 2021 computer science capping group and is maintained by Marist computer science students under the instruction of Professor Algozzine. The ADAS reports the stage height and precipitation readings for the last 30 days, as collected by the LevelVent Logger and tipping bucket system, as well as recommendations for flood mitigation measures at Asher Dam based on weather forecasting.

Hydrologic Ratings Curves

A hydrologic ratings curve was developed in order to assess how quickly water moved at different stage heights. Ratings curves are important as they indirectly estimate streamflow volumes over a period of time and are able to provide information on the behavior of streams. Rating curves use measurements of stage height and water velocity to develop a logarithmic extrapolation of the rate of water flow. Rating curves rely on multiple measurements at the same location over a period of time to minimize uncertainty with the ratings curve and therefore should be developed further in the future.

a. *Methods*

The measurements for the rating curve created at the Landsman Kill were taken directly at the site of the LevelVent Logger and Tipping Bucket. Measurements were taken at three different dates over the course of Spring 2022 to develop this relationship.

To obtain the data needed for a rating curve, at each visit, the stream was then divided into two sections, each having relatively uniform velocity. This stream was about 5.7 meters wide, with the slower moving section about 1.5 meters across, and the faster moving section about 3.7 meters across (but this width is variable depending on water level). For both the slower and faster moving sections, depth and width were recorded. For each section, the width was multiplied by depth to find the area, then that value was divided in half, as the shape of most streams are assumed to be triangular shaped. This value found is the cross sectional area (Figure 6a).

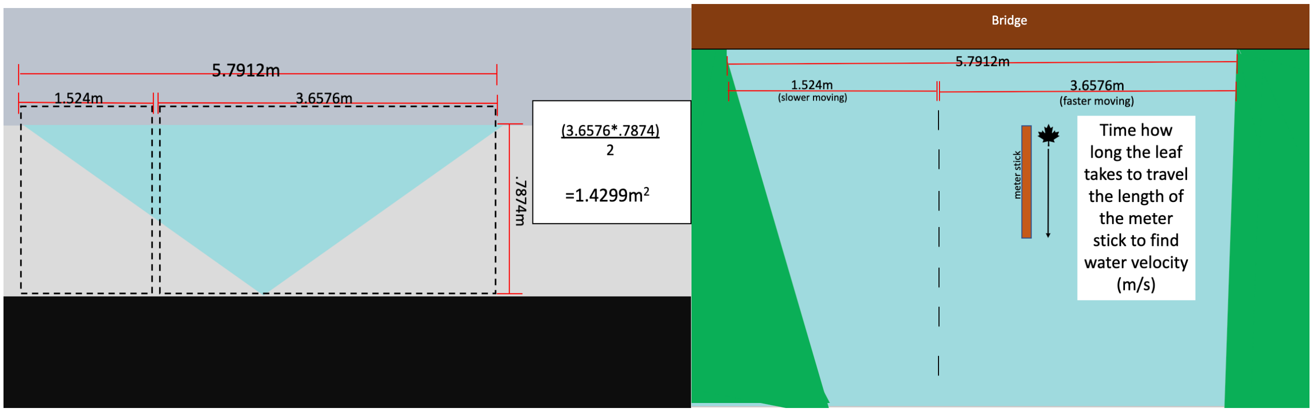

Figure 6a&b: Graphic showing how measurements were taken for cross sectional area and velocity

At both sections, water velocity was taken with the use of a meter stick and any floating object. The meter stick was laid on the stream in the direction of water movement and a floating object (leaves were mostly used) was placed at the top of the meter stick. The floating object was dropped at the top of the meter stick, and the time the object took to move the length of the meter stick was recorded. The average of three trials were taken for both sections of the stream. This provides a measurement of water velocity for each section of the stream (Figure 6b).

As both section 1 and 2 have measurements of water velocity and cross sectional area, volumetric discharge was then calculated. For each section separately, velocity was multiplied by cross sectional area to obtain a volumetric discharge value for each section. Their sum was the volumetric discharge measurement for the stream at that stage height.

b. Results

Collectively, the volumetric discharge values for different stage heights displays a logarithmic relationship of flow (Figure 7). This rating curve uses data from the dates, 3/25/22, 4/1/22, and 4/18/22.

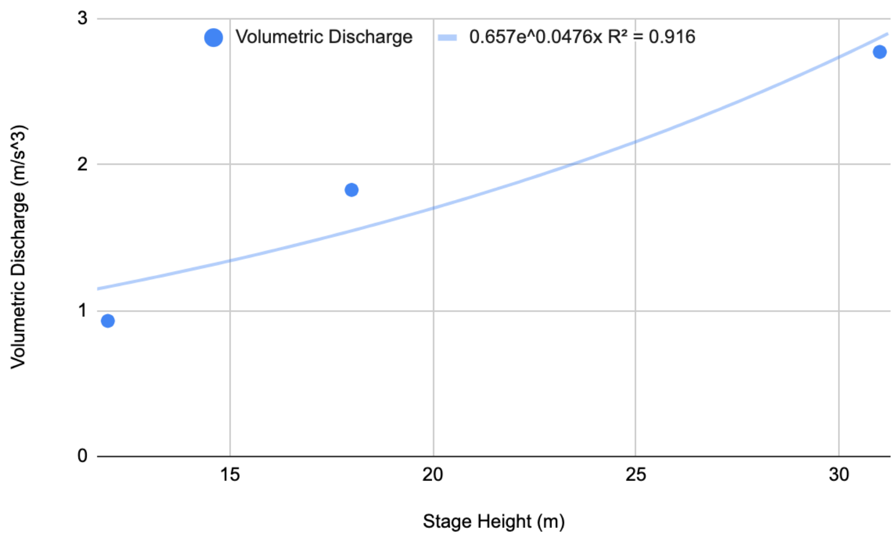

Figure 7: Rating Curve of Stage Height and Volumetric Discharge

Typical stream behavior shows rating curves display a logarithmic relationship. The trendline of this rating curve shows the equation $y=0.657e^{0.0476}x$. The R-squared value is shown to be 0.916, indicating that the rating curve line fits the model very well. However, more data points are required before full behavior of this creek can be assessed.

This rating curve is able to provide some information on how the stream behaves and allows for predictions of flood events. This ratings curve equation will become more refined and can be used along with data from the LevelVent Logger and Asher Dam Alert System to predict how the stream will behave during storm events. As the Asher Dam Alert System displays the stage height of the stream, the equation can be used in order to determine the flow rate of the water passing through as well as how much water is passing through the stream and will accumulate within Crystal Lake.

Rating curves become more effective and consistent with more readings and at different times annually including a variation of seasons. As more data is collected, the rating curve is able to be refined to display a stronger relationship. Rating curves extrapolate from normal stage heights to show possible volumetric discharge values. Since this information is used in predicting flood events, the accuracy of the extrapolated results are essential. USGS recommends a minimum of ten measurements throughout a year. This is to account for seasonal fluctuations in stage heights during storm events and snowmelt. Rating curves also have the ability to change fairly frequently as natural deposition and sediment transport is able to have an effect on volumetric discharge of water within a stream. Rating curves also show increasing uncertainty with increased stage heights as these predictions are hypothesized, emphasizing the need for more measurements. As this rating curve started at the beginning of this spring; further measurements should be taken throughout the year to gain a clearer understanding of how flow behavior changes with seasonal changes to more accurately represent stream behavior and flow rates.

Precipitation vs. Stream Level

At the outset of the Spring 2022 capping group's work on the Landsman Kill Project, precipitation data was not being collected from the tipping bucket. Precipitation data over the period coinciding with stream-level data collection was needed in order to model the precipitation to stage height relationship. For this period, starting with the beginning of our LevelVent Logger data on October 12 and up until the spring reinstallation site visit, precipitation data was sourced from a nearby personal weather station reported through Weather Underground's Weather Station Network. The weather station we located and accessed the data through this service is identified as the KNYRHINE7 station, located approximately 4,000 feet north of the Levelogger installation site at 41.941° N, 73.887° W.

The precipitation and stream level data for the period between October 2021 and February 2022 was organized for analysis prior to the reinstallation and recalibration of the on-site equipment. Over this period over 18,000 stream level readings were calculated into daily averages and were compared to daily precipitation at the KNYRHINE7 station (Figure 8).

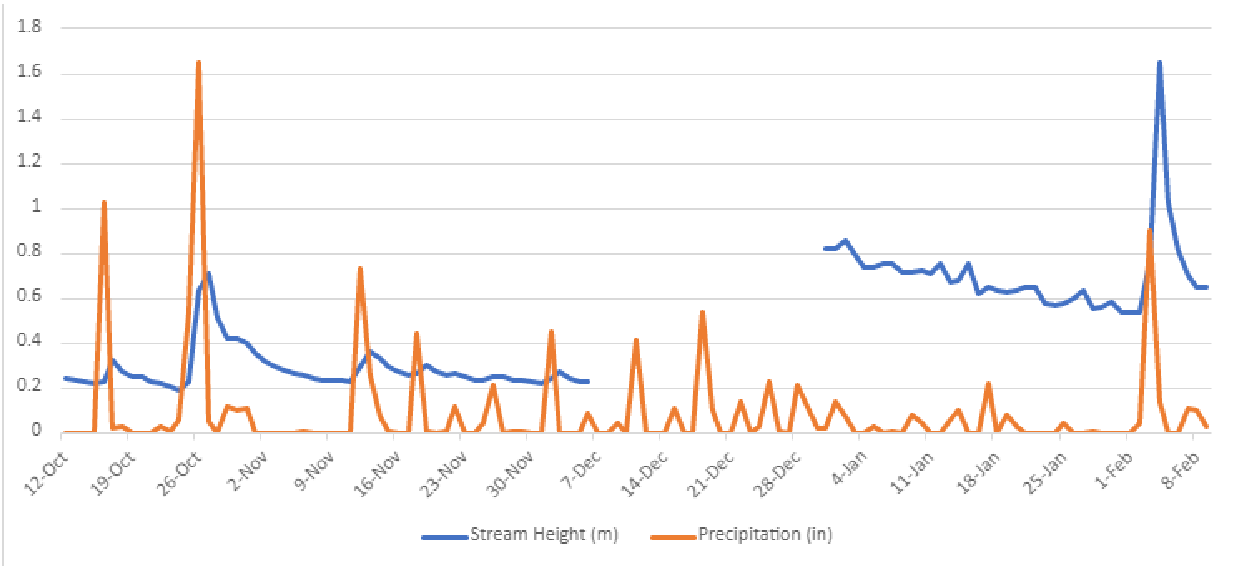

Figure 8: Daily average stream level and daily precipitation, between October 12th, 2021 and February 8th, 2022. Stream level data from December 7th through December 30th was not recorded.

This visualization of the stream level and precipitation relationship is the first for the Landsman Kill project, and represents a key component of the work of this capping group. Precipitation events are easily connected to the corresponding rise in stream level. After taking this broad approach to visualizing the stream level and precipitation relationship, we focused on the period of October 24th through October 29th, the most significant precipitation and stream level events in the data set, illustrated in Figure 9.

The first noteworthy observation is that the peak stream height occurred 18.5 hours after the peak precipitation rate for this event. The second noteworthy observation is that the stream rose 0.6 meters in height from 1.65 inches of precipitation.

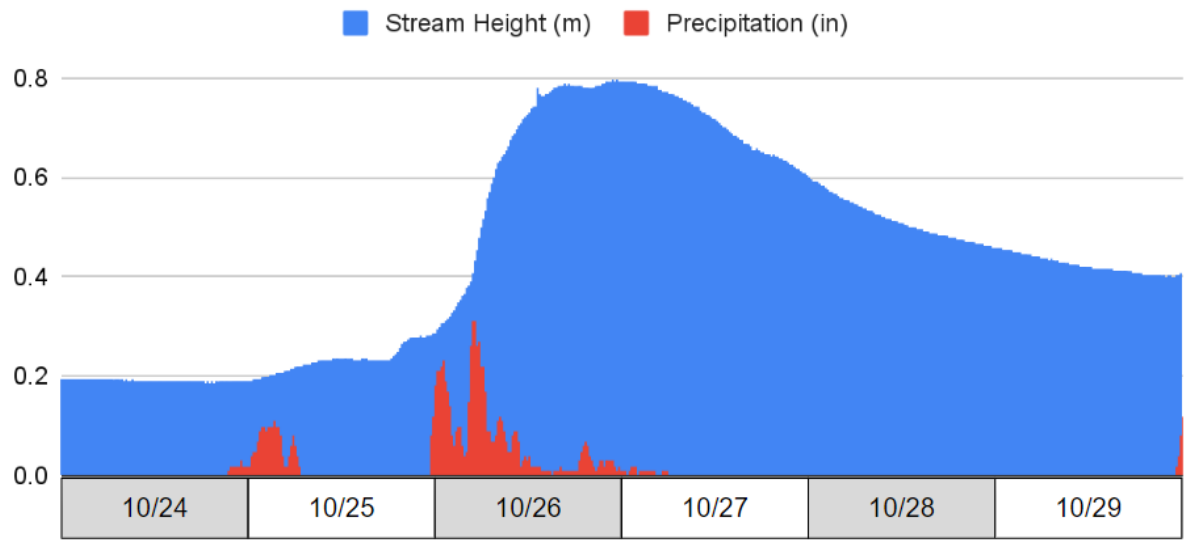

Figure 9: Precipitation rate and stream height graphed over the period of October 24th, 2021 through October 29th, 2021.

Future Plans

a. **Resources For Next Group**

i. **Data from Algozzine**

Over the course of the Spring 2022 capping group's work on the Landsman Kill Project, multiple uploads of data directly from the monitoring site were provided by Professor Algozzine, who has served to bridge the capping groups in this project. This semester's capping group was able to collect these discrete datasets into a spreadsheet that is continuous over the period of data collection as performed by the LevelVent Logger and correlate it to the precipitation data from the KNYRHINE7 weather station. This dataset, including the transformations performed for analysis purposes, will be handed off to the next capping group to work on the Landsman Kill project, ensuring the raw data behind the products of this semester are preserved and maintained into the future.

ii. **Continuing Rating Curve**

As USGS recommends a minimum of ten readings annually, the rating curve should be developed by next year's capping group to gain a greater understanding and a model that has a better fit for predicting flow rates. Continuing rating curve readings throughout the next few years is essential because it will show how the Landsman Kill Creek changes through seasons, will show how the behavior of flood events can change along with climate change, as well as show how natural occurrences like deposition and sedimentation can also affect the creek. Also, after a solid set of data and overall understanding of the behavior of the Landsman Kill Creek, the rating curve can be used to assess how the amount of water is flowing at certain intervals of time, the amount of water entering Crystal Lake at storm events, and could even be used in cooperation with the Asher Dam Alert System.

Conclusion

Each group that has contributed to the larger project has made significant contributions to keep the project moving forward. We are looking forward to seeing how our contributions can aid in laying the groundwork for future projects and help the Village of Rhinebeck better understand and mitigate flooding in the Landsman Kill. Although we ran into some technical roadblocks throughout this semester, our contributions have been substantial and we achieved most of the goals we had set in the beginning of the semester. This report serves as a record of accomplishments made by the Spring 2022 Capping group, in which we were able to find and analyze local precipitation data, monitor and analyze stream level data from the LevelVent Logger, start a ratings curve measurement process, reinstall and reconfigure the LevelVent Logger, install and configure the Tipping Bucket, and develop efficient methods to analyze and work with the incoming data from the equipment. By completing these tasks and continuing this project, we hope the next capping group can improve upon our work and create new resources and insights on flood mitigation and awareness for the Village of Rhinebeck.