Flood Mitigation and Monitoring on the Landsman Kill and Crystal Lake

Rhinebeck Village, NY

2021

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1. Introduction

Climate change has affected every aspect of the planet. With the increasing severity of climate change, there will be more severe storms and as a result infrastructure and communities will suffer the consequences. Flooding is one example of a climate disruption that is going to worsen, especially without intervention. Marist College Environmental Science & Policy capping classes have been determined to assist the Village of Rhinebeck to reduce the flooding problems many of their residents have faced. This project was a culmination of our four years of study at Marist College in the Environmental Science Department, using the work of the 2019 and 2020 capping classes, we continued to investigate modeling, monitoring and mitigation for flooding of the Landsman Kill. Community based learning was the focus for this course, aiming to work together with various community members of the Village of Rhinebeck. Building upon the work of the previous capping groups, we developed a model to calculate the amount of water added to the watershed from a certain rainfall, implemented a LevelVent Logger so that stream height could be measured, created GIS maps to help with land planning, and conducted community outreach efforts including the planning and hosting of a tree planting event surrounding the Landsman Kill. All of these actions will directly contribute to protecting the Village of Rhinebeck from climate disruption, specifically that of flood damage. This report details the semester-long culmination of ten undergraduate students' work and dedication to improving the community of Rhinebeck.

The modeling team worked on creating a detailed formula to determine when to open the Asher Dam valves, to help prevent flooding of some properties. While the watershed proved to be a system far more complex than originally predicted, this group has laid the groundwork for successive classes to continue working on the model with more empirical data. With the help of Scott Minn and other village workers, we were able to conduct a controlled release in which the valves of Asher Dam were opened and the rate of water level decline was determined. This work created the basis for a model that should be worked on for many semesters.

The equipment implementation team worked on determining where the LevelVent Logger should be placed within the Landsman Kill. Through trial implementation at Marist College and examination of the Landsman Kill behind the Village highway garage, we were able to determine the conditions and location needed for the equipment to be protected from damage and readily accessible while also monitoring water levels.

The mitigation, policy, and public outreach group (MiPoPO) used GIS and created maps using software that allowed them to create visuals of various factors that relate to the flooding of the Landsman Kill, focusing mainly on soil drainage classes and impermeable surfaces. Using ArcGIS and ESRI, detailed maps were made of both the watershed and the village. From these maps, the modeling team was able to accurately determine the area of the watershed and the amount of impermeable surfaces in the village. The maps also helped with designating locations of bottlenecks in the Landsman Kill, which may play a significant role in flooding.

The other aspect of the MiPoPO group was community outreach. By reaching out to local residents, this group was able to get personal experiences of someone who has experienced this flooding for over four decades. We also worked in conjunction with the Rhinebeck High School to try to gain access to their weather station data, as well as have high schoolers interested in the project. The past capping groups have looked into green infrastructure as a way to help alleviate flooding risks. This has been shown in various municipalities to be successful and environmentally friendly. This year, over 110 plants were added to the area to provide more stability to the soil and hopefully prevent erosion. By continuing these practices, we hope to inform and intervene with community flooding. This group also organized a Trees for Tribs program in which they planted 110 plants with residents of the Village of Rhinebeck rehabilitating a riparian environment to help with flooding and establishing native vegetation.

We hope that all of our efforts throughout this semester will be helpful for the residents of the Village of Rhinebeck and reduce future flooding issues. The following report goes into more detail about what each group did and how they accomplished their work.

1.2 Flooding History of The Village of Rhinebeck

Many people in the Hudson Valley pride themselves on their environmental stewardship, and the Village of Rhinebeck is no different. With the Landsman Kill running through some of their properties, flooding is common to some of the residents. Asher Dam is located at Crystal Lake and is used as the main defense against upstream flooding. To open the valves for the dam, however, is often dangerous and of unpredictable effect. As shown by Hurricane Irene in 2011 and Superstorm Sandy in 2012, release of water through the dam is not foolproof. Flooding still occurs, especially during heavy storm events. Some residents who live along the creek are all too familiar with flooding of their property. The following quote is from Ralph Roe, a longtime resident of the Village of Rhinebeck:

> *"Several feet of shore have eroded from the north edge of the creek. 3 foot drop offs are left which used to slope to the water. There seems to be more runoff. Vegetation has been washed out on the south edge and not grown back. Recently many large ash trees died on that same edge to ash borers. Parts of the creek are feet shallower; a small island has built up. Deep pools are missing. Flooding has become more dramatic, especially after tropical storm Irene when the water reached to the top of our 4 foot foundation and flooded 5-6 feet deep in our basement. Furnace and appliances there had to be replaced. Although two sump pumps continued to work; we had to evacuate."*

This is just one man's account of an issue that affects over 2,500 residents of the Village of Rhinebeck, though not as drastically as Roe.

2. Modeling of the Landsman Kill

2.1 Modelling of the Landsman Kill and Asher Dam

The capping class of 2019 began creating a hydrologic model to be used to determine how the Asher Dam can be used to successfully prevent flooding. This model was not accurate, but it was useful. To accurately create a model that reflects the conditions of the creek during flood stage, we needed to investigate the relationships between precipitation, infiltration, discharge, overland flows, and hydrologic systems in general. The 2020 capping class create Figure 1 to help map the relationship the model will have to the landscape. While we were unable to determine all these different factors, due to the complexity of the system, we were able to determine the amount of water being added to the watershed during a precipitation event. This report will detail our successes and how this model needs to be developed.

Figure 1: Overview of the Landsman Kill's flow into Crystal Lake (A), Crystal Lake, Asher Dam, and the Landsman Kill outflow outlined (B), photo taken of Asher Dam's overflow in March (C), and a photo taken of discharge of the two large valves into the outflow of the Landsman Kill in March (D).

2.2 Components of Model

The model works by using the area of the watershed to predict the change in level of Crystal Lake. Using expected incoming rainfall (cm), a total volume of water entering the watershed (cm^3) is calculated. From the total volume of water, a change in lake level can be calculated from the area of Crystal Lake. The data we collected included the area of the watershed and lake, amount of impervious surfaces and poorly drained soils in the village (from Figures 2 and 3), and the rate of lake level decline with two valves open.

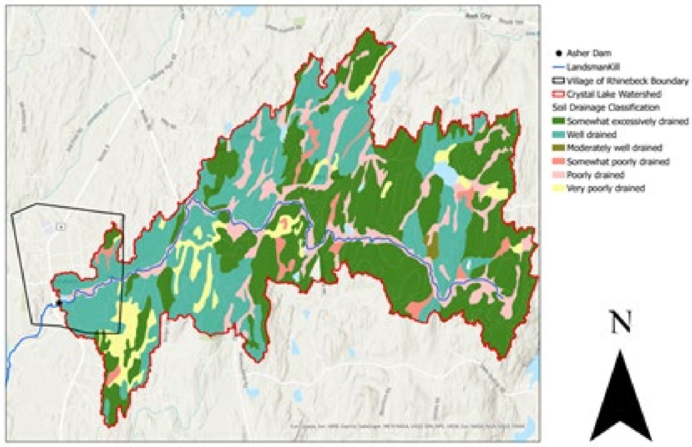

Fig. 2: Crystal Lake Watershed Soil Classification: The soil survey of Dutchess County outlining the drainage types of soils within the Crystal Lake Watershed. The Rhinebeck town boundary has been included to show its intersection with the watershed. Asher dam, which indicates the end of the upper Landsman Kill is displayed inside the Village boundary.

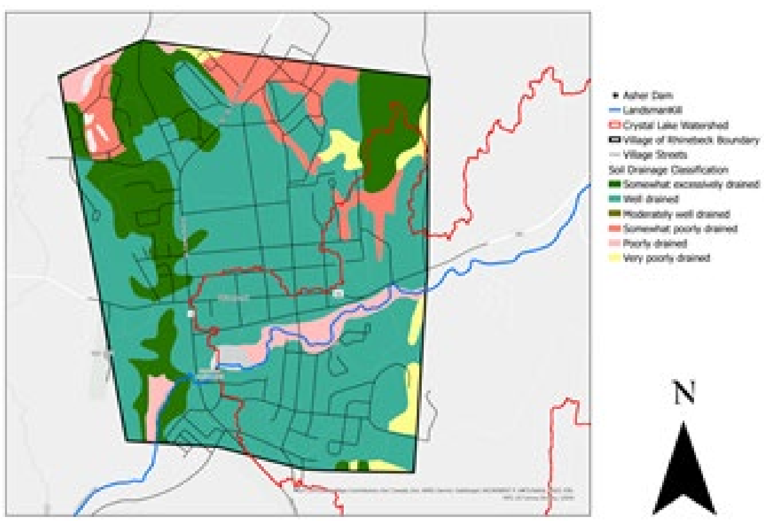

Fig. 3: Village Soil Classification: This map focuses on the soil drainage classification within the Village of Rhinebeck. The soil survey of Dutchess County was trimmed to the Village boundary. The classifications move from somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. The jagged line intersecting the south-eastern part of the Village represents the Crystal Lake Watershed. Asher dam, which indicates the end of the upper Landsman Kill is displayed inside the Village

boundary. Note that most of the well-drained soil in the Village is being developed over. This is indicated by the location of the Village streets in the Village.

2.3 Controlled release and model

On April 16, 2021, we were able to do a controlled release to calculate the rate of lake level decrease. The two smaller valves were opened at 8:41 am and were left open for 80 minutes (Fig. 4). To determine the rate of decrease, we used meter sticks and periodically measured the distance from a drawn pencil mark. Figure 5 shows how we measured the change in water levels.

Fig. 4: Small valves opened during the controlled release.

Fig. 5: Measurements of lake decline taken during the controlled release.

This data was used in the following mathematical model:

$$Volume\ of\ Rainfall = A_w * x$$

$$Change\ in\ Lake\ Level = \frac{Volume\ of\ Rainfall}{A_L}$$

$$Time\ to\ Leave\ Valves\ Open = \frac{Change\ in\ Lake\ Level}{R}$$

The components of the model include A_w, which is the area of the watershed accounting for including impermeable surfaces and poorly drained soils, x, which is the amount of rainfall, A_L, the area of Crystal Lake, and R, which is the rate of lake level decrease with the valves open. The area of the watershed was calculated to be the total area of the watershed, 27.2 km^2 minus the area of excessively drained, well drained, and somewhat well drained soil classes plus the area of impermeable surfaces in the Village of Rhinebeck. The area of the lake was determined using Google Earth Pro. A_w was determined to be $7.9685 \times 10^{10} cm^2$ and A_L was determined to be $2.567 \times 10^{8} cm^2$. As we can see, there is a 10^2 difference between the area of the watershed and Crystal Lake, which could have skewed the results.The rate of lake level decrease during the controlled release was averaged to be 3.12 cm/hr. Testing out the model, we used 1 cm of rainfall and were given a time of 100 hours to open valves, which is not what reality shows.

2.4 Complexity of Watersheds

Because we were unable to accurately account for the watershed interactions, we looked into what factors affect the stream based upon many different factors. Figure 3 below shows the complexity of calculating stream discharge from minimal information.

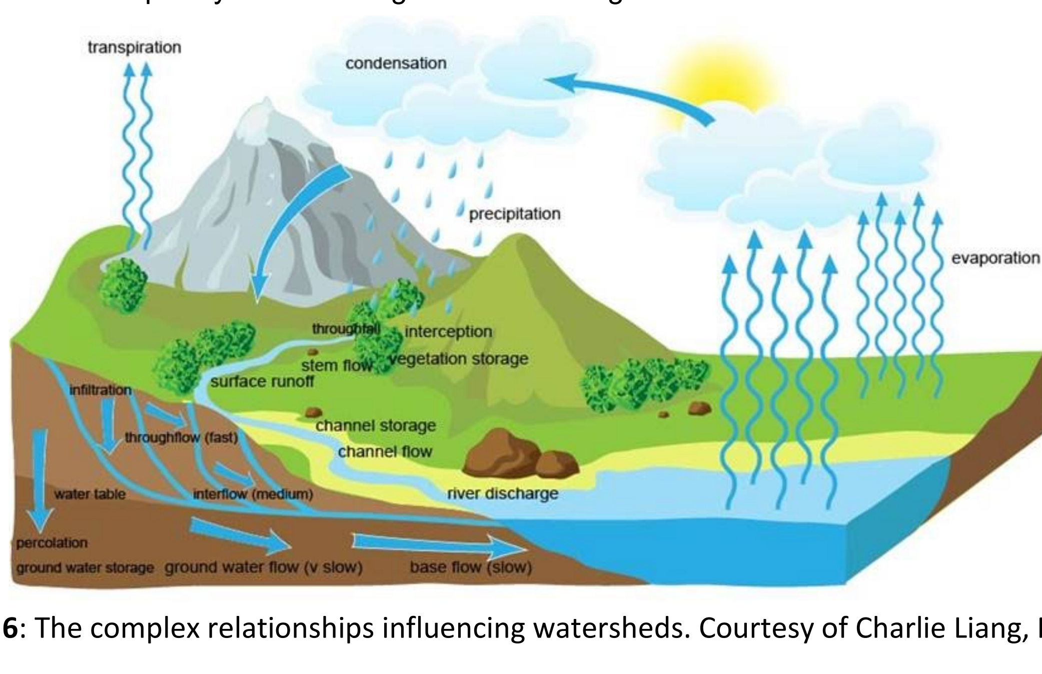

Fig. **6**: The complex relationships influencing watersheds. Courtesy of Charlie Liang, NYC DEP.

Figure 6 shows the complex processes that a watershed undergoes. Groundwater infiltration we suspect plays a major part as to where precipitation is going. Soil moisture is highly variable spatially and temporally, influencing how much precipitation enters surface waters. Evapotranspiration plays a huge role with the hydrologic cycle. This was not something we were able to account for in our model. Land usage is the third factor we were unable to account for. For instance, just upstream of Crystal Lake, there are several bottlenecks including at the S. Parsonage St. bridge that will control the rate of flow into Crystal Lake. The bottlenecks likely influence the stream discharge in ways that may increase the duration of flooding at susceptible properties upstream of Crystal Lake, and may reduce the influence of releasing water from Crystal Lake. While we were able to determine the amount of water added to the watershed for a particular precipitation event, we were unable to account for these watershed factors in determining how much water enters the lake during a rain event.

3. Equipment Installation and Monitoring

3.1 Introduction to the Equipment

Monitoring a stream or any other body of water for flooding requires analysis of the surrounding watershed as well as conditions upstream of areas of concern to classify all potential contributions to flooding and risk. The Landsman Kill has a unique morphology with multiple bottlenecks, impediments (in the form of the dam, sharp bends, and two bridges), sinuosity, and a changing elevation. All of these factors must be analyzed to determine which are contributing to flood risk the most strongly. These factors are of particular concern during storm events and large inputs to the stream, which raise the level of water of the stream and induce flooding at specific locations throughout the floodplain.

In tracking conditions over time that lead to flooding throughout residential areas, the Village of Rhinebeck can characterize the Landsman Kill stream and determine at what stream water levels and precipitation forecasts require opening of the valves of Asher Dam. The LevelVent Logger has been installed at the Village highway garage to determine the level of the stream based on a pressure sensor underwater, and this will help to characterize the morphology of the stream that indicates flooding. Data is currently being collected with the Solinst Application, downloaded as software on a laptop computer. This application allows the user to set collection start and end times and receive the raw data and figure models (Fig. 9) of the pressure and temperature sensors of the LevelVent Logger.

The LevelVent Logger has been paired with a mathematical model in order to quantify precipitation events that lead to increasing stream discharge. It was determined that the water levels collected by the LevelVent Logger somewhat mirrored the use of the model to open the dam valves. Moving forward, it will be important to strengthen the relationship between the data collection and the model by collecting more long term data over a range of conditions within and surrounding the stream that are indicative of flooding and flood risk.

3.2 Installation at Highway Garage

As of April 23rd, 2021 the LevelVent Logger has been installed at the highway garage and has begun collecting data (Figure 7) based upon the prior Capping teams overview (Figure

8). The installation was optimal at this location because it is extremely accessible to connect to the Logger with a USB cable. The data currently cannot be collected wirelessly through the telemetry box because the Village is still deliberating on future purchases of the necessary components to make that aspect operational.

Fig. 7: Current placement of the Level Vent Logger at the Village Highway Garage

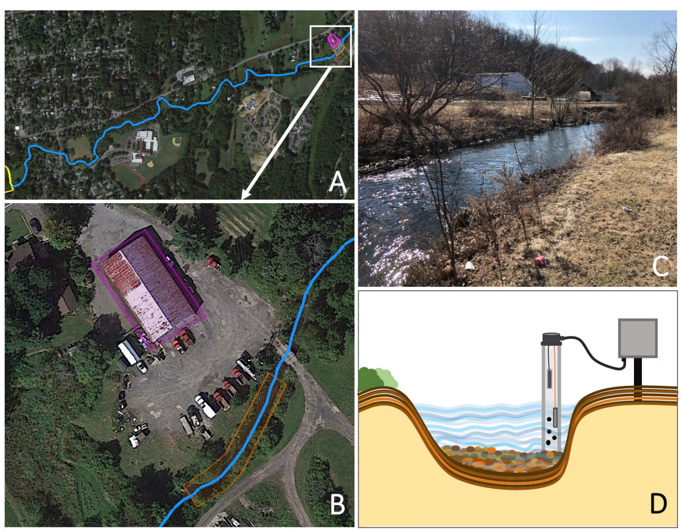

Fig. 8: Overview of the Landsman Kill through the Village of Rhinebeck's highway garage and implementation micro-site boundary (A), aerial close-up of the highway garage and the implementation micro-site (B), a photo taken of the implementation site from the stream bank (C), and a conceptual diagram of the sensors (D).

The highway garage is also approximately one mile upstream of Crystal Lake and the Asher Dam, with the areas of highest risk of flooding contained between the highway garage and Crystal Lake. At this location, the conditions of the site and the data collected by the LevelVent logger has the potential to be vastly different than other areas of the stream experiencing flooding within the Village. However, the LevelVent logger located at the Village highway garage does give a broad visualization of the Landsman Kill and what conditions upstream are most strongly linked to flooding downstream and thereby giving indications of when to open the valves at Asher Dam.

3.3 Data collection

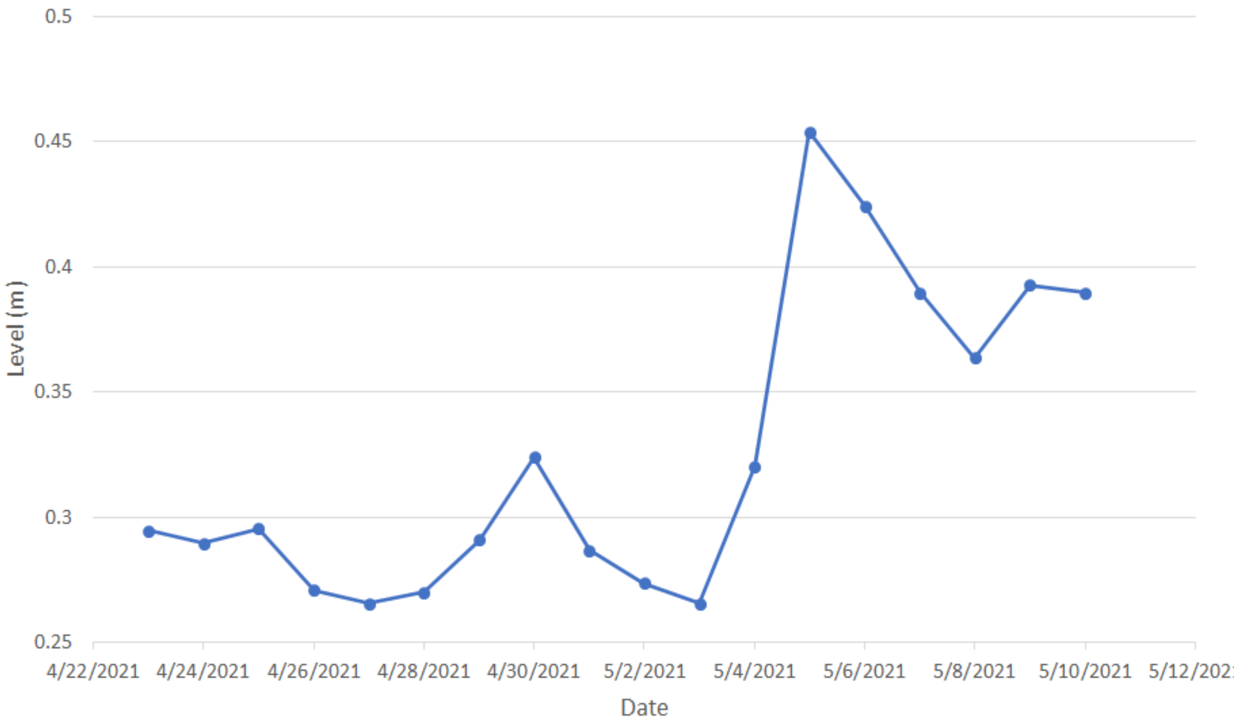

Fig. 9: Shows a sample collection of the water level of the Landsman Kill collected from April 22-May 10, collecting data every hour. Data collection was averaged for each day in order to depict the average level change of the Landsman Kill over the days shown above.

4. Mitigation: Trees for Tribs

4.1 Collaboration

Trees for Tribs is a state program and collaboration between three groups: Marist College, the Village of Rhinebeck, and the Department of Environmental Conservation (DEC). Trees for Tribs is a program that provides the plants, and an abundance of advice on site details, plantings plans, species descriptions, and volunteer advisory. Throughout the process, there was a constant stream of communication between the students organizing the event, the DEC, and Village officials as we worked together towards the planting day. It cannot be overstated how helpful it was to have the Village's Highway Department drill the planting holes ahead of time with an auger.

The DEC played an integral role as the event came closer. With the assistance of Anna Palmer, we were able to fully plan out the details of the site, as well as specific locations of where to plant the trees. She provided a list of species that were received and planted, as well as details of their preferred environment (shade, sun, wet, dry).

4.2 The Day of the Event

On May 2, we had 14 amazing volunteers show up from the Village of Rhinebeck, Marist College, and the Rhinebeck High School Environmental Club. To plant all 110 plants, it took 3 hours with our moderately sized group. Approximately 20 different species of trees and shrubs were planted throughout the day across the primary site (on both sides of the Landsman Kill south of the bridge), and the secondary site (north of the bridge across the Landsman Kill).

4.3 After Care

In the planting proposal, the DEC provided links and an after care plan for the trees and shrubs that were planted. As we are graduating college students that will be moving on, the information regarding care was passed along to Vanessa Bertozzi as the Highway Department will be taking over care of these plants. Should any questions arise, they can contact Anna and Beth from the DEC, or myself (Zak Kircher).

5. GIS Mapping

5.1 Mapping

GIS (geographic information systems) is the process of integrating various datasets in order to form actionable visuals (maps). These datasets are sourced from a multitude of different organizations such as FEMA, USGS, DEC, and many others. These layers can display things such as current flood zones, extent of watersheds, streams, and roads, which are then overlaid onto basemaps. This allows for easy visualization of the issues of interest, as well as many different analyses to answer questions. One of the main maps created was of the permeability of the Village of Rhinebeck to assist the modeling team. This was done by overlaying layers consisting of the streets of the village with a buffer included, as well as a layer containing the building footprints on top of a satellite image of the area of concern.

5.2 Bottlenecks

A focus of the GIS group this year was the influence of potential stream bottlenecks on the flooding of the Landsman Kill. A bottleneck can be considered a choke point, an area in which the flow of water is impeded. This causes a buildup of water upstream from that point, which can have a great impact on the flooding patterns of the creek. The main area of flooding concern consists of 3 known properties (Fig. 14) and there have been two separate potential bottleneck locations pointed out downstream of this area (in the form of two bridges and at least two sharp bends). The first is a series of long meanders where the water is forced to slow down when changing directions. The second one is at house number 168 with its private bridge that runs over the creek as part of the homeowner's driveway. It should be investigated further as to its effect, along with the other bottlenecks, on the flooding of the Landsman Kill.

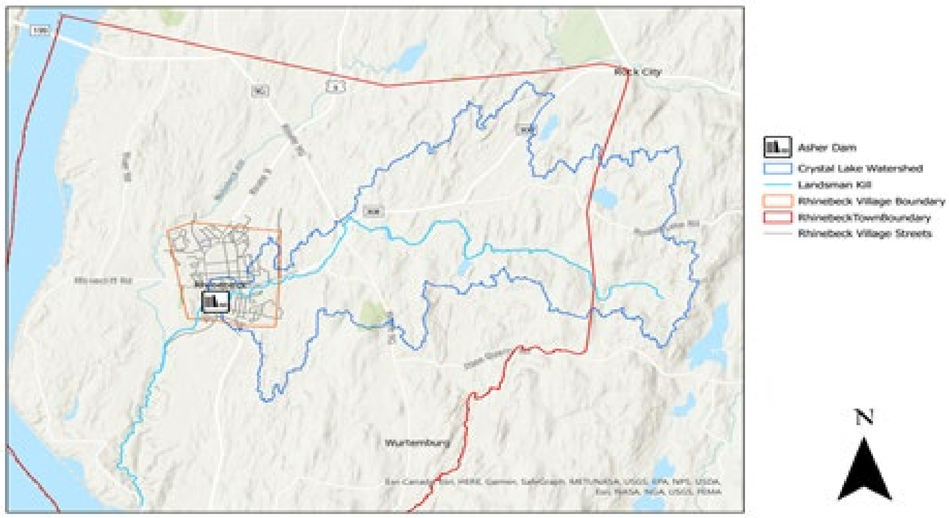

Fig. 10: Crystal Lake Watershed and Landsman Kill tributaries: It focuses primarily on the upper Landsman Kill behind Asher Dam that flows through the Village of Rhinebeck. The Watershed consists primarily of the Upper Landsman Kill and the streams that serve as its primary tributaries. All of which flow into Crystal Lake.

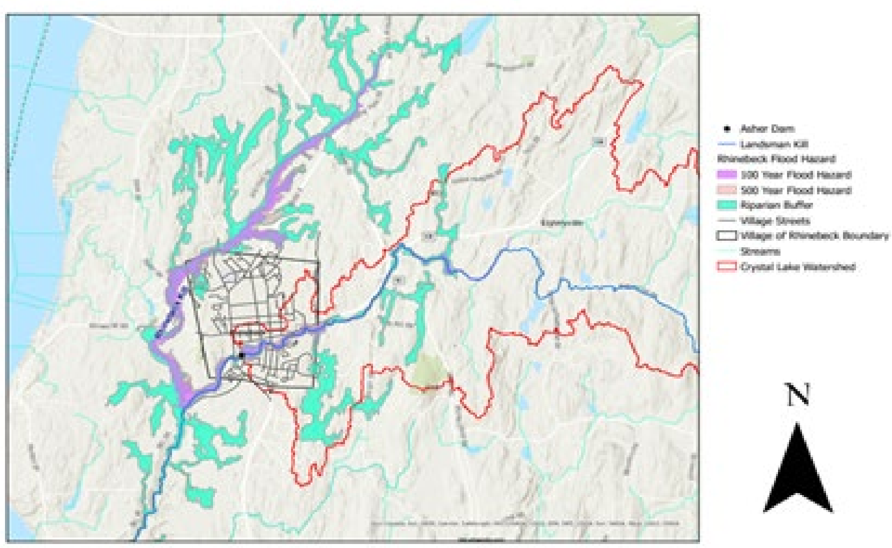

Fig. 11: Riparian Buffers and Flood Hazards: This map focuses on the New York Natural Heritage Program riparian buffers flood hazards intersecting the Village of Rhinebeck, including the Crystal Lake Watershed. Asher Dam, located on the Landsman Kill, is surrounded by a riparian buffer and 100 and 500 year flood hazard.

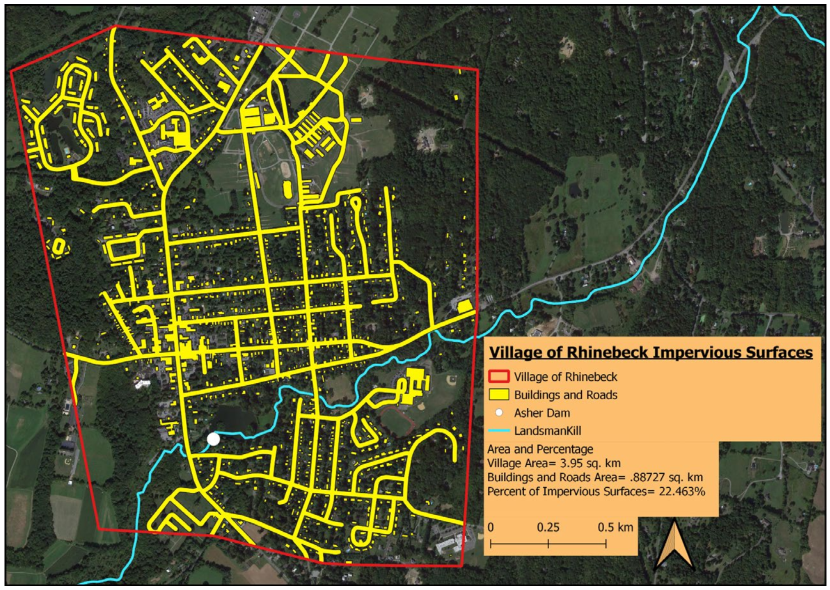

Fig. 12: Impervious Surfaces: This map illustrates the areas in the village of Rhinebeck that are impermeable through visualizing the buildings and roads of the village in yellow over an aerial scan of the area.

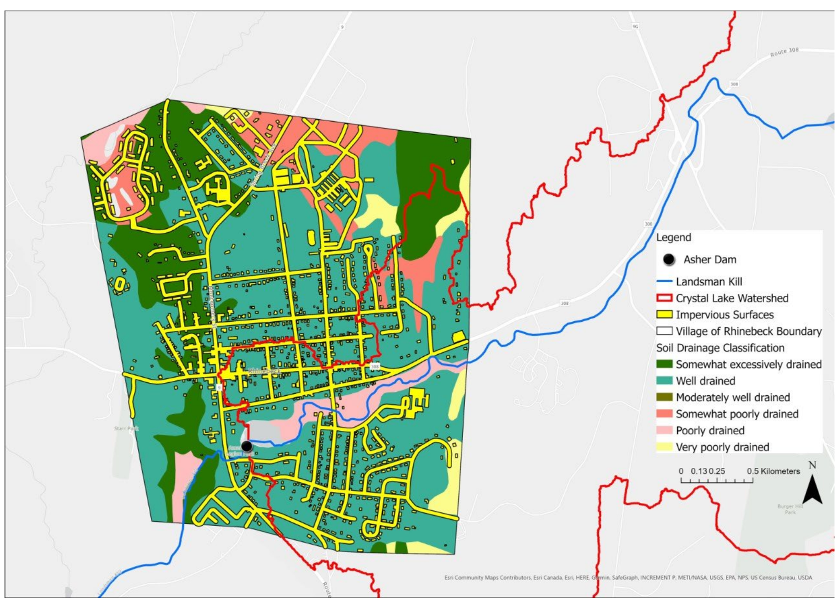

Fig. 13: Impervious Surfaces and Soil Drainage Classification: This map illustrates the impervious surfaces and the soil drainage classifications in the village of Rhinebeck...

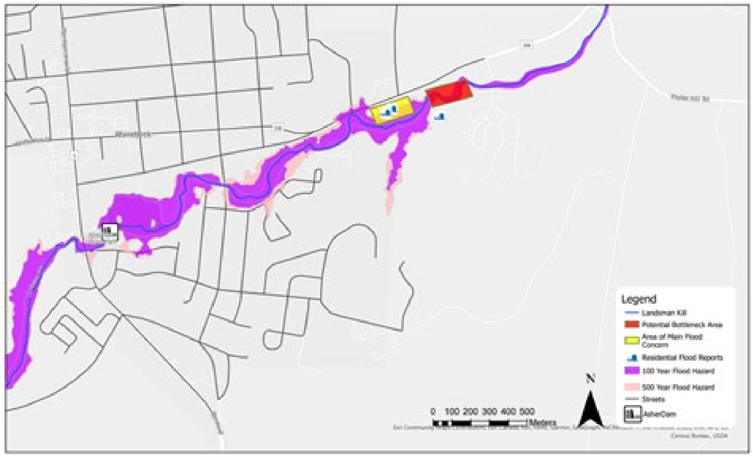

Fig. 14: The Village of Rhinebeck's elevation change of the Landsman Kill as it flows through a bottleneck area with 100 and 500 year flood hazards.

6. Public Outreach

6.1 Weather Station

In hopes of using precipitation data for planning water releases, we aimed to get access to readings from the weather station located at Rhinebeck High School. We contacted Stephen Boucher, the Rhinebeck Central School District Athletic Director. He is the main contact for the weather station because the school district uses it to plan its sporting events and practices. When describing our project, Mr. Boucher was happy to assist us and gave us access to the weather station's data collection. This data only goes back to November 2020 and is not enough for the Modeling Team to utilize; however it is potentially useful in planning the water release at Asher Dam in the future to prevent further flooding of the Landsman Kill by predicting the weather prior to major storm events.

6.2 Affected Citizens

As part of the public outreach effort, contact was made with Ralph Roe, one of the citizens who lives along the Landsman Kill and has been impacted by these flood events for years. Mr. Roe has lived along the Landsman Kill for over forty years. Mr. Roe recalls the erosion of shorelines by several feet on the north edge and sharp three foot drop offs which used to be gentle slopes to the water. On the south edge of the creek the vegetation has been washed out and has never grown back. Some parts of the creek are shallower, an island has built up, and deep pools are missing. Mr. Roe experienced great damage to his home from flooding during Hurricane Irene. Water reached the top of the four foot foundation and flooded between five and six feet of basement, causing appliances to be replaced. Despite two working sump pumps, Mr. Roe had to evacuate his home. Mr. Roe is only one citizen, but he is not the only one Rhinebeck's citizens living in this area being impacted in similar ways.

7. Future Plans

7.1 Discharge Modeling

The next steps for this model are to investigate, using the Level Vent Logger and the discharge from the streams to determine a volumetric amount of water entering the lake. There is a bridge upstream that is causing a lot of flooding so that should be investigated as well. In the future, more Level Vent Loggers, tipping buckets, and should be purchased and hooked up to a cellular device. These should be placed at each of the identified bottlenecks so a detailed ratings curve can be made at each location. Special attention should be paid to the bottleneck closest to Crystal Lake as this will control the flow into the lake from the entire upstream watershed. In the future, real-time rates of flow from this location can be used to make informed decisions as to when the valves of the dam should be opened.

The Level Vent logger should be used along with precipitation data to create a detailed ratings cure. A ratings curve will allow us to equate stream height to volumetric discharge at the location of the Level Vent Logger. There are several bottlenecks and bridges upstream of Crystal Lake where volumetric discharge should also be determined. These bottlenecks and bridges most likely control how much water enters Crystal Lake. Additionally, detailed studies of land usage, impermeable surfaces, and soil classifications and moisture should be investigated downstream of the bottlenecks. This is the only part of the water not accounted for by the Level Vent Logger.

The future of this model is going to have to take place over decades of research. By using decades worth of precipitation data and volumetric discharge, we hope it will accurately represent flooding conditions. This information will tell us how much water goes into Crystal Lake based upon the precipitation. To best understand the dynamics of this particular watershed, a 100 or 500 year flood needs to be analyzed. These events, while rare, are needed for comparison to seasonal conditions. There are also dams upstream, created by people, that will need to be accounted for in the model. To do this, a rating curve needs to be compared with the seasonal conditions and soil characteristics.

7.2 Equipment Implementation

The LevelVent Logger paired with the Rain Logger, which collects input of precipitation when paired with a tipping bucket, both work to fully characterize the inputs and the conditions which are suggestive of flooding. When both of these loggers are connected to the STS Edge telemetry box, data can be tracked wirelessly over a long period of time to establish a level of confidence at which points and levels of water within the stream necesitate valve opening at Asher Dam. The tipping bucket must be attained and paired with the Rain Logger in order to receive precipitation data at the highway garage site. The Rain Logger and tipping bucket will need to be deployed at the highway garage and both will need to be connected to the telemetry box. In addition, the village needs a smartphone to receive wireless data from both loggers after deployment.

We received outside assistance from a local expert on hydrology as well as long-term experience with tipping buckets, Chris Mitchell (NYS DEC). Chris is a knowledgeable contact to have on the project and he is willing to continue assistance, especially with tipping bucket maintenance and usage tutorials. His information is listed within the valuable contacts section of this report.

After consulting with Chris Mitchell, we have determined that the unheated TE-525 tipping bucket supplied by Campbell Scientific would be the most compatible with the Solinst Rain Logger. The Rain Logger has already been purchased by the Village, but to be operational it needs a compatible rain gauge or tipping bucket. The tipping bucket should be purchased by the mayor in the coming fiscal year and supplied to the Capping 2022 group or Professor Chris Algozzine's Computer Science Capping 2021 group for assembly and deployment at the highway garage, alongside the LevelVent Logger.

Once both loggers are successfully deployed and connected to the telemetry box, wireless connection will need to be achieved through cellular connection. The Village will need to purchase a smartphone to connect to the telemetry box through Bluetooth connection to receive wireless data from the two loggers.

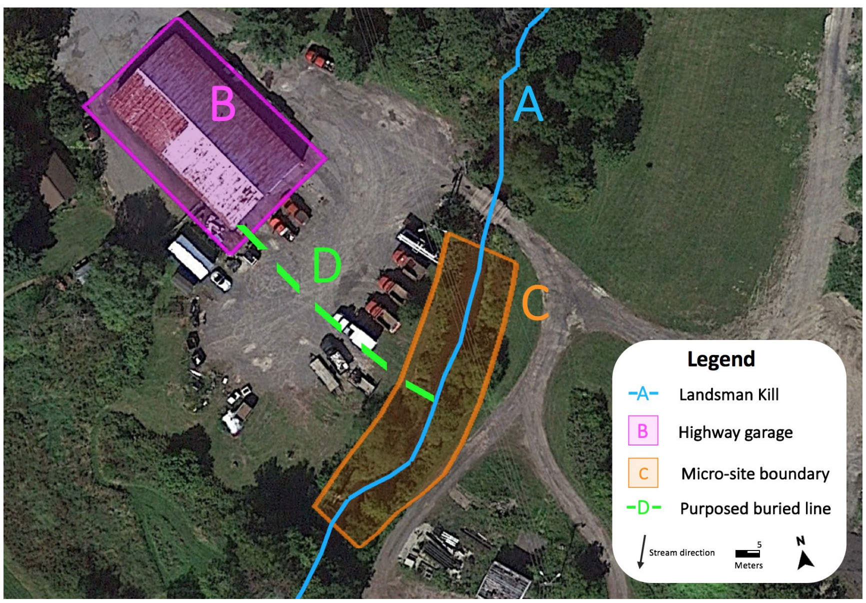

Fig. 15: Previously proposed buried power line from STS Edge to highway garage, created by 2020 Environmental Capping group. Note that the placement of the proposed power line burial has changed since the creation of this map.

In addition, recommendations from Chris suggest the importance of including a barometric pressure sensor at the highway garage site in order to work in conjunction with the LevelVent Logger pressure sensor. The barometric pressure sensor will compensate for the changes in air pressure at times of extreme weather events or localized storms, which will therefore influence the pressure sensors underwater in the LevelVent Logger. It can be conveniently purchased from a variety of scientific equipment providers and Chris can be contacted for suggestions on make and models that are preferred.

Further analysis of the watershed as a whole, taking into account the surrounding impervious surfaces and the lag time of precipitation entering the groundwater system after a large rain event, must be completed in the future to better characterize the Landsman Kill and its multiple flood risks. The aforementioned occurrences have not been considered in previous analyses, and when doing so, could provide information or suggestion that other areas along the Landsman Kill would be better suited for the two loggers in order to collect the most useful data for the areas most at risk for flooding. Because not many other facets of hydrological features of this stream, including bottlenecking, sinuosity of the stream, impervious surfaces, and lag time have not been previously accounted for, it is important that these factors are further researched because they could be contributing to the flooding more so than the opening and closing times of Asher Dam. Further, there should be more research into mitigative work on other streams that have similar morphologies (ie. bottlenecks and sinuosity), and what methods were helpful in decreasing the severity of the flooding in these areas.

7.3 Mitigation, Policy, and Public Outreach

There are three facets to this area of recommendations. The first is in reference to Trees for Tribs. The saplings that were planted will serve a great use in the coming years in flood mitigation, however they must be taken care of in the meantime. They are still young and fragile and must be cared for and protected for approximately the next five years, information on care provided by the DEC to Trustee Bertozzi. After this period of time passes the trees and shrubs should be able to live on their own. The necessity of vegetation within the floodplain is great in order to mitigate erosion and provide structural flood control. However, placement of the vegetation is crucial in comparison to the bottlenecks seen throughout the morphology of the stream. Vegetation placed at the bottlenecks should be avoided so as not to further the bottleneck effect, but planted strategically upstream so as to decrease the severity of the sinuous curves. It would also be beneficial to have experts in bioremediation (potentially those from the Cornell Cooperative or the New York State Department of Environmental Conservation and other organizations that the Village is working with) working together with local government in order to determine the best placement and species of vegetation that would aid the most in mitigating flooding based on plant morphology.

The second part is community involvement. This issue is not one that can be solved overnight by one person, it will require community engagement and support to come to fruition. By continuing to garner public support and utilizing the knowledge and experience of Rhinebeck's citizens, residents will become more involved in their local government and the issues that matter to them. More public efforts such as Trees for Tribs and community outreach will be beneficial in mitigation of the flood impacts.

Finally, the last recommendation is the implementation of green infrastructure, specifically permeable pavement. The Village of Rhinebeck now has access to a number of maps related to the Landsman Kill such as the watershed (Fig. 10), soil classifications (Figs. 2&3), and impervious surfaces in the Village (Fig 12). The implementation of permeable pavement, especially in places where the soil has a high rate of drainage, is incredibly important in reducing flooding. Though this will be a great undertaking on the part of the Village, the benefits that would come from this would help mitigate flooding exponentially.

8. Conclusion

Each team on this project made significant contributions in its own way in order to progress from years past capping groups. We are hopeful that the strides we have made will be helpful in laying the groundwork for the coming groups.

The modeling was able to successfully formulate a mathematical equation that will be helpful in conjunction with the implemented equipment to predict the valve opening at the Asher Dam. This model will be increasingly helpful with a greater quantity of data collected in the coming years.

The equipment and implementation team was able to successfully deploy the Level Vent Logger at the Village highway garage and collect useful preliminary data, showing the change in the water level upstream of Asher Dam. In addition, we were able to identify the best brand and model of a tipping bucket that should be purchased by the village in the coming fiscal year. We are hopeful that these two loggers will work together to collect long-term data that aids in determining imminent flooding and potential opening and closing of Asher Dam.

The mitigation, public policy, and outreach was extremely successful in finishing several aspects of the project that have been lingering for the past two years. The GIS maps will be extremely helpful in future land management and planning in terms of green infrastructure, and in conjunction with the riparian vegetation planted by the Trees for Tribs program, the Village has a multitude of new resources to monitor and grow. In addition, this team was able to contact residents and acquire first hand accounts of how the problem of flooding impacts real people. These accounts will be helpful moving forward in gaining further support for mitigation.

The Village Board, including Mayor Gary Bassett and Trustee Vanessa Bertozzi, have been very receptive to our work and seem eager to continue working on this issue that impacts a number of their citizens. The flooding of the Landsman Kill has garnered much more public support and is now within the public eye of the Village of Rhinebeck. This report serves as a record of accomplishments made by the 2021 capping group, in which we were able to further describe the entire watershed through GIS mapping, monitor the Landsman Kill through the deployment of the Level Vent Logger, assist in finalizing the mitigation project Trees for Tribs, and provide further information and recommendations for others involved in this project. By continuing this project, we hope the next environmental science capping group can improve upon our work and create new insights in order to aid the residents of the Village who have been suffering the effects of flooding on their properties for far too long.

9. Data Documentation

- **Maintaining Agency:** NYS GIS Program
    - Website: NYS GIS Clearinghouse
    - URL: http://gis.ny.gov
  - **Dataset**: NYS Civil Boundaries (includes NYS County Boundaries - Shoreline Version)
  - **File Name**: NYS_Civil_Boundaries.shp.zip
  - **Date Accessed**: February 25, 2020
- **Maintaining Agency:** USDA Natural Resource Conservation Service
    - **Website:** Soils for Dutchess County
    - **URL**: http://websoilsurvey.nrcs.usda.gov/app/
  - **Dataset**: Soils
  - **File Name**: wss_SSA_NY027_solidb_US_2003_[2018-09-18].zip
  - **Date Accessed:** February 10, 2020
- **Maintaining Agency:** NYS GIS Program
    - **Website:** NYS GIS Clearinghouse
    - **URL:** http://gis.ny.gov
  - **Dataset:** NYS Streets
  - **File Name:** streets_shp.zip
  - **Date Accessed:** February 12, 2020
- **Maintaining Agency**: Department of Environmental Conservation
    - Website: NYS GIS Clearinghouse
    - URL: http://gis.ny.gov

- **Dataset:** Dams
- **File Name:** nysdec_dams.zip
- **Date Accessed:** September 8, 2018

- **Maintaining Agency**: Department of Environmental Conservation
    - **Website**: New York Natural Heritage Program
    - **URL**: https://nynhp.org/treesfortribsny
  - **Dataset**: Riparian Buffer
  - **File Name**: Buffer_Shapefile.zip
  - **Date Accessed**: February 10, 2020
- **Maintaining Agency**: Federal Emergency Management Agency (FEMA)
    - **Website**: FEMA Flood Map Service Center
    - **URL**: https://msc.fema.gov/portal/advanceSearch#searchresultsanchor
  - **Dataset**: NFHL DataCounty (1)
  - **File Name**: 36027C_20160712 (1).zip
  - **Date Accessed**: September 9, 2018
- **Maintaining Agency:** New York State Department of Environmental Conservation
    - Website: NYS GIS Clearinghouse
    - **URL:** http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1118
  - **Dataset:** Water Quality Classification
  - **Filename:** nysdec_wtrcls
  - **Date Accessed:** September 12, 2017
- **Maintaining Agency:** TBA
    - Website:
    - **URL:**

- **Dataset:** Buildings Blueprints
- **Filename:**
- **Date Accessed:** May 1, 2021

10. Valuable Contacts

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