Hydro Citizens

Requirements Specification Document

Version 4

December 13, 2017

Sponsor:
Dr. Benjamin L. Ruddell

Team Mentor:
Dr. Eck Doerry

Team Members:
Luis Arroyo
Logan Brewer
Ryan Ladwig
Kelli Ruddy

Accepted as baseline requirements for the project:

For the client: ______________________________ ______________________________
Signature Date

For the team: ______________________________ ______________________________
Signature Date

1. Introduction

Our waterways and wetlands have an important role in our everyday lives and the more knowledge we have about them, the better. Hydrological data is water height data, groundwater modeling, and stage gauging of rivers, reservoirs, lakes and other waterways. This data is important when it comes to flood prediction/prevention, water management, and public education/knowledge. If we have more data, we can more fully understand how rainfall fluctuation affects a specific area. Flooding is one of the most destructive aspects of increased amounts of rainfall and can result in loss of homes and even death. Although we can never fully predict how severe a flood will be, we can better understand how increased rainfall will affect that area if we have the data. Another importance of hydrological data collection has to do with water management. Water management deals with measuring river flow and runoff as well as how that relates to infrastructure design. Infrastructure design refers to how roads,neighborhoods and even cities are built to handle increased amounts of rainfall. Public education/knowledge is directly connected to water management in that if a community more fully understands how increased amounts of rainfall could affect their area, this may influence how they vote for public officials i.e. they may be more likely to vote for someone who understands why this data collection and design is so important. Right now the United States Geological Survey (USGS) collects most of the hydrological data in the U.S., but the problem with this is that they only collect data from large waterways and reservoirs. This is because the gauges they set up to collect this data are extremely expensive so they usually do not collect data on smaller waterways or ephemeral rivers, which are rivers without flowing water all the time. We need to understand how rainfall fluctuation affects certain areas not gauged by USGS. Without this knowledge, certain areas could be negatively affected by increased amounts of rainfall. Having more data is also important because then we can more fully educate the public on hydrological information and its importance. Having the public understand why we need to continue collecting this type of data is important, especially when it comes to our solution.

Figure 1.1 *- Our gauging solution*

Dr. Benjamin Ruddell is our sponsor for this project. He specializes in the water and climate sector with a focus on hydrologly and data collection. He has noticed the lack of data points on smaller rivers and waterways and so with a colleague he created the idea for a citizen science web application for hydrology reporting. The idea is to get the community involved in the data collection process.

Our solution to this lack of data is to develop a mobile application that allows users to take pictures of a gauge which, unlike USGS's expensive equipment, will be a PVC pipe with red and white stripes as seen in Figure 1.1. There will also be a wooden post at each gauging location.

The wooden post will have a QR code attached that can be used to uniquely identify the site and to provide more information to passersby. Once the user has taken a photo of the PVC pipe, our image processing algorithm will add a horizontal line to where it believes the water height is in the photo. The user may adjust this line to get a more accurate water level.

Figure 1.2 is showcasing how the application will basically work. The user will submit a photo on their phone which will then be sent to a server and local database to be processed.

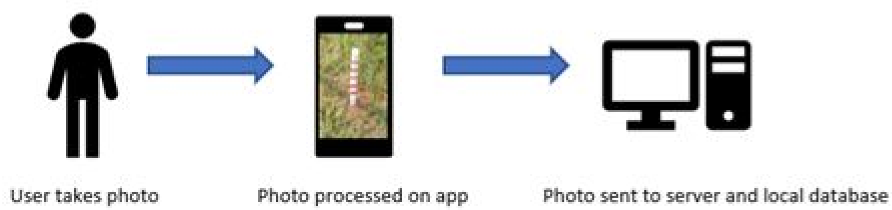

Figure 1.2

We will use the user's phone's geolocation in order to plot exactly where the photo has been taken and this location will be stored with the photo upon submission. From there we will store the image, location, and water height data in our local database. We will then take the water height data and send this to our local HydroServer and then it will be joined with the main national HydroServer which is where a lot of the national hydrological data is stored. Once the user has uploaded their information, we will give them feedback on their submission, which may include previous data points collected at that location or a graph showing how their contribution helps this data crisis. One key feature that separates our application from anything else will be the offline capabilities. Some of these gauges and waterways will be in areas without cell service or internet and this is where our application comes in. The user will be able to take a photo and store the information that goes along with the photo on our application and will be ready for submission when they are back in an area with coverage. The user should still be able to receive some confirmation that would have been stored on the application just for this.

2. Problem Statement

The United States Geological Survey is the main contributor for hydrological data. They collect gauge height and streamflow from large lakes, rivers and reservoirs. This data is collected from large water gauges, seen in figure 2.1, every 15 to 60 minutes. The data is then stored onsite and sent to a USGS location for analyzing every 1 to 4 hours. The onsite data is sent via telephone, radio or satellites. This data can be available online within minutes or after a full day of data collection, the information is transformed into a daily summary and released online for the public. The daily summary can be a graph showing *stage* in terms of cubic feet per second. The user can also view the summary of all available data for that specific site which may consist of more graphs. To access the daily summary takes a minimum of 6 clicks to view. Another problem with the current system is the funding to maintain these gauges. To install and maintain a USGS water gauge is around $14,000 - $16,000.

Figure 2.1 *- USGS water gauge at Salmon Falls Creek located in Nevada*

Since 2013, there have been 18 discontinued water gauges due to lack of funding and there are currently 9 water gauges in danger because funding is unlikely to come. The funding comes from Federal, State, Tribal, local agencies and funds specifically appropriated to the USGS. More efforts are going into exploring new ways to get funding but until this happens, more and more gauges will be discontinued. Without these gauges, certain regions will suffer because no information on their local waterways will be analyzed. The problem with the USGS's data collection method, although extremely accurate due to the equipment, is the cost and scarcity of data points.These water gauges are expensive to maintain and install and will result in fewer data points if they cannot get funded and must be shut down. If lack of funding continues, our hydrological data collection will begin to deplete. Also, USGS only collects data at larger waterways due to the cost of a water gauge. Ephemeral rivers and smaller waterways do not get data collected on them so we do not have a lot of knowledge on how these waterways act in a situation of increased rainfall. The more data we have the better we can prepare in the event of a flood.

The daily summary given to users is not very effective in that it takes at least 6 clicks to get to a graph and summary of a specific gauge. The graph is not descriptive and often times difficult to understand for a person not very familiar with hydrologic terms. This makes it difficult for the community to find interest in the collection of hydrologic data. We hope through our solution to provide more data points on smaller waterways, waterways where there is a discontinued USGS water gauge and get the general public more involved in the collection process.

3. Solution Vision

Now that we know the problems, we are going to talk about how we are going to solve these problems. We are going to build a mobile app that will allow the users of our application to collect this hydrological data from all of the small waterways that USGS is unable to collect data from. Dr. Ruddell's currently existing web application is in place and being used to collect this data.We will be majorly improving this process and allowing the user to quickly and efficiently collect this data.

Figure 3.1- Example Layout

Some specific features our solution will include are:

- An efficient and easy to use interface that allows the user the get what they want quickly as seen in figure 3.1.
- A very easy to obtain and easy to understand graph showing the user the data.
- An inexpensive way to collect data from these small and ephemeral waterways.

We will be implementing this in a multitude of ways. The main data that we are going to be collecting is hydrological data, which will include:

- the location the data was collected
- the date and time the data was collected
- the height of the water at the time is was collected

This data will be used to educate the public on how rainfall affects runoff in smaller waterways. It will also be used to fill missing data points for smaller waterways and ephemeral streams where data isn't currently being collected. Our local database will be storing the images, water depth, location, and date for all the data entries. From there, we will take the hydrologic information and send it to our local HydroServer. Finally, all the data from our local HydroServer will be federated to the national HydroServer where it can be used to fill in gaps in the National Water Model.

This will be a large improvement for our client. Instead of his current web-based version, this mobile application can more easily be distributed to more people, as well as increase the speed at which these people can collect this much needed data. We will also be able to teach the public about hydrologic information in a much easier manner with this mobile application. They will be able to see not only their collected data, but how that data is needed in today's society.

When looking at all of the possible solutions, we had several mobile application frameworks, databases, computer vision and data visualization tools that we can choose from. After performing an initial feasibility study, we have decided to begin initially with Meteor, D3.js, OpenCV, and MongoDB. However these are subject to change if they prove to be unusable in our project. Our solution will enable users to collect this very important hydrologic data very quickly and efficiently around the entire world.

4. Project Requirements

4.1 Functional Requirements

4.1.1 Secure Individualized User Management System

The sponsor for this project has expressed the need to integrate various types of user accounts into systems. This section details the individual requirements for each type of user account.

4.1.1.1 User Accounts

A user can have an account which is not required but gives more access to the user.

4.1.1.1.1 Supports unlimited authenticated user accounts.

4.1.1.1.2 Users have option to create an account.

4.1.1.1.3 Provide access to user account registration via website.

4.1.1.1.4 User can submit a photo of a water gauge.

4.1.1.1.5 User can add notes and data on their photo before submission.

4.1.1.1.6 User can view past submissions.

4.1.1.1.7 Users can log into their account.

4.1.1.1.8 Users can log out of their account.

4.1.1.1.9 Users can interact with other users who have contributed to the same gauges.

4.1.1.2 User Profiles

A user has access to edit their profile if they decide to create an account. A profile will include a notification center for users.

4.1.1.2.1 Users can update the frequency and type of notifications from application.

4.1.1.2.2 Users can update their email preferences from application.

4.1.1.3 Guest Accounts

A user may be a guest which means they choose not to create an account but would still like to submit photos.

4.1.1.2.1 A guest can submit a stage reading and photo of a water gauge.

4.1.1.2.2 A guest can add notes and data such as notes, user defined stage on their photo before submission.

4.1.1.4 Water Gauge Manager Accounts

A user may have a water gauge manager account if they set up a water gauge.

4.1.1.4.1 This account can register as a water gauge manager.

4.1.1.4.2 Provide access to water gauge manager account registration via website

4.1.1.4.3 This account can create a new water gauge.

4.1.1.4.4 This account can view observations made at their water gauge.

4.1.1.4.5 This account can edit their water gauge.

4.1.1.4.5.1 This account can change the name of the water gauge.

4.1.1.4.5.2 This account can edit notes associated with the water gauge.

4.1.1.4.6 Water gauge manager users can log into their account.

4.1.1.4.7 Water gauge manager users can log out of their account.

4.1.1.5 System Administrator Accounts

A system administrator account has all the same access every account type listed above has with more administrator features.

4.1.1.5.1 Give this access to Dr. Ruddell and our team.

4.1.1.5.2 This account can view all water gauges in system.

4.1.1.5.3 This account can create a new water gauge.

4.1.1.5.4 This account can view data collected from all water gauges in the system.

4.1.1.5.5 This account can edit any water gauge in the system.
4.1.1.5.6 This account can delete any water gauge in the system.
4.1.1.4.7 System administrator can log in to their account.
4.1.1.4.8 System administrator can log out of their account.

4.1.2 Secure Database System

One of the current issues with Dr. Ruddell's existing system is that the HydroServer databases are unable to store photos. As part of our final project, we will provide a database that will be able to store both the data that will need to be later transferred to a HydroServer and pictures taken of water gauges.

4.1.2.1 Store user or guest submitted photos.
4.1.2.2 Store user or guest submitted notes.
4.1.2.3 Store user or guest submitted water depth data.
4.1.2.4 Store latitude and longitude of where photo was taken from.
4.1.2.5 Store date and time reading.
4.1.2.6 Store user name.
4.1.2.7 Store user settings preferences.
4.1.2.8 Store user account type.
4.1.2.9 Store all water gauge locations and metadata such as conditions, weather.

4.1.3 Data Visualization Creation

One of the key features of the mobile application that we will be developing for the project sponsor is data visualization. The application should be able to plot user-collected data against data reported by the National Water Model and National Weather Service precipitation data. The following low-level requirements fulfill and support this requirement.

4.1.3.1 Create HydroGraph

A HydroGraph should help the user to understand their submitted data and its relation to the water model.

4.1.3.1.1 All system users can see a HydroGraph plotting their collected data.
4.1.3.1.2 All system users can see a HydroGraph plotting all collected data from any water gauge.
4.1.3.1.3 All system users can see a HydroGraph of data from the stage of the National Water Model for this location of gauge.

4.1.3.1.4 All system users can see a HydroGraph of data from the precipitation of the National Weather Service for this location of gauge.

4.1.3.1.5 All system users can see a HydroGraph comparing their data to data from the National Water Model.

4.1.3.1.6 All system users can see a HydroGraph comparing their data to data from the National Water Model.

4.1.3.1.7 Can see user-defined stages plotted, e.g. flood stage.

4.1.3.1.8 Can see National Weather Service or National Water Model stages, e.g. official flood stage.

4.1.4 Geolocation

Dr. Ruddell has expressed that users should receive notifications when they are close to water gauges that are registered within the Mobile Hydrology system. Users should also be locate able to locate the water gauges by looking at a digital map. Lastly, water gauges should be able to be uniquely identified by their location. The low-level requirements in this section support the requirement of geolocation.

4.1.4.1 All System Users

All users have access to view the map and as well as where the locate where the water gauges are located.

4.1.4.1.1 Users can view the map.

4.1.4.1.2 Users can view the locations of the individual water gauges.

4.1.4.1.3 Users can view their reported location.

4.1.4.2 Notifications

A registered user will be able to receive notifications when they are within the range of a water gauge.

4.1.4.2.1 User can receive notifications when they are at a certain distance of the water gauge.

4.1.4.3 QR Code

A user will have the option to take a picture of the QR Code and we can determine an accurate reading of the location site.

4.1.4.3.1 QR Code can store the longitude and latitude of the location site.

4.1.4.3.2 QR Code can match the location site by storing the URL.

4.1.4 Computer Vision

The mobile application that we will be developing for the project sponsor will need to record water height data that is taken by analyzing images of a striped PVC pole that is placed within a stream or other body of water. The following low level requirements support this functional requirement.

4.1.4.1 The mobile application will use Computer Vision algorithms provided by the client to measure the water height at each water gauge.

4.1.4.1.1 The algorithms will not require internet access to function.

4.1.4.1.1.1 Algorithms must run natively on a mobile phone.

4.1.4.1.1.1.1 At a minimum, the algorithms will run on Android phones (see requirement 4.4.1), however the team will work towards developing for both iOS and Android.

4.1.4.1.2 The mobile application will display its guess of where the water line is to the user.

4.1.4.1.2.1 The user must be able to adjust the algorithms' guess of the water level

4.1.4.1.2.2 The mobile application will store and submit a finalized measurement of the water level after the user has verified the water line.

4.1.6 Gamification Implementation

The client has expressed that our mobile application should contain a set of features that will help retain user interest in our application. While Dr. Ruddell has given us some degree of creative freedom over the methods that we will use to engage users, we will be providing the below functionality regarding this requirement, at a minimum.

4.1.6.1 Notifications

A registered user will be able to get notifications in order to retain interest in data collection.

4.1.6.1.1 User will receive push notifications when it is going to rain.

4.1.6.1.2 User will receive push notifications when a gauge they have read before is missing too many data points.

4.1.6.1.3 User will receive push notifications if the National Weather Service issues a warning for this location.

4.1.6.1.4 User will receive push notifications when the stage passes a threshold, e.g. flood stage.

4.2 Performance Requirements

4.2.1 A user account should be able to register for an account in less than five minutes.

4.2.2 A water gauge manager account should be able to register for an account in less than five minutes.

4.2.3 A user account should be able to log into their account in less than ten seconds.

4.2.4 A water gauge manager account should be able to log into their account in less than ten seconds.

4.2.5 A water gauge manager account should be able to log into their account in less than ten seconds.

4.2.6 A page on the application should take no longer than 10 seconds to load.

4.2.7 Users will receive a HydroGraph in less than 7 seconds, but ideally less than 3 seconds.

4.2.8 Map of the water gauge locations will load in less than 10 seconds with stable Internet connection.

4.2.9 User will receive push notifications when they are within 300 meters of a water gauge.

4.2.10 User will receive push notifications when they haven’t collected data within 30 days.

4.2.11 After a user has taken and submitted a picture of the striped PVC pole, the algorithms' initial measurement of the waterline will be displayed to the user within 20 seconds, but ideally within 10 seconds.
4.2.12 After the user has submitted their adjustments to the waterline measurement on the PVC pole, the final measurement of the waterline will be complete within 10 seconds, but ideally within 3 seconds.

4.3 Documentation Requirements

Dr. Benjamin Ruddell expressed that he had a requirement of "Evergreening". Dr. Ruddell has informed our team that no more than a small group of individuals will be updating and maintaining our final project. The project should be as low maintenance as possible so that such a team will be able to provide long-term maintenance for the mobile application once we have delivered our final product. The following requirements detail the non-code documentation that we will be delivering to Dr. Ruddell as part of the final product.

4.3.1 The team will provide a document to the client that will describe the functionality of the final product

4.3.1.1 This document will list each of the external services that the mobile application relies on.
4.3.1.2 This document will describe the role of each of these services within our project.
4.3.1.3 This document will describe the expected/required inputs and outputs of each service.
4.3.1.4 This document will describe and outline how all parts of the project communicate with each other.

4.3.2 The team will provide code comments for all coded functions and classes.

4.4 Environmental Requirements

The client has requested that we develop a mobile application that will not only fulfill the functional requirements as detailed above, but will also communicate with existing services that are currently maintained by the client.

4.4.1 Ideally, the team will aim to develop the application for both Android and iOS mobile devices, however, at a minimum, the application will run on the following platforms:

4.4.1.1 Android mobile phones

4.4.1.1.1 Android versions 4.4 up to, and including, 8.0

4.4.2 The system will connect to a project database that will store collected data and pictures.

4.4.3 The project database will connect to a HydroServer to report hydrological data to the CUAHSI Water Data Center.

4.4.4 The system will connect to a web server for user logins.

4.4.5 The system shall require an internet connection to send and receive data.

4.4.6 The mobile application will not require users to login to an account in order to collect data from water gauges.

5. Potential Risks

In this section of the document, we will describe the potential risks that could prevent us from implementing the minimum requirements for this project. Through discussions with the client and researching the parts of our project and how they will fit together, we have developed a table of the potential risks to the development of our project. Figure 5.1 shows the table of the potential risks to the development of our project. The first column demonstrates the possible risk. The second column demonstrates if the risk were to happen, how severe will it affect the application. The third column demonstrates how likely will the risk happen.

Risk	Severity	How Likely
Compatibility with the Hydroserver.	High	High
The National Water Information System data format is outdated.	Low	Medium
Changes to other applications and services that our mobile application will rely on.	Low	Low
Geolocation Accuracy	Low	Low

Figure 5.1 - Table of the potential risks. Based on a level scale. Low being less severe. High being very severe.

5.1 Compatibility to the HydroServer

HydroServer is a software that is used for publishing hydrological data. Our local database will need to connect to the HydroServer and send the hydrological data that the user recorded from the gauge. However, the local database could be incompatible with the HydroServer. Because of this, we will need to ensure that our database will be able to connect to the HydroServer and submit data in the proper format.

In order to mitigate this risk, we plan on setting up our own HydroServer for development purposes. We will test the communication between our local database and our test HydroServer before connecting to a live HydroServer.

5.2 The National Water Information System Data Format is Outdated

USGS provides access to their collected water data through the National Water Information System (NWIS). We will be using this data to show the user how their observations compare to those of the Nation Water Model (NWM). They have acknowledged that their data distribution services, that use tab-delimited data files (RDB), are severely outdated. They have announced plans to update the format in which their data is available, but have not made an official announcement as to how the data access will be modernized or when these changes will take place. Possible data file types include Keyhole Markup Language (KML) or Excel spreadsheets. While they have not announced when these changes will take place, their website claims that data in the existing RDB format will be provided for an extended period of time, even after the new data formats are made available, and for this reason we consider these potential changes to be of medium risk to our project.

5.3 Changes to Other Applications and Services that our Mobile Application will Rely On

The application will be using APIs such as the National Weather Service (NWS), National Water Model (NWM), and other packages that the mobile application will be using. However, any of the APIs or services that we will be using could be modified by the original owner. If a package or packages changes, the mobile application will need to adapt to change.

In order to mitigate this risk, we will have well-documented, modular, and service-based code. We want to make it easier for other developers that will continue maintaining and working on this project. With having well-structured code, developers will have less of an issue to modify the application services.

5.4 Geolocation Accuracy

One of the key requirements for this project is to implement geolocation in order to point where the gauges are on the map. We want the user to find these gauges easily and in efficient time. However, there could be issues when trying to pinpoint where those gauges are for the user. Since we will be using a package for the geolocation, we are relying that the package provides a longitude and latitude accuracy. According to some research, there have been accurate readings from within 3 meters (~10 feet) from a destination. But, there have been other research that the reading has not been that accurate. The reason it obtains the incorrect information is because it depends on the signal that is transmitting from the satellite to the antennas, which provide geolocation towards the phone.

This is a low risk because we can use the QR code to pinpoint the site's locations. The QR Code can store data such as URL. When the user takes a picture of the QR Code, it will obtain URL and it will be stored in the database. The QR Code will provide more of an accurate reading compared to the geolocation because we will know where the picture was taken and if the picture they took was at a streamflow.

6. Project Plan

In this section of the document, we will describe our plan to implement the minor key requirements into the application. The Figure 7.1 demonstrates our plan to implement the milestones for our project. The milestones that we have are:

- Parts Feasibility
- Back-End Development
- Front-End Development
- User Testing
- Code Refactor
- Presentation

At this stage of the project, we are working on the parts feasibility. Each member of the team will be implementing each of the functionalities separately so that they will become familiar with their assigned functionalities. The functionalities are connecting to the database, and implementing basic data visualization, geolocation, and image processing. Once each functionality has been implemented separately, we will combine them into one coherent application.

From the start of January until the mid-March, everyone will focus on working on the back-end development of the key functionalities. The back-end development will be responsible for the interaction of the database and the performance of the application. With the database, we need to be able to add, and store data from the local database to the Hydroserver.

From the start of February until the end of March, we will be working in front-end development while still implementing the back-end development. The objective of the front-end is to create friendly user interface design that is easy to use. The reason this will involve some of the back-end development is because when the user presses a button, it will need to have some functionality from the back-end such as being able to submit hydrological data.

During the month of February until the end of March, we will perform several user tests. The users will be students and professors that are interested in the application. We will ask users what they like and don't like about the application, and if it easy to use. With the feedback we receive from the client and the users, we will implement these features if it is feasible. This is the reason why we would need some time implement from the front-end and the back-end.

From the start of April until the presentation date, we should have all the functionalities working. Here we will start having code that is refactored and well-structured in a way that is easy and maintainable for future developers. We will then be prepared to present our mobile beta at the symposium.

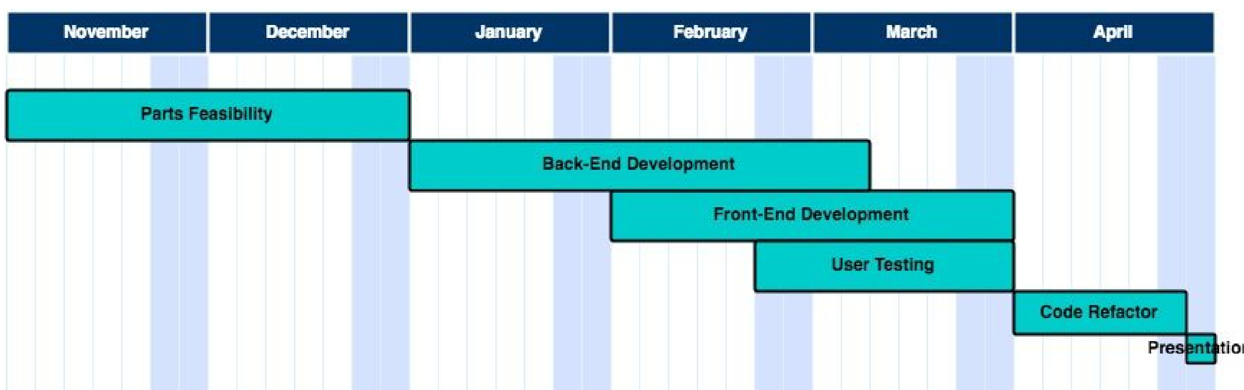

Figure 6.1 - Gantt Chart of the project plan.

7. Conclusion

Flooding is the most destructive natural disaster that we have, costing the United States $20 billion and resulting is at least 75 deaths since 2016. As USGS loses funding for their stream gauges, we must come up with a way to continue the collection of hydrological data of the large waterways that USGS collects data on as well as smaller waterways they do not collect data on. This extreme can be prevented with the continued and increased amount of hydrologic data collection. This is where our project comes in. With the citizens science mobile application for hydrology reporting, we will be able to collect more data on smaller waterways and provide the people who live in these areas with better warnings in the event of a flood. The idea is get the community more involved with this data collection through user submitted images of our gauging stations to our application. This will in turn help the public to understand the importance of this data and how it could affect them. This requirements document will help our team to decide what the most important features of our application will be. We have now outlined the key requirements and will strive to complete each and every one by the end of the year. We will use these requirements to better develop a prototype for our technical demonstration showing key aspects of the project. As a team, we are confident that we will be able to fulfill all of the requirements listed throughout this document and end the year with a fully functioning application that will be able to provide more accurate data points that could help save lives and money.

8. Glossaries and Appendices

Application Programming Interface (API)	A set of tools and protocols for building software applications.
Computer Vision Framework	A library of tools that allows for image processing.
HydroGraph	Graph that plots water depth data versus time
HydroServer	A software application used to publish hydrological data.
National Weather Services	An agency of the United States federal government that provide weather forecasts, warning of hazardous weather, and other weather-related features.
Project Database	Database that will communicate with the mobile application to receive and store pictures and data collected from water gauges.
Stage	Height of the water

Water gauge	A system to monitor water data