Restoring the Santa Fe River

Using mobile technology to engage citizens in monitoring the river

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Authors: Rachele Cox, Daniela Garcia, Lucien LeMenager, Marissa Norton
Sponsor: The Santa Fe Watershed Association (SFWA); Felicity Broennan
Liaison: The City of Santa Fe, Water Division; Claudia Borchert
Advisors: Fabio Carrera; Guillermo Salazar

Email: sf12-water@wpi.edu
Website: https://sites.google.com/site/sf12water/home

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Abstract

The aim of this project was to assist the Santa Fe Watershed Association in their effort to restore the Santa Fe River to a "living river" by enriching the collection and organization of environmental information while engaging the citizens of Santa Fe. This was accomplished by developing a public online repository, designing a mobile application and a companion website that, when fully implemented, would allow citizens to collect and manage data points and photos along the river.

All of these components can be useful for educational and planning purposes. Our app and companion website can be used in the classroom to bring an added technological aspect to the education. With citizens taking photos of various sections of the river, the city can observe sections that have been newly improved or that may need some restoration. This saves the resources of the city so that they can focus their time more on planning improvements than observing the river in the field. Overall, every component of our project aims to help collect useful data about the river and help to educate the citizens.

Executive Summary

The availability of water is of great concern throughout the world due to scarce rainfall, over consumption, and population growth. One fifth of the world is under water stress, as water is depleted faster than it can be replenished (OECD 2008). Water shortages are of special concern in the United States. The average American home consumes 80 to 100 gallons per day, which has resulted in gradually diminishing ground water levels (Anonymous2011b).


Figure 1: Santa Fe River 1910


Figure 2: Santa Fe River 2001

Although the amount of precipitation has not declined over the years, ground water levels have in fact diminished, as can be seen in Figure 1 and 2. Due to the scarce amount of available water, the city of Santa Fe has established dams to control the water flow of the Santa Fe River. These were originally designed to control the floods of the river, but are now mainly used to collect water to provide it to the city and its growing population (Noble 2008).

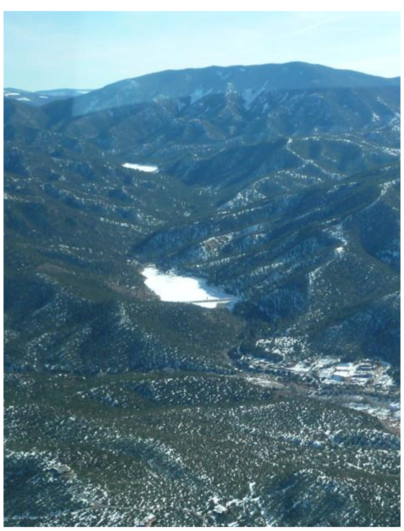
Figure 3: Nichols and McClure Reservoirs

Santa Fe was a fairly well established city in 1881, when it built its first structure on the Santa Fe River, the Old Stone Dam. The Old Stone Dam had a capacity of 25 acre feet and was intended to provide water for the city. However, efforts to tame it were unsuccessful. In 1893, the Two Mile Dam was built; it held 387 acre feet and helped to keep up with the rising population. The old stone dam filled with sediment in 1904 due to a flood, but this was not a loss, since Two Mile Dam was already established (Noble 2008).

In 1928, the McClure Dam was built two miles upstream of the Two-Mile Dam. It held 3,325 acre feet of water, a capacity so large that the river's flow was reduced to a stream (Noble 2008). In the 1930s, an exploding population increased the total number of citizens to over 20,000 from 15,000 in the previous decade (Forstall 1995), which stressed the water supply and surrounding farmland, and led to the need for additional water storage (Noble 2008).

The last of the dams, the Nichols Dam (Figure 3), was built in 1943. Built as the other dams had been, to keep up with the growing population, it held 684 acre feet of water. Its construction once again further restricted the flow of the river (Noble 2008). Two-Mile dam was decommissioned in 1994 due to structural concern (Borchert and Lewis 2009). The current two dams, McClure and Nichols, account for 40% of the municipal water supply.

Water is supplied to the citizens of Santa Fe from city wells, the Buckman Field wells, the McClure and Nichols reservoirs, and the Buckman Diversion and is treated at the Canyon Road and Buckman water treatment plants; 10,000 acre feet of water are treated annually. The water reaches the people of Santa Fe by a network of 500 miles of pipes (King and Borchert 2010, 4). Forty percent of Santa Fe's water comes from the McClure and Nichols Reservoirs, which collect rainfall and snowmelt from the Sangre de Cristo Mountains. Most of Santa Fe's water supply—about 15,000 acre-feet per year—comes from a group of 13 wells called the Buckman Field wells (King and Borchert 2010, 4). Additional water comes into the city from the Buckman Diversion, a pipeline system that pumps water from the Rio Grande to Santa Fe County. The Buckman Diversion began pumping water in March 2011 and is capable of pumping 15 million gallons of treated drinking water per day (Anonymous 2010). Because it can help reduce the demand on water from the reservoirs, the Buckman Diversion can aid in reaching the goal of making Santa Fe River a "living river" as it greatly increases the water supply, yet the demand experiences a relatively insignificant change. A visual history of the Santa Fe water supply structures compared to the increasing population is shown in Figure 4.

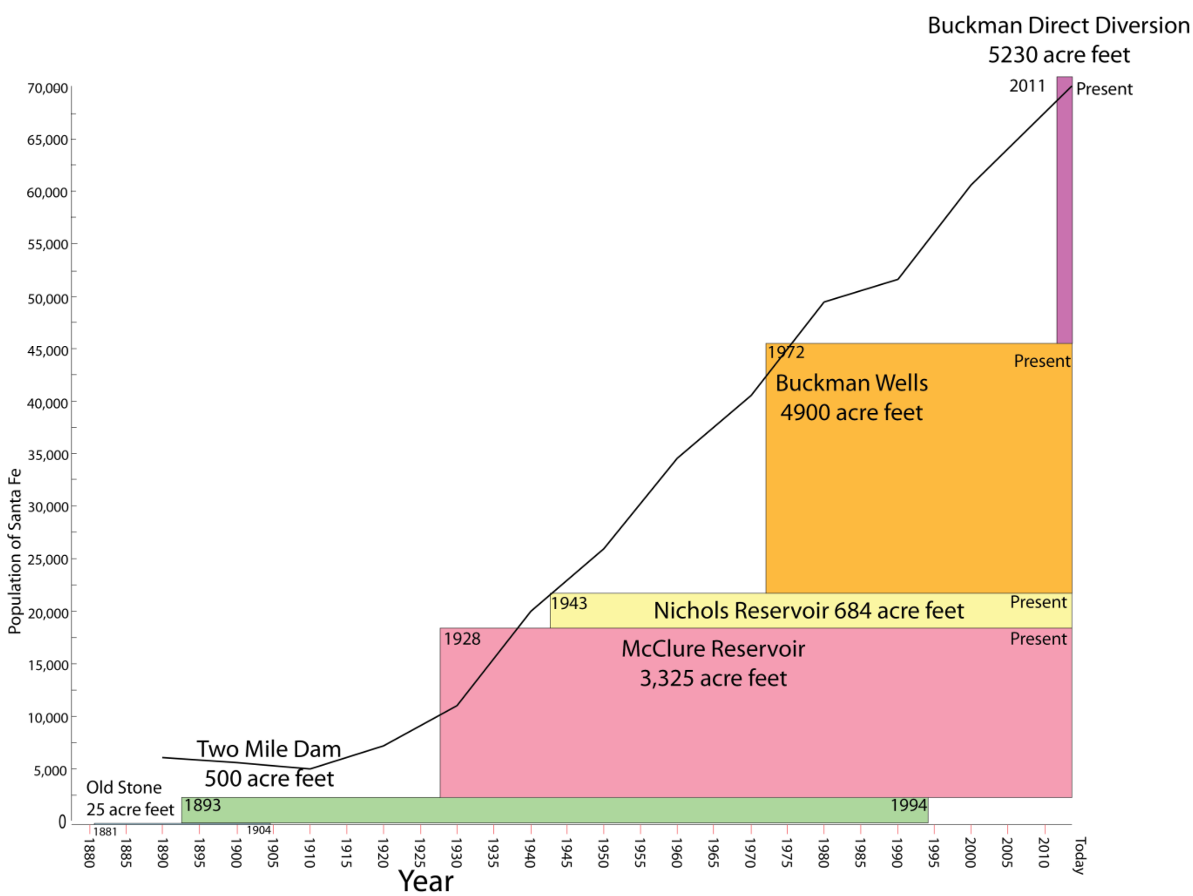

Figure 4: Santa Fe Water Supply compared to Population

A River Flow Bill was passed on February 29th, 2012, requiring that 1,000 acre feet will be released down the river in a normal water level year. This sets a precedent for other cities in the area because Santa Fe is the first city in New Mexico to require water to be used solely for the rivers ecology and not citizen supply (Borchert and Lewis 2009). One of the reasons this was able to be passed was because of the increased water supply from the Buckman Diversion.

When water is released into the river, many citizens are not aware of the fact. The Santa Fe Watershed Association interviewed citizens and some did not know that the Santa Fe River was considered a river because it is dry so often (Anonymous2011). Overall, the citizens are not aware of the condition and the existence of the river, so our project aims to increase their knowledge.

The mission of this project was to assist the Santa Fe Watershed Association in their goal of making the Santa Fe River a "living river" by enriching the collection and organization of environmental information while engaging the citizens of Santa Fe. Specifically, this project aimed to promote citizen involvement in the restoration in addition to increasing the amount of data collected on the Santa Fe River. With information more readily available and presented in an engaging way, citizens are more likely to become interested in river conservation and feel more inclined to help in efforts to manage the water supply. We have accomplished this goal through the completion of the four project outcomes: a shared database, a mobile application design, and website design.

The goal of this project was to enrich the collection and organization of environmental information to benefit the Santa Fe Watershed Association in their goal of making restoring the Santa Fe River into a "living river." This goal was achieved through the implementation of the following objectives:

- Develop an online repository for watershed information. (Figure 5)
- Design a mobile application and companion website to engage citizens in the river restoration process
- Demonstrate the usefulness of the application for educational and planning purposes

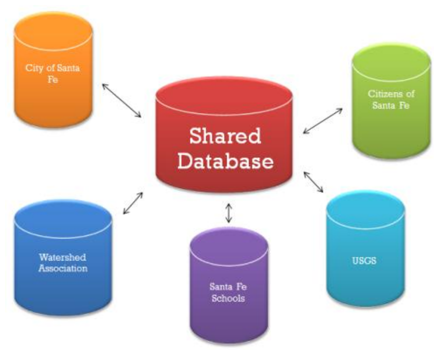

Figure 5: Information web

The data for the created online repository was obtained from professional sources and made available to the public. The two sources of data were the United States Geological Survey and City of Santa Fe Water Division. Our data collection manifested itself in Santafedia pages (Figure 6) on SantaFedia.org, one central location for information on Santa Fe. These pages cover a range of topics including photo points (pre-established locations along the Santa Fe River serving as fixed points to establish an accurate photo history at numerous points along the river for use within the mobile application and corresponding website), stream gauge data, annual river flow and pollution, precipitation, and well and reservoir levels. The SantaFedia pages also contain data collected from the mobile application.

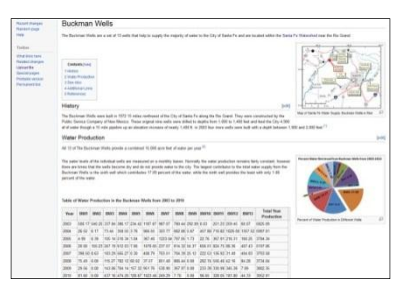

Figure 6: SantaFedia WikiPage

Our project utilized a system used to spatially represent geospatial data known as Geospatial Information System (GIS) maps (Figure 7). This system was implemented in our Santafedia pages, website, and application mock-up. Maps were created with data obtained from the City of Santa Fe and the United States Geological Survey. GIS layers were also obtained from the city which represent the watershed, hydrology, bodies of water, wells, the Buckman wells, and vegetation. Maps made for our project include photo points, river nodes, and river reaches (Figure 7).

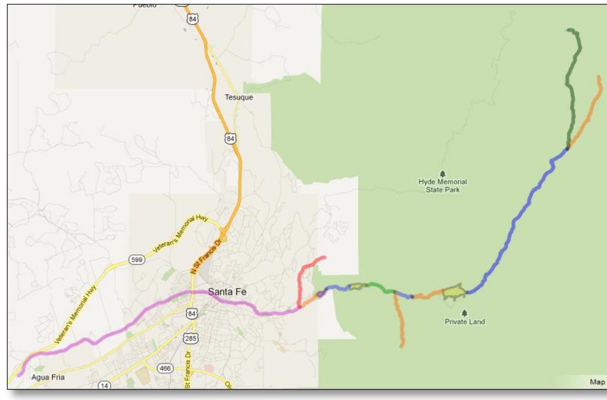

Figure 7: GIS map showing river reaches

Figure 8: The River Restoration Application

Due of the popularity and accessibility of mobile smartphones, it was determined that a mobile application would be the best method for gathering and sharing data. The android platform was chosen as the development of an application on the android market is most open to the publication of applications on its market (as opposed to the apple store). In order to satisfy the second objective of designing a mobile application (Figure 8), the structure for the application and its capabilities had to first be established. Specifically, the flow of the application, its aesthetics, the way qualitative and quantitative data are recorded, and the integration of photo points were the major highlights of the application design.

The companion website (Figure 9) for the application will give users a location where they can download the app, as well as view the data taken using the app. The website may even offer features not available on the app including account management and data graphs. The website is the medium on which website moderators can manage submissions and reject any that are inaccurate such as blurry photos and clear outliers in data. While the app gives a brief description of terminology that are simple and to the point, the website links to full Wikipedia entries on the terminology.

Figure 9: Companion Website

The Santa Fe River water levels fluctuate rapidly throughout the year, and many citizens are not aware of the changing status of the river. Our main audience to engage for data collection is the citizens and schools within Santa Fe.

Many of the schools already have river education programs and collect information about the river. Our app allows these programs to bring technology into the classroom and allow an easier input method than what currently exists. Our system of data collection would also allow the teachers to take this information back to the classroom and analyze it with the students, and then allow the citizens access to the information that the students have collected. This can all be accessed from our website from any computer. In addition to the website, the Santafedia pages can serve as learning tools for the students of Santa Fe giving them background knowledge about various topics relevant to Santa Fe. This information can also be updated to include the data collected by the students. The information the students collect will have a bigger impact on the river as a whole because it will be presented to a larger audience.

In terms of planning purposes, the city can use the collected data and the photo history to see if their restoration efforts are having any effect or if they need to deploy their efforts on another section of the river. By having citizens collect information and a photo history of different sections; it allows the city to be aware of the problems with the river more readily. They can sort through the collected data and find any issues that may need to be addressed. Effectively this crowdsourcing method allows for more data points and less effort on the part of the city thanks to citizen involvement.

Our project resulted in educational web pages, a database of watershed information, and an application design and companion website mock-up. All of these aspects are connected with one another; one piece of our project would not work without another. Due to time constraints, we have a few recommendations for the future. First we would like to see our application and website mock-up implemented into a working system so citizens can actually begin to start getting involved. We would also like to see educational outreach by integrating the application into school programs and expand the focus to encompass schools making it more kid friendly. Lastly would be to implement a system of LED lights on existing adopt-the-river signs to alert citizens to where the water in the river has reached (Figure 10).

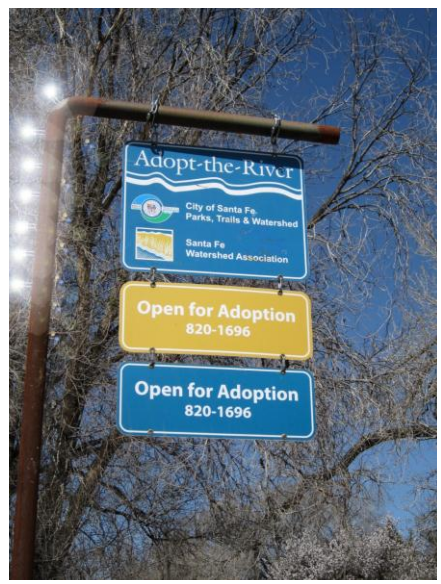

Figure 10: Mock-up of LED system

Acknowledgements

We would like to thank our sponsors the Santa Fe Watershed Association and the City of Santa Fe Watershed Division, specifically Felicity Broennan and Claudia Borchert respectivly. The other members of the Santa Fe Watershed Association, Eileen Everett and Francois –Marie Patorni along with Brian Drypolcher from the City of Santa Fe Water Division. We give thanks to the Santa Fe Water Commission for letting us to sit in on their March and April meetings and allowing us to make our project known. Lastly we would like to thank Pasco Probes for a donation of probes that will measure water quality and help move our project forward.

Authorship

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1 Introduction

Water supply is a concern throughout the world due to scarce rainfall, overuse of water, and population growth. One fifth of the world's population is under water stress, defined as water being consumed at a faster rate than it can be replenished. Current world water stress conditions are illustrated by the red areas in Figure 11. The Organization for Economic Co-operation and Development (OECD) has predicted that by 2030, 47 percent of the world population will be living in areas of high water stress (OECD 2008).

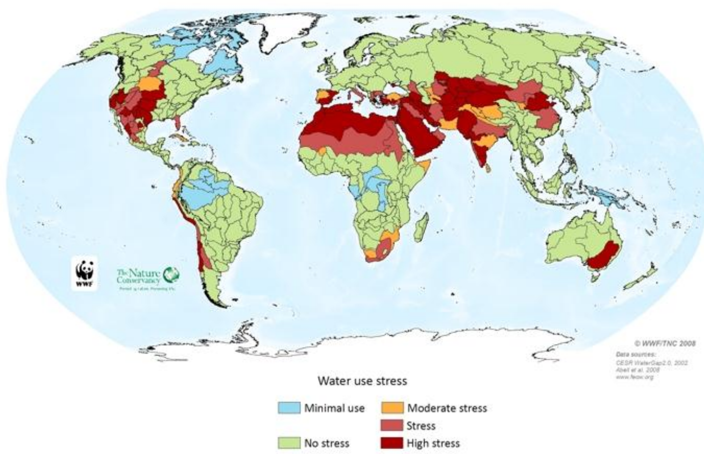

Figure 11: World Water Stress

Water deficiencies are especially a concern here within the United States, as citizens extract up to 46,000 gallons annually per capita from natural resources; more than any other country. Figure 12 shows the OECD's rankings of 29 nations' annual per capita water consumption. The average American home uses 80 to 100 gallons of water per day (Anonymous2011b). Due to this high amount of consumption, ground water levels are gradually decreasing as demand increases and replenishing rates are inadequate to sustain such large demands (USGS 2003).

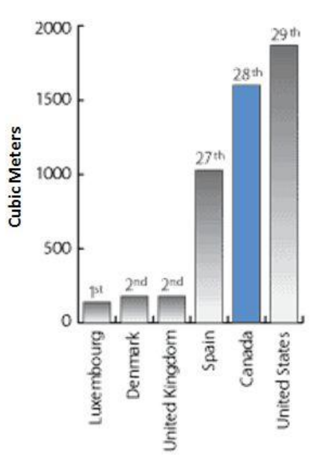

Figure 12: Water Abstractions Per Capita

New Mexico is no stranger to dry conditions; scientists have speculated through, soil analysis, that some droughts in the area have lasted for 19 years (Meko, Stockton, and Boggess 1995, 789-801). A report by the Environmental Protection Agency in 2012 listed January through October of 2011 as the driest months on record in Santa Fe (Matlock 2011, January 23, 2012). Extended droughts still occur today in the hot and arid climate. The increase in Santa Fe's population by 9.2 percent from 2000 to 2010 has placed an additional stress on water availability (Anonymous2012). Daily water consumption per capita in 2010 was 68 gallons in Santa Fe (King and Borchert 2010, 4). In comparison, Boston, Massachusetts had a daily consumption per capita of 40 in the same year, as illustrated in Figure 13. The average American uses 183 gallons of water per day (Anonymous2011a).

Rainfall has not declined over the years, yet ground water levels are decreasing. Although water coming from the city wells is monitored and use is diminishing, there

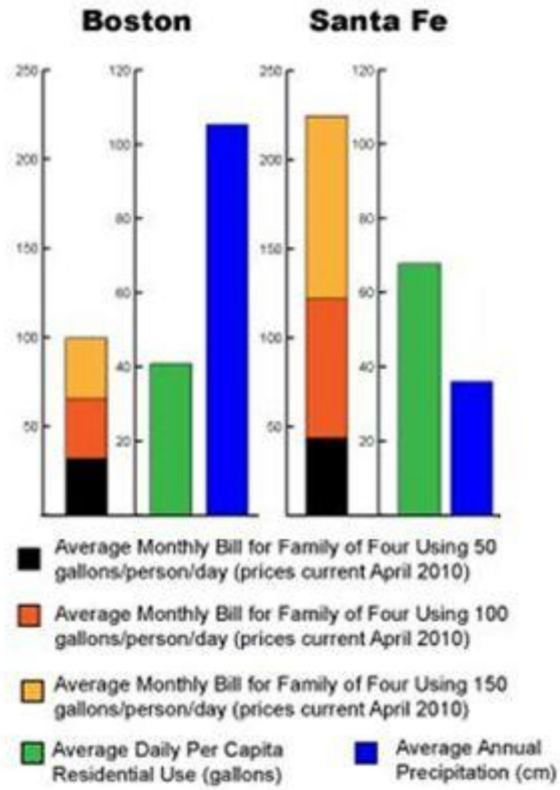

Figure 13: Water Use in the US Cities

is no way to restrict or monitor the amount of water that private wells are drawing from the ground. (Grant and Williams 2009, 1)

Due to the scarce amounts of water, the city has established dams to control water flow in the Santa Fe River, preventing its water from flowing freely. The citizens of Santa Fe are aware of the current water stress on the region as is evident by the decrease of overall water use by 38 percent from 1995 to 2010 (City of Santa Fe 2010) (City of Santa Fe 2010, 10-10). However, the citizens are not informed of how their conserved water is benefitting the Santa Fe River. It has been stated that the city's conserved water "will be considered for allocation to the affordable housing credit pool on an annual basis," and therefore is not directly benefitting the Santa Fe River (King and Borchert 2010, 4).

Our sponsors, the Santa Fe Watershed Association and the City of Santa Fe Water Division, have the goal of restoring the Santa Fe River to a flowing, "living" river. There is no clear way of measuring the progress of this river restoration. The river flow data that shows the progress is available online for anyone to access. However, this information is presented in an undecipherable and non-interactive way that is difficult to quickly grasp the way it currently exists. The United States Geological Survey, The City of Santa Fe, and the Office of the State Engineer are all reliable sources of information. However, the data is housed in different locations and presented it in diverse ways. The information is normally presented in lengthy documents and extensive charts.

It is thought that if this data was presented in an interactive way and in a central location, it would engage the citizens and encourage them to be more involved in the river conservation, along with helping the city with discovering more efficient ways to manage the water supply. This is the goal of our project and in doing this we hope to assist our sponsors with their goal of restoring the river.

We accomplished this task by creating a shared database and a mobile application that will not only allow users to access the information remotely but be able to upload their own river data to the database, contributing through a process called crowdsourcing. It should also accelerate the efforts made by the Watershed Association and will allow past data collection to move forward and be improved upon. This project will encourage the continuation of the water conservation efforts throughout the city.

2 Background

For the comprehension of the goals of this project, a background has been developed. Historical facts of the Santa Fe River and the watershed built the framework to our project. It is necessary to understand the strain that the river has undergone. The Santa Fe water distribution and consumption form the foundation of this project as they are major factors that need to be taken into account.

Some key terms used in this proposal are acre feet, drought, and water stress. Water volumes discussed are measured in acre feet, defined as the amount of water necessary to cover the area of one acre with a depth of one foot. Depending on the scientific field, drought has various definitions, but the hydrologic definition of drought is "a period of below average water content in streams, reservoirs, groundwater aquifers, lakes and soils" (Vujica, Hall, and Salas 1977, 276). Water stress is defined by the Organization for Economic Co-operation and Development (OCED) as "ratio of total water use to renewable water supply." Any ratio above 40 percent is considered "stressed."(OECD 2009, 32).

2.1 Santa Fe River

The Santa Fe River has played an important role in the founding of the city of Santa Fe. Native Americans used it as a source of irrigation, the Spaniards founded the city around this water source, and the Americans built dams to provide water to the city's growing population (Noble 2008). However, a growing population has strained the water supply for the river and caused it to run dry, as seen in Figure 14.

Figure 14: The Santa Fe River in 1910 (Left) and 2001 (Right)

In 1850, the United States made New Mexico an official territory after gaining the land through the Mexican-American War. The city became more established and in 1881, the first dam was built on the Santa Fe River. This dam, known today as Old Stone Dam, was built by the privately owned company, The Santa Fe Water and Improvement Company. The dam with a 25 acre foot capacity was erected in hopes of controlling the river to capture water for the city; however it was not able to tame the river (Noble 2008). The Two Mile Dam was constructed in 1893 with a 387 acre foot capacity that was more suitable for the increased population of the city. Eleven years later, in 1904, Old Stone Dam was filled with flood sediment containing debris that would normally wash down the river, causing the dam to no longer serve its purpose. Although this would have been a major loss, the previously constructed Two Mile Dam had already made the Old Stone Dam obsolete (Noble 2008).

In 1914, the river was analyzed by the state engineer deciding that 400 acre feet would be stored for citizen use and the surplus would be released into the river. During this time the population was rapidly increasing thus the need for an additional dam. The McClure Dam was built in 1928 and was designed to hold 3,325 acre feet of water. It was placed two miles upstream of the Two-Mile Dam. This dam's capacity was so large that once again, water flow decreased to a stream (Noble 2008).

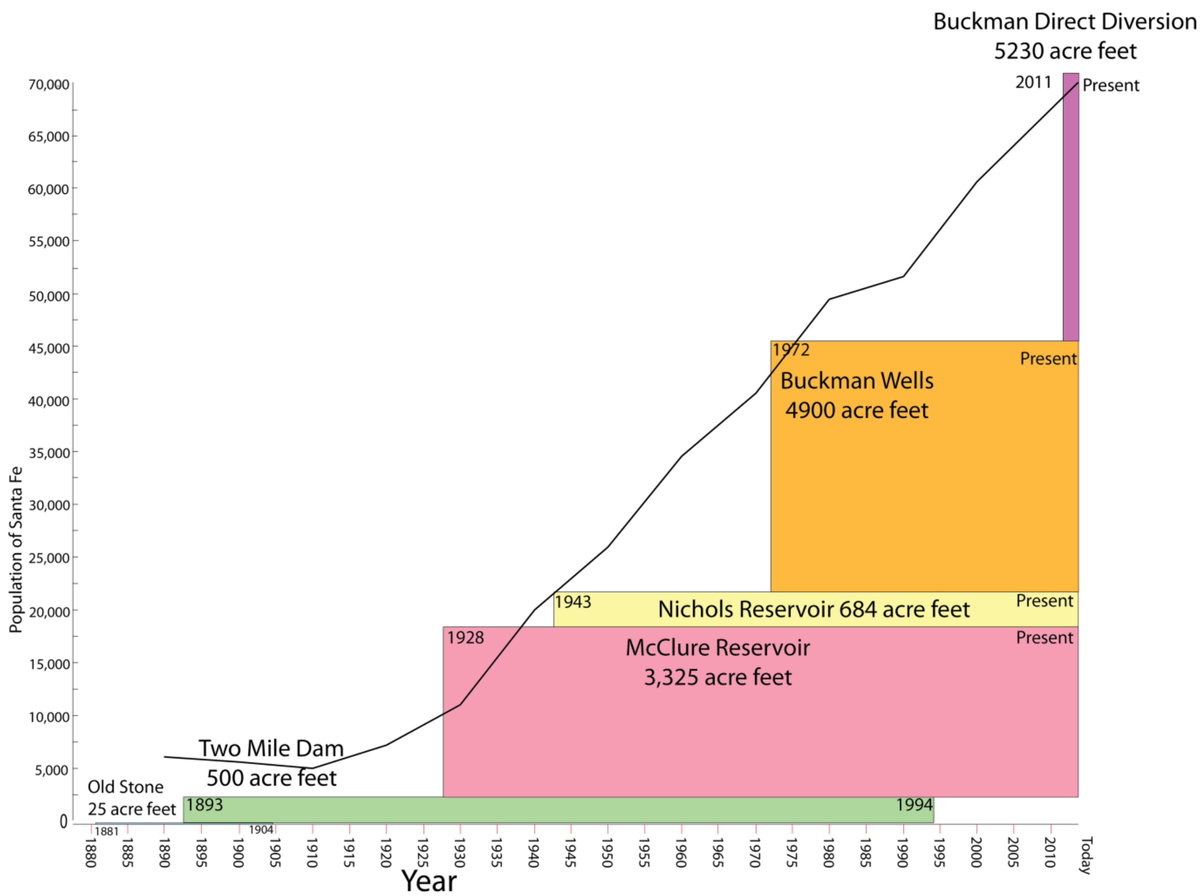

Figure 15: Water supply Timeline Compared to Population

In the 1930s, an exploding population increased the total number of citizens to over 20,000 from 15,000 in the previous decade (Forstall 1995), which stressed the water supply and surrounding farmland (Noble 2008). Downstream of the McClure Dam, the Nichols Dam, with a capacity of 684 acre feet was constructed in 1943. This was the final dam built on the river, and further restricted the flow into the river (Noble 2008). The history of when the dams were established in comparison to the population is seen in Figure 15. Today, the McClure and Nichols Dams are the only active dams as the Two-Mile Dam was decommissioned in 1994 due to possible structural failure and lack of need for it (Borchert and Lewis 2009). These dams are important as they provide 40 percent of municipal water to the city and withhold a great deal of water from the river (Borchert and Lewis 2009). The city of Santa Fe is now seeking alternate sources of water that can help put more water in the river.

2.2 Stream Gages

Stream Gages are inserted into a body of water and are used to measure the volume per second of the water (Anonymous 2012). Although there is a limited amount of water along the Santa Fe River, gages are helpful when there is a large storm and water is freely flowing down the river. There are three different types of gages. The most simple is a staff gage, which is essentially a meter stick that is placed in the water and the height can be read off of markings on the stick. However, this data has to be manually retrieved. The second gage, the crest stage gage, is used for a simpler measurement of viewing where the highest flow was recorded from the last time that the gage was viewed. This is done by having a cork inside a pipe, as water enters the pipe from the increase of water, the cork starts to float higher, and when water starts to recede, the cork attaches itself to the inside of the pipe and stays in the position it was at its highest height (Anonymous 2012). The third type of gage, most commonly used by the United States Geological Survey (USGS) and represented in Figure 16, uses floats present inside of a well to measure water elevation and pressure transducers that measure how much pressure it takes to push a gas bubble through a tube. These gages automatically measure the levels every 15 minutes and the measurements are automatically updated to the USGS database (Anonymous 2012; Anonymous 2009; Anonymous 2010).

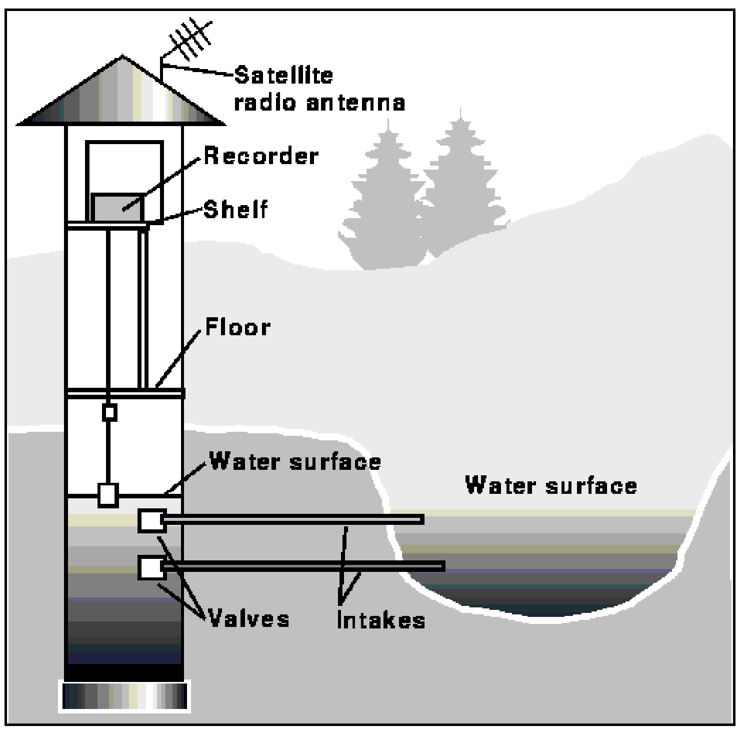

Figure 16: Water Gage Diagram

The gages along the Santa Fe River are all pressure transducers. There are two located above the McClure Reservoir, one near Santa Fe, one below Nichols Reservoir, another above St. Francis, and another at Ricardo Road. The McClure, Nichols, and Santa Fe gages are all automatically updated to the USGS via satellites. The gages above St Francis and at Ricardo Road collect data, however someone needs to go out to the gage and manually gather the data on a monthly basis.

2.3 Water Rights in Santa Fe

Water rights refer to the regulations citizens abide by when using public water. There are two different types of water rights regulations. The first being Riparian Rights, where the allotted water is proportion to the amount of land owned. This would allow farms and those who need more water to be able to have access to more. The opposite of the land based regulation is the Use-Based Rights which allows equal water to all citizens, independent of land ownership (Guerin 2003).
In Santa Fe, water is conserved though a set of strict regulations which control the amount and purpose of water use. There must also be a specific amount of signs in public locations encouraging the citizens to conserve water (Cross 2010, 1-58).

2.4 The Santa Fe Watershed

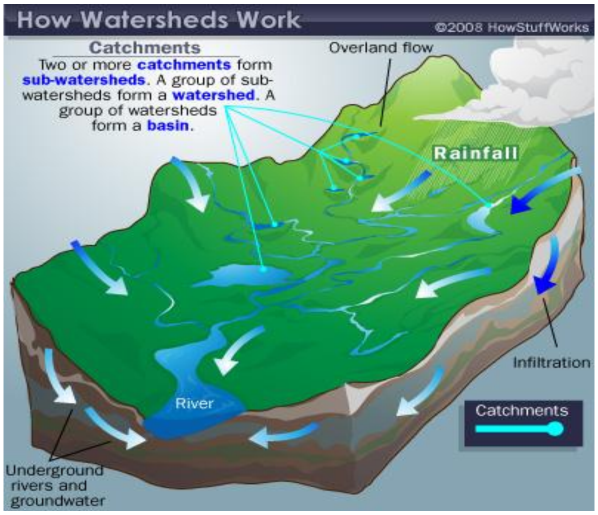

Figure 17: Example of Watershed Flow

A watershed is a land formation in which all water that precipitates or is below ground level drains into tributaries to form a river, as represented in Figure 17. There are 2,267 known watersheds in the United States. Sources for a watershed include rain water, ground water, and snow. (EPA)

The Santa Fe Watershed is a 17,520 acre area encompassing Santa Fe and the Sangre de Cristo Mountains, where the river flow begins. The mountains have a geological makeup of volcanic rocks under the surface, which act as a funnel to allow for the pooling of the water and create the stream flow which is seen when it reemerges at the surface. According to the state of New Mexico, the Santa Fe Watershed is considered a Category 1 Watershed, in terms of restoration due to water quality the Santa Fe Watershed is not in need of assistance. (Grant 2002). The watershed, shown in the blue section of Figure 18, encompasses the two main reservoirs, the Nichols and McClure, along with the Buckman Well Field and Buckman Diversion (Community Responses to Wildland Fire Threats)

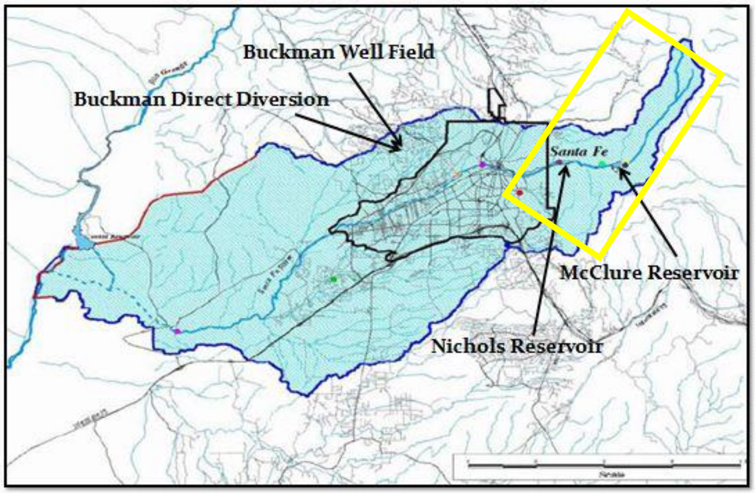

Figure 18: Map of Santa Fe Watershed

The Sangre de Cristo Mountains, located in the yellow box in Figure 18, contain both reservoirs. The area of land that surrounds the reservoirs is closed off from the public. This is to protect the water supply from human influence and to also protect the citizens from the spontaneous forest fires occurring in the area. The overgrowth of pines and ferns increased the fire damage to the area. These fires cause an immediate threat to the watershed and its supplies for the city. However, these fires are able to keep the amount of trees in the area reduced which decreases the amount of water that the trees are able to take away from the watershed. Although the amount of water that the trees are able to take away might not be significant, the city can use all of the water that they are able to get out of the watershed. Due to fire wreaking havoc in the late 1990s, the Santa Fe Watershed Association was founded (Community Responses to Wildland Fire Threats).

2.4.1 Santa Fe Watershed Association

The Santa Fe Watershed Association (SFWA), established in 1999, was formed to oversee the safety of the reservoirs and the watershed, however, since then their focus has shifted. Due to lower water levels, the SFWA has at present been overseeing the Santa Fe River (Santa Fe Watershed Association). The SFWA is looking to restore the Santa Fe River into a living river. To achieve this, the river must be running, clean, and have a steady flow. Other goals for the Watershed Association include education of the citizens, advocacy of resource conservation, and sustaining river flow (Santa Fe Watershed Association).

2.5 Benefit of Healthy Water Flow

Even though it is extremely important for the citizens of Santa Fe to have enough usable water, it is also crucial that there is water in the river. There are many different reasons behind the necessity of river flow, but the most important is the ecological changes that have occurred from the lack of water in the river. Although there are varying amounts of water in the river during the different seasons, there is a lack of consistency and many dry portions of the river. This lack of water leads to the decrease in plant and animal life that would normally reside in and around the river (Grimm 2010). The water would also create a riparian, an area that promotes the diversity in biological life along the river and makes an area of healthy land (Anonymous2009).

The creation of a dam can cause the biological life to become non-existent from the lack of significant reduction in water. It also causes the water that is trapped to have a lower quality and a considerable increase in sediment buildup. The water that is behind a dam lacks the typical flow and cycling of a normal river. The lack of cycling water causes organic molecules, like oxygen, to interact in ways that can create harmful chemicals for the animal life that are be present there (McCully 1996, 36-38). The sediment that builds up in the dams, normally of dirt, sand and nutrients that the river holds for its inhabitants, is also affected by the lack of water flow. Normally, sediment is washed away with the river flow, allowing it to be distributed evenly along the river. However when the dam is blocking that river flow, the sediment builds up and in some cases causes the dam to become useless. All of these issues are illustrated in Figure 19.

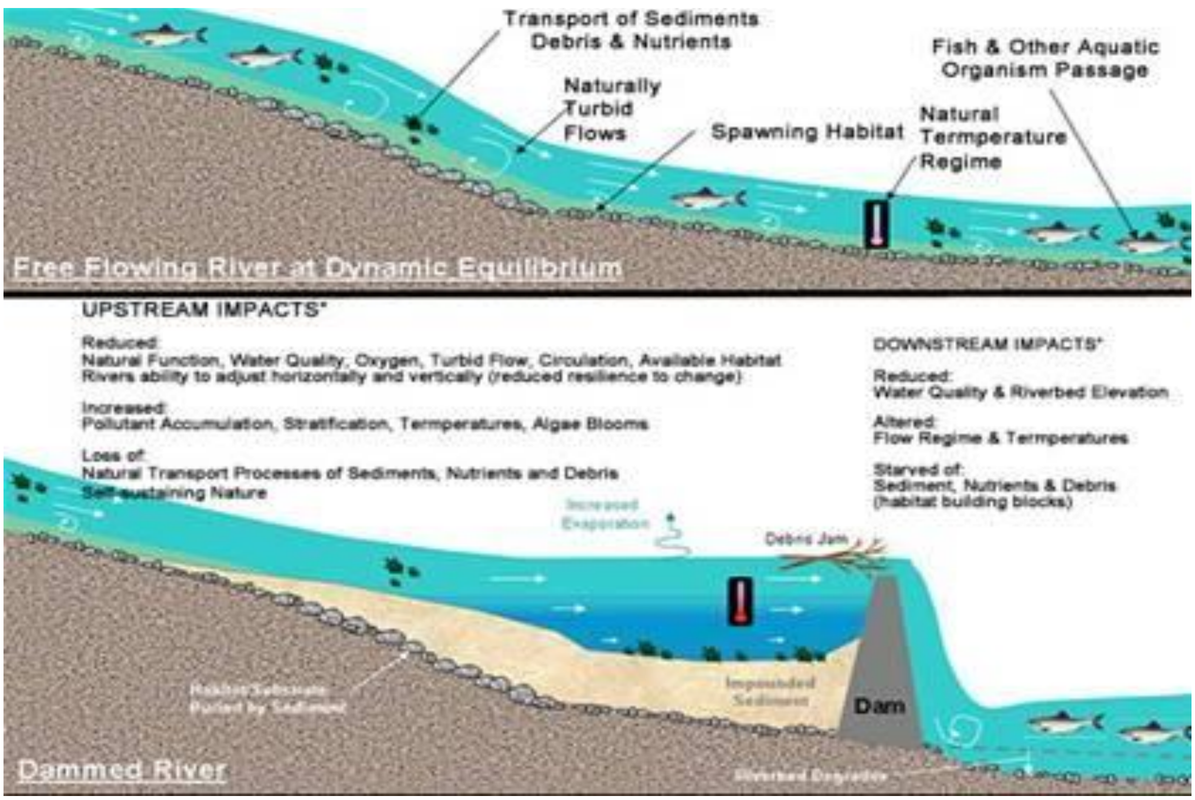

Figure 19: Comparison of Dammed versus Natural River

The existence of water in the river can also benefit the economy of the area. Having a river increases the opportunity to have more recreation and tourist attractions, increasing the revenue. The simplest way to see this increase in revenue is one of the popular American pastimes, fishing. Fishing affects the overall U.S. Economy with more than $116 billion (Anonymous2012). Other economic revenues can come from other recreational sports like boating & kayaking. As the city revenues are currently on the rise from the downward streak after the all-time high of $8.4 million in 2006. In 2010 the revenue of $7.7 million finally shows an upward trend, (Grimm 2010) the added push from the tourism in the river could help the city out with their tourism revenue

Rivers are extremely important to the environment and economy; this is why the reestablishment of the Santa Fe River into a "living river" is an extremely important task that our team is extremely invested in accomplishing. We worked hard to help the Santa Fe Watershed Association realize their goal to have Santa

Fe River flourish with biological life and diversity along with encouraging the tourism in the city to increase with the addition of a new revenue opportunity.

2.6 Natural Water Sources in Santa Fe

Precipitation and aquifers are two natural resources of fresh water. Precipitation is any form of moisture accumulating on the land, such as snow or rain. An aquifer is a "geologic formation that stores water and releases it to a well or a natural point of discharge, like a spring or stream (Grant and Williams 2009, 1)." With less than average precipitation and decreased flow through aquifers, the natural water supply is strained supporting the City of Santa Fe (Grant and Williams 2009, 1).

2.6.1 Precipitation in Santa Fe

Southwestern United States has a semiarid climate, characterized by low precipitation. The Santa Fe area experiences heavy storms in the summer, as is illustrated in Figure 20 with a sharp increase during the summer months. Summer rainfall comes in quick, strong storms that often flood the river. The average precipitation per year is below 10 inches in the river valley but averages 20 inches in the mountains, where the heart of the Santa Fe River lies. Humidity is relatively low, as to be expected with the drier climate, and therefore leads to a higher evaporation rate (Gutzler).

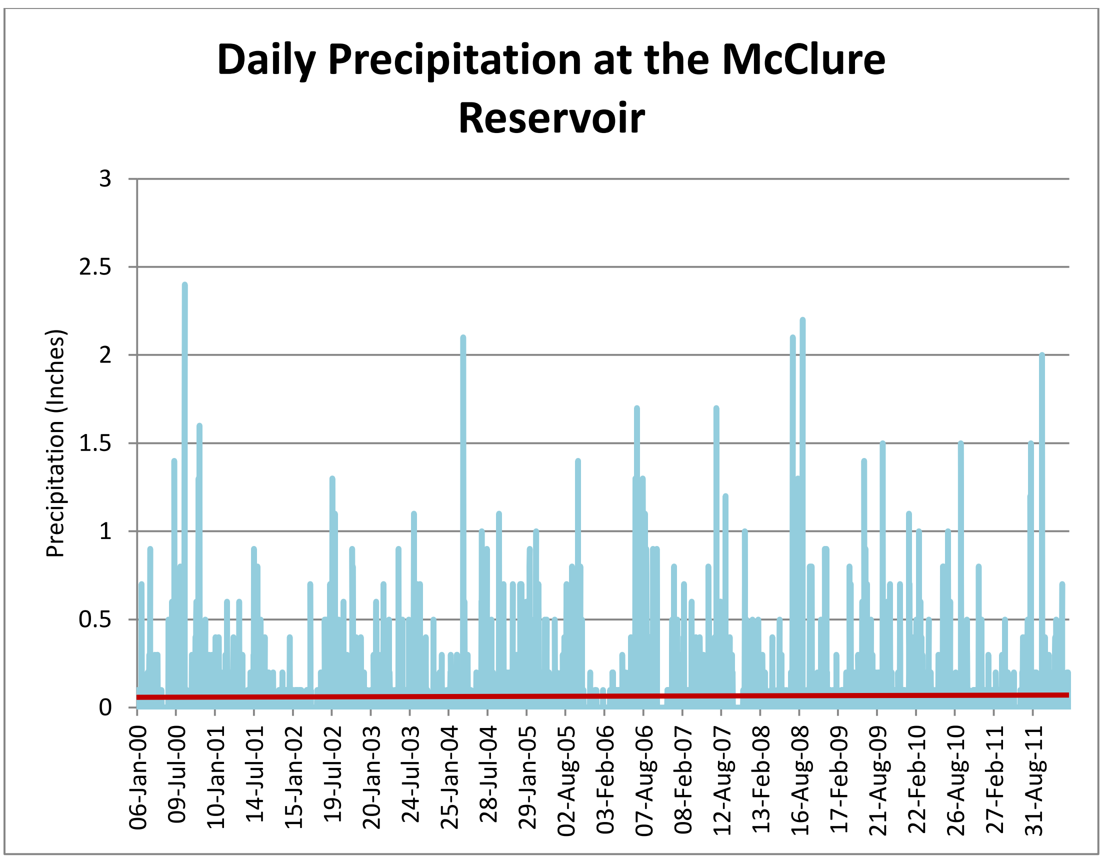

Figure 20: Daily Precipitation (USGS)

Increased precipitation in the mountains is collected in the city's dams and distributed to the city residents. Some of the water collected is allowed to flow down the river, where it leaches into the ground and replenishes the aquifer (Gutzler).

2.6.2 Aquifers Under the Santa Fe Watershed

The Santa Fe River has reaches of the river that are "gaining" and "losing". The gaining regions are where water flows through the river, for example, immediately after the dams and where the water treatment plant flushes its water. Losing regions are where the water in the river seeps into the ground to replenish the aquifer and very little water, if any, is apparent in the river bed. The Santa Fe River is composed of the Ancha and Tesuque Formation, as is seen in Figure 21. The Tesuque formation (tan) is north of the Ancha formation (orange), with the Santa Fe riverbed (yellow) between the two rock formations.

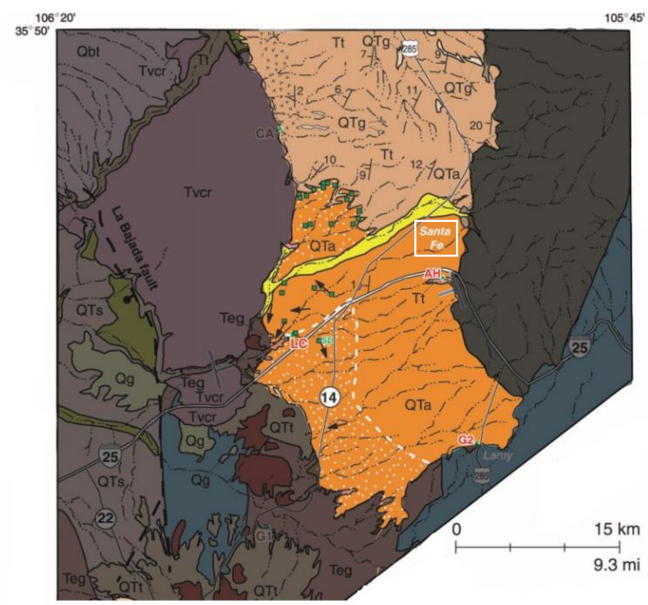

Figure 21: Aquifers of Santa Fe County

2.7 Water Distribution in Santa Fe

The city of Santa Fe supplies its citizens with water from city wells, the Buckman Field wells, the McClure and Nichols Reservoirs, and the newly built Buckman Diversion. 10,000 acre feet of water is treated annually at the Canyon Road and Buckman water treatment plants, and supplied to the city via 560 miles of pipes (King and Borchert 2010, 4). Below, in Figure 22, the sources and distribution can be seen schematically throughout the city in residential and commercial facilities.

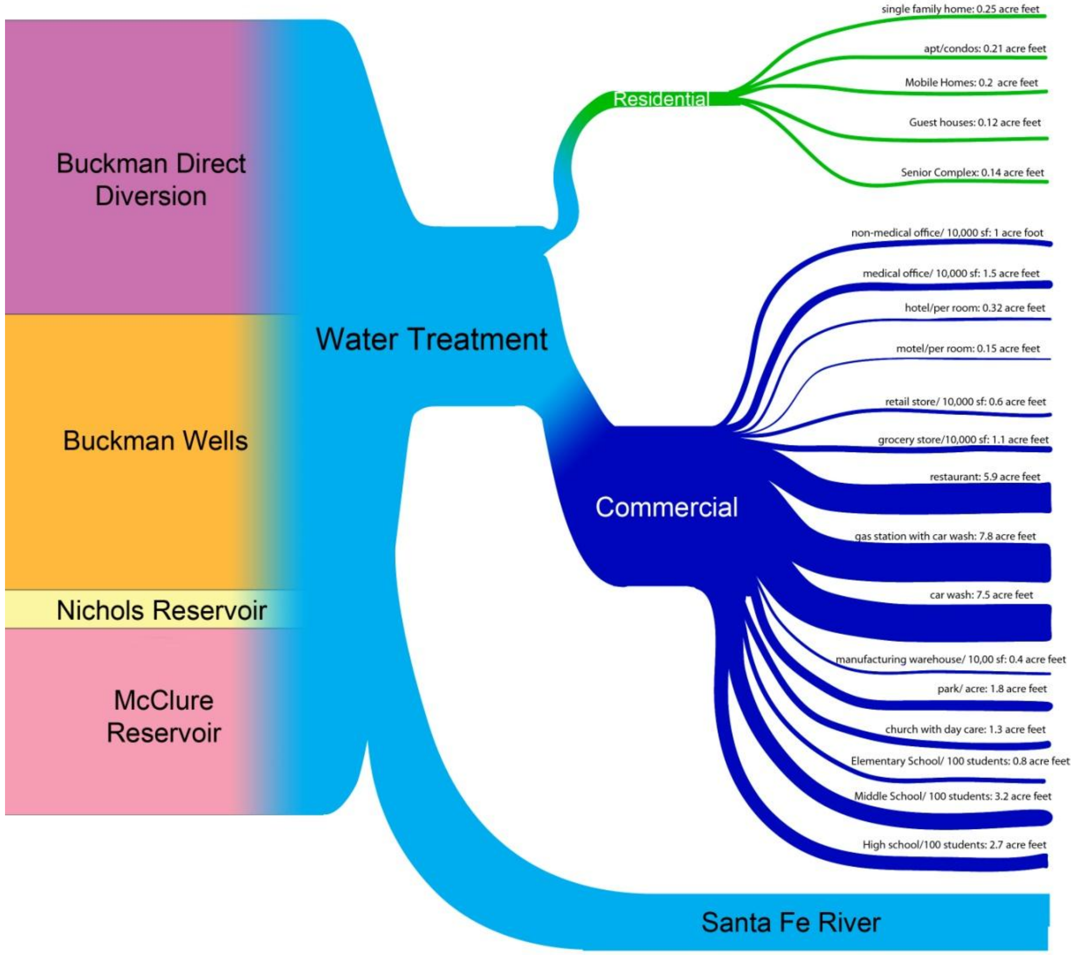

Figure 22: Water Sources and Distribution in Santa Fe

2.7.1 City of Santa Fe Water Division

The City of Santa Fe Water Division is charged with the management of the city's water. The Water Division supervises water rights and regulations, citizen billing, conservation and quality of water, as well as producing daily and annual reports. The Water Division has the consumption and distribution data that will be used in this project (Santa Fe, NM and its representatives 2012).

2.7.2 Santa Fe Reservoirs

The Santa Fe River was historically the city's water source, and dams were built on the river to contain the water for citizen consumption. The McClure and Nichols Reservoirs were built in the Sangre de Cristo mountain range where they could collect rainfall and snow melt. They are capable of storing 3,985 acre-feet jointly and supply the city with 40 percent of its municipal water source. Due to their large capacity, and addition sources of water, the city is required to release 1,000 acre-feet of water into the river annually from the reservoirs. However, due to percolation into the ground and a high evaporation rate, this is not enough water to support a consistently flowing river (Borchert and Lewis 2009).

2.7.3 Buckman Well Field

The Buckman field wells supply a majority of the city's water. These wells were created in 1972, where nine wells were drilled 15 miles north of the city along the Rio Grande River. In 2003, an additional four wells were drilled to pump additional water. The water from these wells is then pumped to the city. They are capable of producing around 15,000 acre-feet per year (King and Borchert 2010, 4). Along with their own city wells, the city has water rights to the Buckman field wells, a group of 13 wells drilled northwest of the city in order to supply the city of Santa Fe with additional water resources. Diversion tunnels were built, directing water from the San Juan River Basin to the Rio Grande Basin which encompasses the area surrounding the Santa Fe River (Glaser). As seen in Figure 23 a recent project, the Buckman Direct Diversion has brought water from the Rio Grande closer to the city.

2.7.4 Buckman Direct Diversion

Buckman Direct Diversion is a combination of water processing facilities and pipelines that pump water from the Rio Grande to Santa Fe County to supply residents of Santa Fe with drinking water. The diversion is co-owned by the City of Santa Fe and the Santa Fe County, supplementing the current water supplies of the McClure Reservoir, Nichols Reservoir and wells. Figure 23 is a map illustrating the expanse that the pipeline covers in relation to other water sources. The diversion began pumping water in March 2011 and has the capability of pumping 15 million gallons of treated drinking water per day. The Buckman diversion makes the Santa Fe "living river" reachable goal because it will supply the needed water to the city and allow less water to be taken from the reservoirs, therefore allowing water to flow down the river (Anonymous 2010).

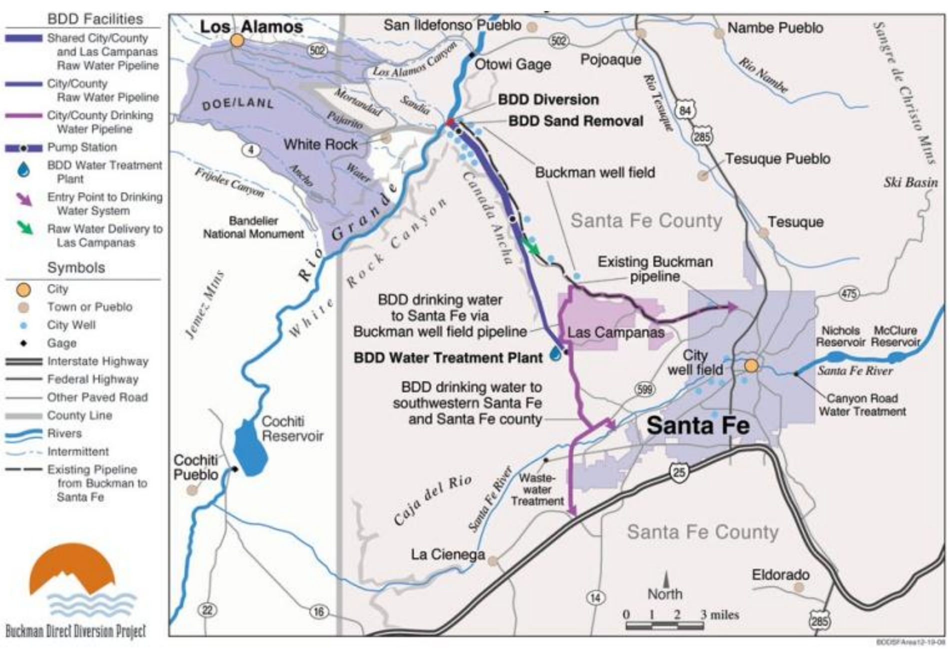

Figure 23: Buckman Direct Diversion Project

2.7.5 Waste Water Treatment

The last segment of the Santa Fe River begins at the Waste Water Treatment Plant and ends at the Rio Grande River. The plant, formally known as The City of Santa Fe Paseo Real Wastewater Treatment Plant is a conventional treatment plant. The treatment plant processes 13,000 gallons of water daily which is outputted into the last segment of the river (Santa Fe 400). The Wastewater Treatment Plant is Santa Fe's second most energy user, behind the Water Division, with 40 percent of its total energy from solar power (Grimm 2010).

2.8 Water Consumption in Santa Fe

Santa Fe is subject to New Mexico's Statutes and Court Rules which are very specific in regards to water usage (State of New Mexico 2012). The 'State Engineer' is in charge of water management and is responsible for issuing water permits, well relocation, the diversion or storage of water, and politically in water usage offences. The state also recognizes beneficial and acceptable water usages to be; agriculture, commercial, domestic, industrial, recreational, conservation goals, and stock watering (Western States Water Laws 2001). Legislature is not able to agree on the issue of water rights and how to allocate water in times of drought. This has caused tension between different levels of government as well as confusion among citizens (Matlock 2010).

In 2010, Santa Fe consumed 34,832 acre feet of water; a 9.2 percent increase from the year 2000 (King and Borchert 2010, 4) (Anonymous2012). Increased population has heavily contributed to this increase. Although the SFWA and the City of Santa Fe Water Division have been successful in their conservation techniques as water usage per capita has decreased by 38 percent from 1995 to 2010, the overall demand has increased (King and Borchert 2010, 4)(Anonymous). This creates a continuous loop of more demand of water as the city continues to grow. Although the per person consumption has decreased, the overall population increase has raised the demand. To combat this, the City of Santa Fe passed a rate schedule in January 2008, published on the city's website, requiring citizens to pay a yearly fee, ranging from 4 USD to 750 USD to support water conservation programs (Anonymous).

2.9 Water Conservation in Santa Fe

Santa Fe has worked hard to conserve available water for their citizens and have succeeded with this endeavor. After the droughts of 1996 and 2002, the need for long term conservation planning was recognized. The City of Santa Fe Governing Body has worked since to decrease the water consumption throughout the city. As seen in Figure 24, these conservation efforts have caused the consumption per person in 2009 to decrease by 42 percent from the late 1990's. This is especially notable considering the steady increase in population over the years that would require the more use of water (Cross 2010, 1-58).

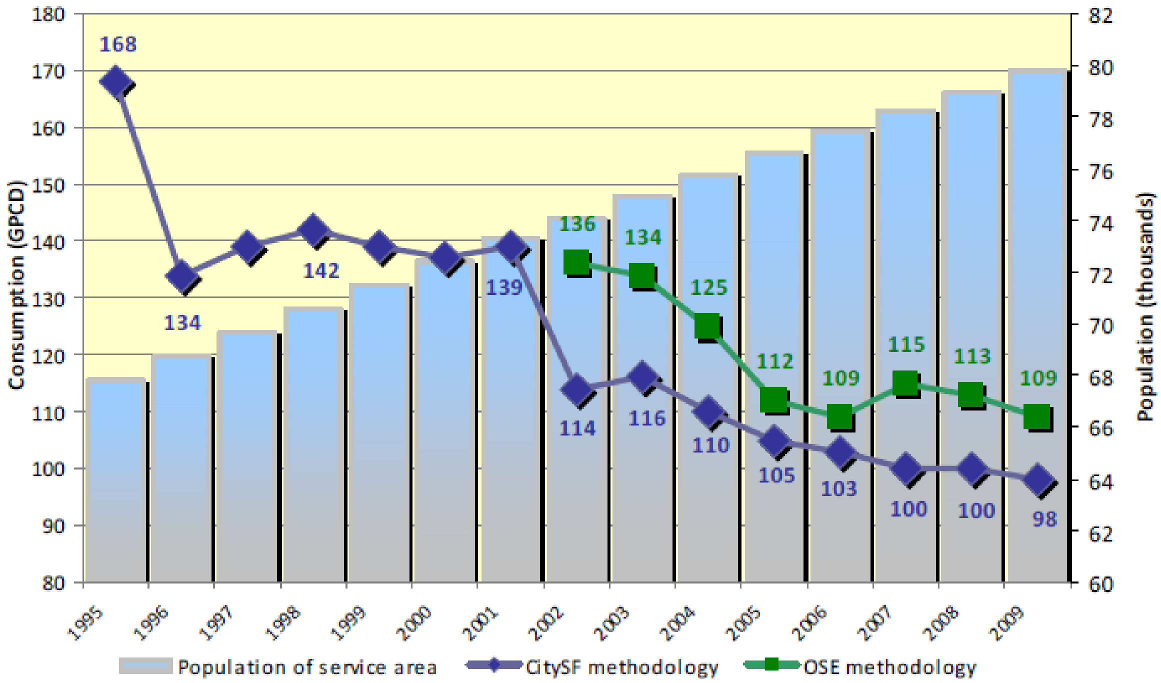

Figure 24: City of Santa Fe Per Capita Water Demand from 1995-2009

The water consumption has been successful through government regulations and citizen effort. Figure 24 demonstrates the water per capita demand (gallon per capita demand) versus population calculated by the city (CitySF) and state engineer (OSE). These include codes and ordinances to encourage conservation, the use of water efficient appliances, water-efficient processes and the reuse of water. The city's long term plan to further these conservation efforts includes increasing groundwater sustainably, optimizing the existing water rights and improving water quality. This is in hopes of minimizing the emergency drought restrictions and helping to convert the Santa Fe River into a "living river" (Cross 2010, 1-58).

The city has taken action to further decrease water use. Automated Meter Reading Devices (AMR) were part of a previous city water project and were installed to residential and commercial customers in order to help to educate the citizens on the exact amount of water used. The benefits of these meters allowed continuous leaks to be noticed more rapidly and allowed the citizens to change their water usage habits based on the meter readings. Many citizen awareness campaigns exist, ranging from posters, DVDs, educational classes, poster contests and festivals. They also provide incentives for buying water saving devices though the use of rebates. Combined, these efforts have decreased the overall water use in Santa Fe however; there is still enough excess water to fill the Santa Fe River (Cross 2010, 1-58).

2.10 Citizen Engagement

While citizens are aware that they need to conserve water, they are not aware of the current condition of the river. The people of Santa Fe were asked, "What is the closest river to Santa Fe?" Some of the responses were the San Juan and La Chama, one man even said "It's not the Santa Fe…" When they were told it was the Santa Fe River, one woman responded with "Is it the Santa Fe? But there's hardly ever any water in it." It is comments like these that are motivation for our project; we want to educate citizens about the river and its progress. (Anonymous2011)

2.10.1 Citizen Involvement

Every year, Santa Fe holds a fishing derby in the Santa Fe River, which is sponsored by the city and the Santa Fe Watershed Association. Water is released from the reservoirs and the river is stocked with fish. Citizens can come out to the river and fish for free for one day; there is entertainment and food as well, it's an all day celebration of the river. After the day celebration the city is able to make commission by having citizens purchase fishing licenses.

Awareness is also spread about the river through planting days along the river. Wild Earth Guardians sponsors the event, in which citizens volunteer planting along the river bed to prevent further erosion. However, these days are normally only attended by those citizens who are already committed to the river, and not the average citizen.

2.10.2 Crowdsourcing

One way to directly engage citizens is through crowdsourcing. This occurs when a large group of people, typically outside of traditional employees, gather information and ideas to benefit the company (Anonymous 2012). The advantages to using crowdsourcing is that the large group of people will be able to gather information that it would normally be time consuming and costly to have standard employees collect this information. It also allows for more time and data points. Another advantage is when advertising for citizens to collect information; it helps to raise awareness for the cause that is being dealt with. However, the disadvantages of crowdsourcing is that the information is being gathered might not always be collected correctly, therefore the cost that is put into creating the forum for the data collection will not be paid out by the amount of information that is collected, and that it would have been more cost effective to use employees {{723 Anonymous;}}.

Crowdsourcing has made a leap forward by being used though a mobile application. In 2009 the Children's Hospital in Boston created an application called MedWatcher (Anonymous) which allowed users to update information about the adverse side effects certain medications were causing. The creator of the application, Clark Freifeld describes his hopes for crowdsourcing in a quote he made about the application, "[MedWatcher would] prompt increased participation in surveillance, empowering people to participate in the public health process" (jessicaday603 2011).

The popularity of cell phones has increased since their popularity increase in the 1990s, to a record of 90 percent of Americans owing a computerized gadget, 85percent owning cell phones (Gahran, Amy 2011).The popularity of the mobile phone, and now the data plan containing application and internet access allows a broader use for the phone, other than just making phone calls. The first applications were created in 2008 after the introduction of Apple's iPhone and their popularity skyrocketed within the first weekend of their release (Rowinski, Dan 2012) Although the popularity of Applications were outranked by surfing the web in 2010 with the average user spending approximately 64 minutes a day browsing the internet, while only 43 minutes using applications. However, in January of 2012 it was states that the tides have finally turned, where

Americas are using 72 minutes on the web, with 94 minutes devoted to the use of applications. This increase in popularity of the mobile application encourages following the trends and appealing to citizens in a way that allows them to use the devices that they already have in a process that they are already engaging in.

2.11 Project Organization

The goal of this project was to enrich the collection and organization of environmental information to benefit the Santa Fe Watershed Association and the City of Santa Fe in their goal of making restoring the Santa Fe River into a "living river." This goal was achieved through the implementation of the following objectives.

- Develop an online repository for watershed information
- Design a mobile application and companion website to engage citizens in the river restoration process
- Demonstrate usefulness of application for educational and planning purposes

The first objective of this project was to create an online database that compiles data of the Santa Fe River from previous years to present obtained from the Santa Fe Watershed Association and the City of Santa Fe Water Division. For the purposes of this project, SantaFedia.org is the location of this database. The second objective, engaging citizens through the use of a mobile application, was addressed through the development of a data collection mobile application. Types of data collected include photo history, temperature, water flow, pH level, etc. Through the GPS capability of smart phones, citizens are directed to pre-established photo points. Once at a designated photo point, users are instructed how to capture images for the given location. These photos are used to create a visual history of those particular sections of the river. All of the captured photos are then stored on the companion website, where users can manage their photos.

This project spanned from March 18th to May 4th in the year 2012. The project had a focus on the urban reach of the river, through downtown Santa Fe along the newly created Santa Fe River Trail. Listed below is a schedule of events for the course of this project upon arrival in Santa Fe, NM. We had weekly sponsor meetings very Tuesday morning and advisor meetings Thursday afternoons to make sure our project was on track. The exact schedule of our time in Santa Fe can be found in Appendix A.

3 Online Watershed Data Repository

When creating an online repository, there needs to be reliable information sources that are able to be transferred to the host site. The collected data also needs a form of organization. There are various ways of displaying the information and programs that can be used with this data. The most important aspect of this data repository for our project is for it to be available to anyone; this will achieve our objective of making this data more easily accessible to citizens.

3.1 Methodology

To achieve our goal of creating a database of watershed information, water data was collected from all possible sources to allow for completeness. Water information regarding the river and stream gages was found online from the Unites States Geological Survey and the City of Santa Fe Water Division as is illustrated in Figure 25. Once data was collected, it was imputed into Google spreadsheets and was added to SantaFedia.org along with analysis of the collected data.

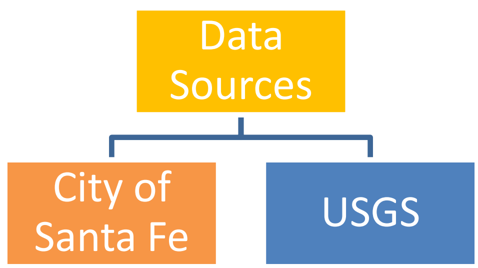

Figure 25: Data Collection

3.1.1 Obtaining water consumption and river gage data from the City of Santa Fe

To obtain data from the City of Santa Fe, the Water Division section of their website was first researched. On this website, water flow data is available for three of the river gages. Our liaison from the Water Division, Claudia Borchert, connected us with the most recent data from those gages. In addition, we also needed to gather water consumption and distribution trends from the city. The available water reports contain trends from the recent year, but historical trends would also be useful. However, water distribution is sensitive material and can be difficult to collect, so we determined that it was not necessary to have. Various water report documents were found on the city's website and can be analyzed statistically to educate citizens about the condition of the river and will be presented on SantaFedia.org articles. Figure 26 shows the specific data categories we have obtained.

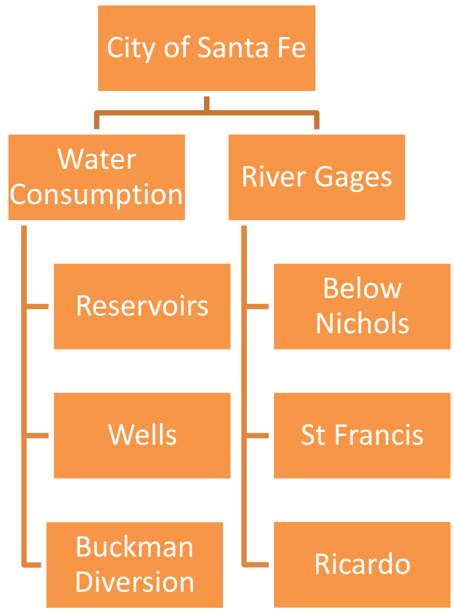

Figure 26: Data Collection from the City

3.1.2 Obtaining data from the United States Geological Survey

The United States Geological Survey (USGS) has a large amount of data available for the river and reservoirs. We obtained annual river flow and river pollution data as well as reservoir storage and daily precipitation levels. The precipitation data is measured at two separate locations, one at the McClure Reservoir and another at the Nichols Reservoir. We have also combined the well data we received from last year's project group with the well data found on the USGS site. Our goal was to collect data dealing with the accumulated river flow, reservoir level, and well levels and place it into one central location. Figure 27 illustrates the specific data we will obtain.

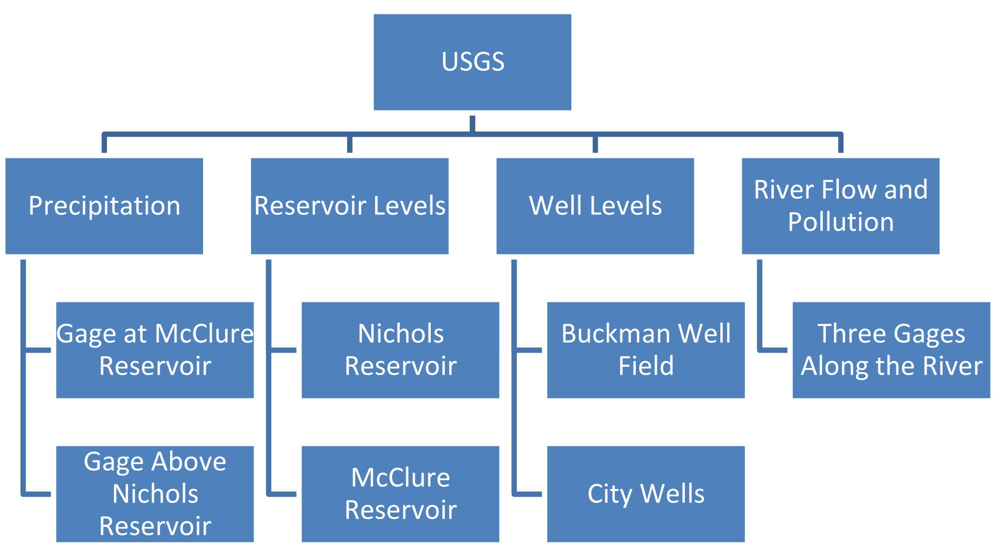

Figure 27: Data Collect from the USGS

Explanation of Santafedia.Org

Through the development of an online repository to store watershed information, the data storing program used is discussed below.

SantaFedia is a WPI created Wikipedia website about Santa Fe, NM. It contains articles that students have written whom are working on their Interdisciplinary Qualifying Project in Santa Fe. The data collected is embedded in SantaFedia so that it can be accessed from the website as well. Water related articles have been added to represent trends and data collected.

3.2 Results and Analysis

Our collection of data and analysis of the information has resulted in several SantaFedia pages. These pages were used in a data collection and informative way. Some pages are used in a purely data format, while others are more informative about the general subject of the page. An example of a Santafedia page is shown in Figure 28. Topics include photo points, stream flow gages and various aspects of the Santa Fe Water Supply. Certain pages contain the data that is being collected by our phone application, including probe data and the photo history. All of the Santafedia pages are listed in Appendix B.

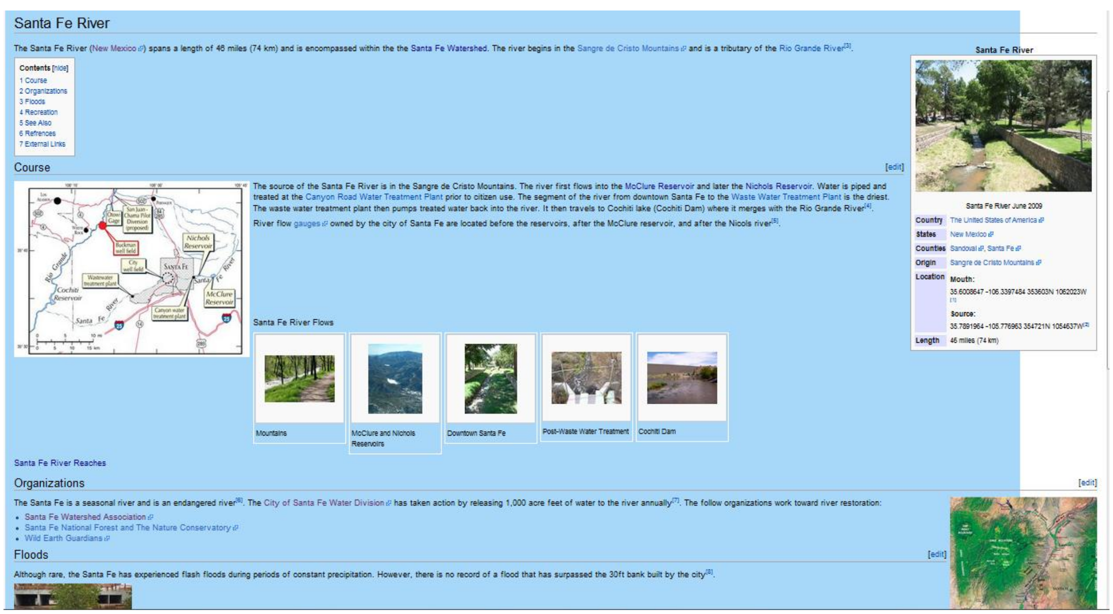

Figure 28: Santafedia Page about the Santa Fe River

All of these pages are located on SantaFedia, one central location for information on Santa Fe. This central location was used with the intention of making information more easily accessible by having it in one place.

3.2.1 Photo Points SantaFedia Pages

There is a general photo points page that directs to every photo point along the Santa Fe River. This page describes what a photo point is and where all of them are located. The page contains an interactive map to make the locations of the points more observable. Most photo points are on public bridges, but a few are along the path next to the river. Figure 29 is the Santafedia page that is an overview of all of the bridges that cross over the Santa Fe River, where a majority are used as photo points.

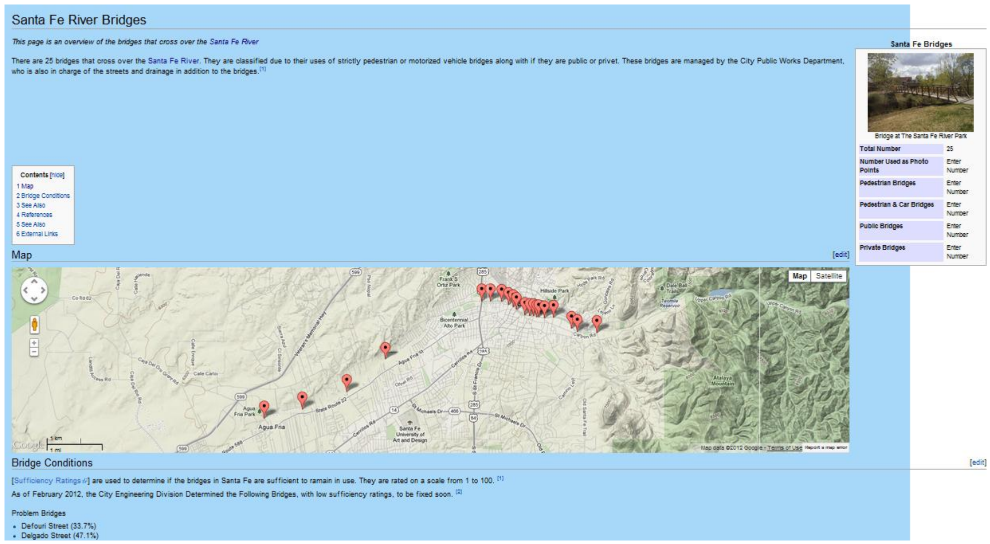

Figure 29: Santa Fe River Bridges Overview

By using a link within the page to a photo point, one can view a page of a specific location. On these pages, shown in Figure 30, the most current photo is displayed on the upper right hand corner. There are sections describing the intersections, displaying the photo history, a photo of the bridge at which the photo point is on, and various statistics of data that has been collected in the areas. Located on the bottom of the page are links to other photo points and various other pages where river topics have been discussed.

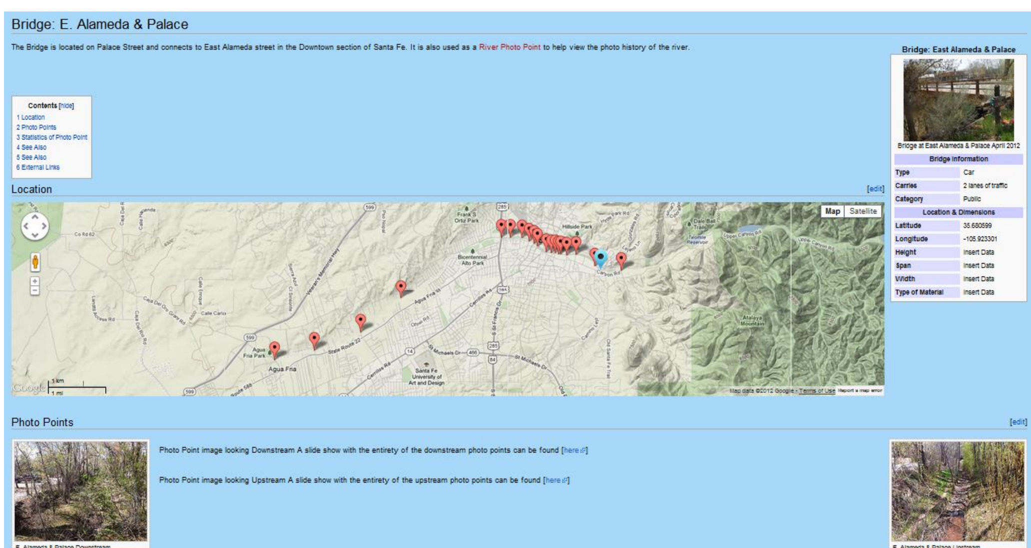

Figure 30: East Alameda & Palace Photo Point Bridge Santafedia

3.2.2 Stream Flow Gages SantaFedia Pages

Each of the stream flow gages have separate pages, all of which are linked via a general page, Figure 31. This overview page describes what type of gages they are and how the data is collected, as well as the various locations of the gages. Like the photo points page, this page also has an interactive map showing the locations.

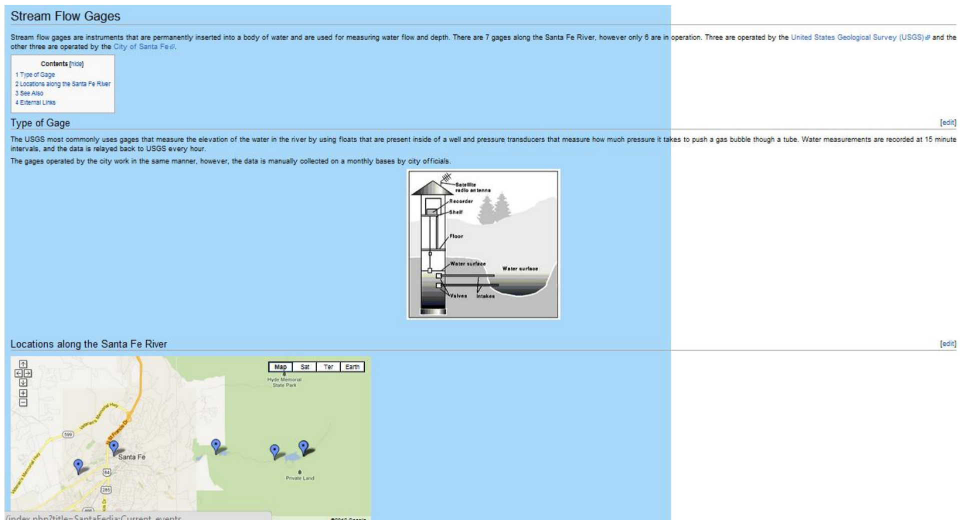

Figure 31: Stream Flow Gages Santafedia Pages

The individual pages contain the data associated with each gage, an example seen in Figure 32. There is an interactive graph displaying the data, a link to the processed data, and a link to the USGS website with the raw data.

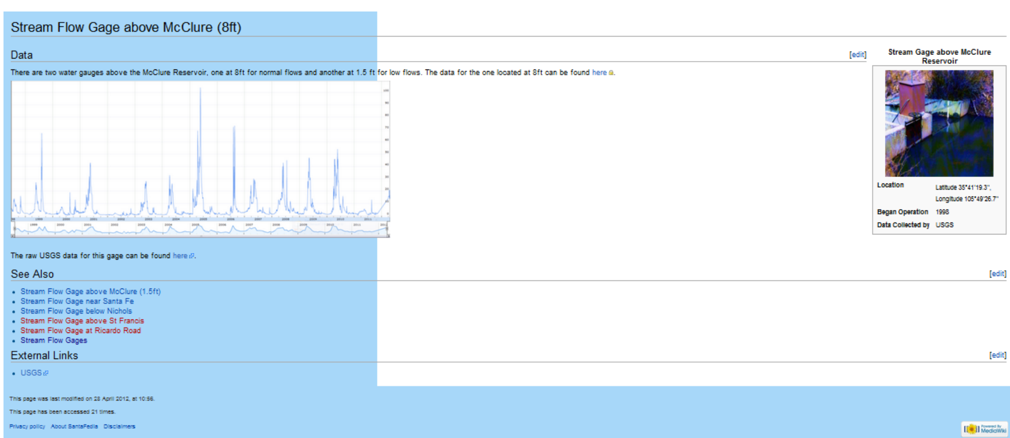

Figure 32: Stream Flow Gage above McClure

3.2.3 Santa Fe Water Supply SantaFedia Pages

There are a number of pages that contain general information about aspects of the water supply. There are pages directly relating to the water supply like the Nichols and McClure Reservoirs, Figure 33, as well as the water treatment plants. Pages also exist related to the river itself, such as acequias and the Santa Fe River.

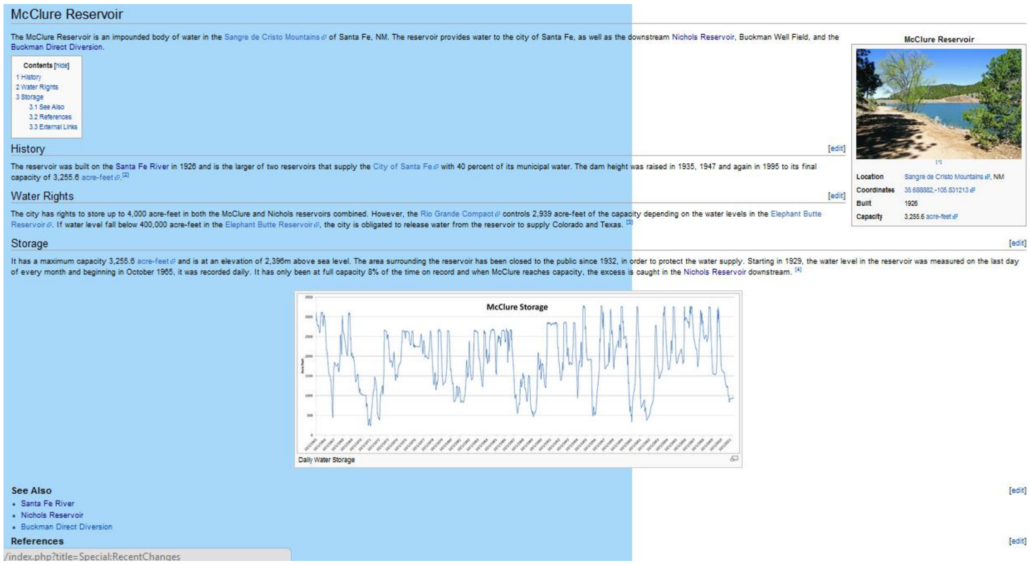

Figure 33: McClure Reservoir Santafedia

The rest of the Santafedia pages can be found in Appendix B.

3.2.4 GIS Maps

Geographic Information System (GIS) maps allow for geospatial data to be mapped on interactive maps. This technology was utilized for this project to spatially represent data. The purpose for the integration of this technology was to allow for the generation of custom maps to be used within the developed SantaFedia.org pages, website, and application mock-up. Programs utilized for this purpose were Google Maps as well as GIS Cloud.

Created maps were developed from both obtained data and established coordinates. Maps from obtained data from the City of Santa Fe and the United States Geological Survey include a map of the USGS river flow gages. In addition prior GIS layers were obtained from the city representing the watershed, hydrology, bodies of water, wells, Buckman well, and vegetation. Unique maps were also composed of data points established for the purpose of this project. These maps include the establishment of photo point, river nodes, and river reaches. All developed maps are located within Appendix F.

4 Mobile Application

We felt that a phone application would be the best way to collect data as well as share that data. The phone has many capabilities that are useful for our envisioned mobile application. The popularity of the smart phone has significantly increased over the last decade; since the Smartphone debut ten years ago, 35 percent of Americans are now Smartphone users (Anonymous2011). With the popularity of Smartphones, we want to include citizens in the river's restoration and encourage them to follow the river's progress. A phone application is the best way to spread the information and make the interaction with the river engaging.

4.1 Methodology

The reasoning behind the use of a phone application was to engage and educate the citizens about the status of the Santa Fe River developed for several reasons. Presented information is easily accessible and convenient for all Smartphone users.

4.1.1 Defining Application Criteria

The main technology that the mobile application emulates is the Digital Earth Watch (DEW) (Anonymous 2011). This program encourages the users to take pictures of the nature areas surrounding them. To ensure that the correct photo locations are taken GPS location directs the user to a specific location while an onion skin layer is used to overlay the camera so the user can match up the surrounding area. This application is demonstrated in Figure 34.

Figure 34: Screen Shot of DEW Application
(Image: Android Market)

The second program that this application emulates is Picasa, which allows the user to upload pictures to an online website. It automatically puts the photos into a map and sorts them by location and date for future viewing (Anonymous 2012)

4.1.2 Developing Preliminary Design

To address the second objective, we first had to establish the aesthetics of the application. The application would be linked to a website that contains all of the data on the river. Users can access the application on their Android smart phone when along the river, where they will be prompted to take observations of the river though the use of qualitative, quantitative and photo points. They will also be able see the data that is already uploaded about that point along the river that they are currently located at. Figure 35 shows the main page, on the left, and one of the ways of entering an observation on the right.

Figure 35: Illustration of Phone Application

The following programs were used in the creation of this mobile application design:

The Photo Point aspect of the application will be based off of the application Digital Earth Watch (DEW). This application design will allow us to create an onion layer view of the photo that will allow the user to directly match up with the previous photos for accurate photo history.

Picasa is a photo containment site that is hosted by Google. Picasa will allow photos to be uploaded to an online database through the use of a computer or from a mobile devise. When a user selects to add to the photo history, the photo will be uploaded to a Picasa account that can then be accessed and linked to the general database.

Photoshop was used to create the ions that were seen in the application.

PowerPoint is used to put all of the icons and images together along with making an interactive mock up.

4.2 Results

Our application prototype allows the citizens to interact with the Santa Fe River by taking data points and contributing to the Santa Fe Watershed Association and the City of Santa Fe's collection processes. In the end our application was able to take different types of data on the river. These three different types are Photo Points, Observations and Measurements.

Photo points are important to show the visual history of an area over time. This allows the impact of the lack or addition of water over time to be seen in Figure 36. These figures show the river in the same location with a difference of 91 years. The photo on the left with a fully running river is a drastic difference from the photo on the right where the river has run dry for many years. This visual history shows how much of an impact not having water in the river can have. For all of the current photos of the Photo Points can be found in Appendix C.

Figure 36: The Santa Fe River in 1910 (Left) and 2001 (Right)

To perform this function the user finds the location that they are currently at and selects the option that allows them to add a photo to the history; these two instructions are shown in Figure 37. These locations are normally located on bridges that are easily accessible to pedestrians. Bridges are chosen because the photo can be taken in the middle of the river and see further up and down the river.

Figure 37: Map & Map Options View

Once the user decided to take a photo they will be prompted to take four photos, one facing upstream, one facing downstream, one in the river bed and the last up to see the overhead foliage. As each photo is taken a 'compass' in the corner will partially change colors as each photo is taken. A set of example photo is shown in Figure 38.

Figure 38: Different options for adding a Photo Point

To ensure that the photo points are in the same locations on onion skin layer will show up over the camera view helping the user to line up the photo to the exact location. This layer is also in the photo point examples shown in Figure 38.

The next way data can be imputed is though the observations. These observations are qualitative, meaning that they are simple yes or no questions about the river. These observations pertain to if there is litter in the area along with if there is water and if the water is flowing. To answer these questions the user needs to simply select yes or no. There is also an option to take pictures of notable observations in the river, even if it is not at a set photo point. This page can be seen in Figure 39.

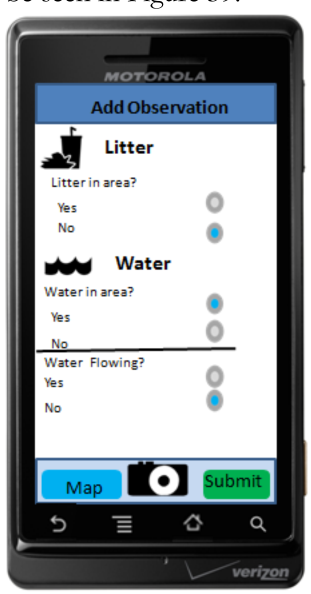

Figure 39: Add Observations Page

Quantitative information is added in the third way through the measurements function. There are two ways to add these types of measurements, the first is to use probes that are able to connect with the phone and automatically update the measurements. The phone will recognize that the probes are present and read the data to upload. Figure 40 shows how the probes interact with the phone and how the application would input the automatically detected information.

Figure 40: Pasco Probes Connecting with Phone and automatically detecting information page

If the user does not have a probe at hand then they can manually enter the information though the manual entry pages depicted in Figure 41. By selecting the type of data that they would like to input, including pH, river depth, flow speed, dissolved oxygen, temperature, conductivity, turbidity, water quality colorimeter and an option to add other data. Once selecting the type of data to be imputed the page contains a slide bar or a type in option to enter the data along with a description of the type of data that is being imputed into the application. The slide rule shows a visual measurement of the data (depth, temperature or on a pH scale) while the description ensures that the user is taking the correct measurement.

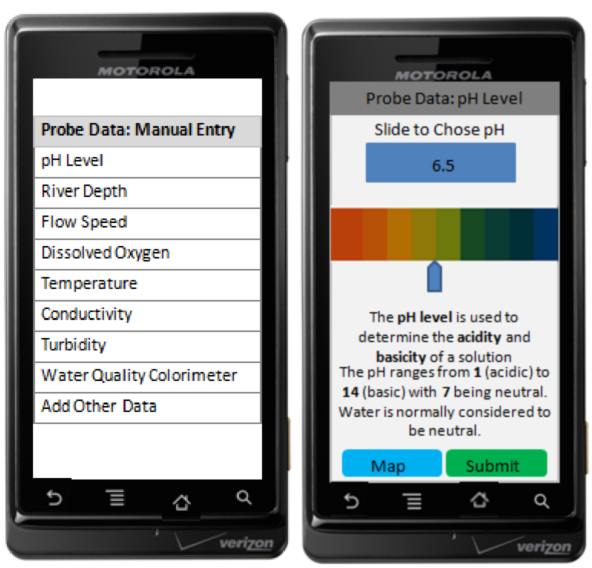

Figure 41: Manual Data Entry Pages

The citizen engagement and involvement does not stop at just collecting information, but at feeding it back to the user so they can learn about the river in the process. The phone will allow a user to choose the location where they would like to see data on the river. The page will then show a photo history of the area though a slide show along with the max, min and median measurements of the data taken in that particular river reach that the location is a part of (Figure 42).

Figure 42: River Facts Page

The information is also feedback on the river locations page where the user can see the data measurement locations that were taken in the last 10 days, as depicted in Figure 43. This will encourage the user to take a data point in a different location.

Figure 43: Map Showing Data Points in Last 10 Days

The full extent of this application and all of its functions can be seen in Appendix D.

4.3 Conclusion and Recommendations

Overall the applications uses crowdsourcing though the use of data collection to engage citizens in the monitoring of the river and getting involved to push for more conservation of water and for water to be placed into the river year round. This interactivity will entice tie citizens to become more involved and aware of the problems that a lack of water can cause.

Our group recommends that our application is created. We hope to find someone who has experience coding a mobile application and will be able to make the program. One of the major problems with this request is that it requires funds to hire the developer.

Once the application is made it is recommended that the application is tested, feedback from citizens is considered and it is improved upon to make sure that not only all of the desired functions work, but that its main purpose of engaging the citizens is working properly.

The last recommendation for the application is to start the photo history even without the phone application. We suggest using the Flikar or Picasa phone application to take pictures that are automatically uploaded and organized by location. This will help the visual history start up even though the application is not yet functioning.

5 Application Companion Website

Many phone applications have websites that mirror the app and contain all of the same information. The companion website allows users to view the information that would be on the app from any home computer or any other device that has a web browser. This is important because it allows users to view their information on a larger screen and contain more information than their smart phone. The website should also be a host to many features that are not available to the phone such as charts and graphs as further in-depth photo histories and account management.

5.1 Methodology

The website also allows a place for citizens to download the application. If someone searches for the River Restoration website, it allows them to download the app straight from the website instead of having to go into the Android market on their phone. The website not only allows information to be spread but also involving them with the data collection by making them aware of the application. Users are able to monitor the information on the website after they gathered it and watch as others add their information.

The first step in developing a website is to determine what must be done and what purpose the website serves. In our case, the website serves to supplement a mobile application. All the information gathered from the application should be available on the website. It is also important to determine the target audience. In our case it is the citizens of Santa Fe of all ages. Keeping this mind, it would be good to make the website user friendly, but without skimping on the details. Another point to determine is what purpose this site serves that other sites do not. In our case it is a site that serves to work with an app and update the data live. The second step is to design the actual website. It needs to have all of what was determined to be of importance in the initial site design. At this point is where we can determine what kinds of information can be on one page, and what kinds of information will need their own page. For instance, photo history would go on its own page while data like water temperature, turbidity, and depth could all be on the same page on a spreadsheet. We currently have a basic skeleton done for the website; all that needs to be done is to integrate code that displays the collected data. This will take place when there is a functioning app that can be used with the website. The final step is to secure a reliable hosting source and upload the website and have it go live.

5.2 Results and Analysis

Figure 44: Homepage

The ultimate goal of the website design is to give it an interface that mimics the purpose of the app while taking advantage of being on a web browser in an easy to read, highly compatible HTML format. Keeping this in mind, it no longer constrains the design to being on a mobile device, but at the same time it keeps us limited to what a browser is capable of (Figure 44). Thankfully because of advances in HTML, languages such as HTML5 and JavaScript allow for web browsers to do almost everything an app is capable of. The initial goal of the website was to display the information that was gathered from the application as well as serve in distributing the application. There are also links (located in the River Facts section) on the site to go to various SantaFedia pages as well as pages on the site explaining certain properties of water (such as turbidity, water depth, conductivity, etc.). There is a page where someone can scan a QR code on the page and download the app directly to their phone. The website allows users to manage their photos that they have taken; there is user profile page to help manage that (Figure 45).

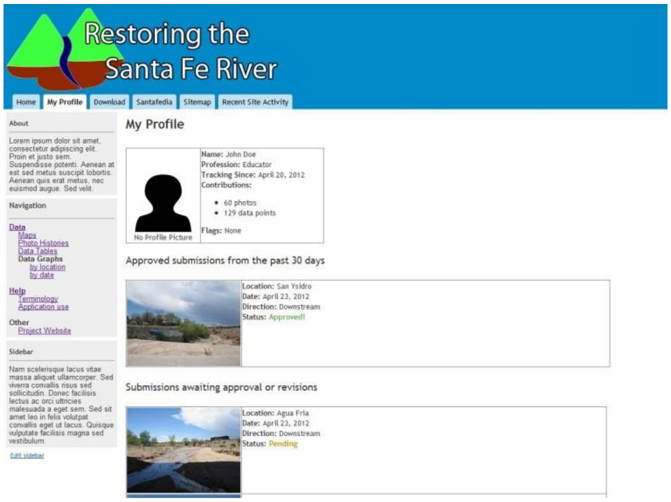

Figure 45: User Profile Page

5.3 Conclusions and Recommendations

It would be possible to also add a functionality that allows users to input data on the site. This would allow anyone who does not have a phone compatible with the application to take down measurements while on the river or possibly take photos and when they reach a computer, they can upload their data and photos from a specific photo point.

6 Citizen Engagement and Usefulness

The Santa Fe River currently has very little water flowing through it, only when there is a rain storm. This water barely sustains the river flow and for most of the year there is no water in the river. In hopes of revitalizing the river, the city passed a bill that requires the city to release water into the river annually depending on the rain fall of the year. This ordinance sets a precedent for other cities with in New Mexico, as Santa Fe is the first one to designate water strictly for the river's use. With the river's health improving do to its water allowance, our project worked to engage citizens with the river restoration and collecting data to follow the rivers improvement. Our main target audiences for this engaging and data collection are the citizens and schools within Santa Fe. We feel that all of our projects components can be useful for educational and planning purposes.

6.1 Educational Usefulness

Educating citizens within Santa Fe is a goal of our project, but educating students within Santa Fe is also important because they are the ones that will be taking care of the river in the future. Some of the schools already have river education programs implemented in their curriculum and have water probes that they use on a regular basis to take data on the river. Our app will allow them to input the measurement values directly into the application where it would automatically compiled the collected information which can be easily accessed from any classroom via the companion website. A website currently exists that complies some of the schools data, but it has to be inputted on a website at a computer and is not used by all the schools. Our app allows them to input the values in the field where it is very convenient. Teachers can use the companion website as an educational tool in their classrooms to analyze the data. They would be able to go down to the river and use the gages to measure the pH along with other measurements, and input the data into our application. This data would be available to anyone using the app after it has been screened to make sure that it is accurate. The students could then bring their data back to their classroom and analyze it to observe any trends. The teachers could use our app as an effective learning tool and to educate their students about the Santa Fe River in a more hands on way. It is also an effective way of bring an added technological aspect to the classroom.

To further educate the students the application will have information on each of the measurement pages informing the students more about the type of measurement that they are recording.

As a good background to introduce students to the river, the SantaFedia pages can be view to provide a detailed history and information about various water aspects in Santa Fe and how they affect the river. The pages contain general information as well as data from the city and USGS which can be analyzed. This data is presented in interactive graphs and maps, so it will be more enticing for the students than just reading static data and maps.

6.2 Planning Usefulness

In addition to being useful for educational purposes, it is also helpful for planning purposes. Having citizens collecting information, it allows the city to be aware of the problem with the river more readily. They can sort through the collected data and find any issues that may need to be addressed. The photo history is one of the more helpful aspects of our application. By looking though the visual history, one can view the changes in the river flow and vegetation that result from the different environmental factors. The city can see if their restoration projects are in fact helping the river (Figure 46) or if there are sections of the river that need modification. Effectively this crowdsourcing method allows for more data points and less effort on the part of the city thanks to citizen involvement.

Figure 46: New River Construction at Frenchy's Field

7 Conclusions and Recommendations

Our project results in educational web pages, a database of watershed information, and an application design and companion website. All of these aspects work in conjunction with each other to help educate citizens about the Santa Fe River and to assist the city in collecting information about the river. However, we are restricted to a short 14 weeks to design and complete our project, so there are additional things that would be helpful and we would like to see done.

Every aspect of our completed project is connected with one another. The SantaFedia pages contain GIS maps of the phone application photo points which can be viewed on the companion website. It is all combined and one aspect would not be up to its full working ability without the other.

The shared database, in the form of SantaFedia, is completed and we are in the process of handing our water pages over to our sponsors so that it can be maintained and carried out for future use. The GIS maps which we received from last year's group have been updated to the best of our ability and modified to be more helpful. We have also created our own maps, which help to illustrate the river more clearly. Our application design and companion website have been created in a detailed form so that a programmer will be able to make the two with ease and be able to connect all four components of our project together.

7.1 Future Work

Due to time constraints we were not able to accomplish all that we wanted. Here is a detailed list of recommendation for the future to continue this project and make it even more of a success.

7.1.1 Application

We hope to see this app programmed and fully developed by either the city of Santa Fe or the Watershed Association.

- Conduct Programming
- Link Application to interactive maps, SantaFedia, and Restoring the Santa Fe River
- Publish app on Android Market
- Develop and publish application for Apple products

7.1.2 Educational Outreach

We hope to see the Santa Fe Watershed Association integrate this into their education program as well as advertise this to the schools in Santa Fe.

- Receive confirmation of helpfulness for educational use
- Integrate application into school programs
- Expand school focus with a kid friendly aspect

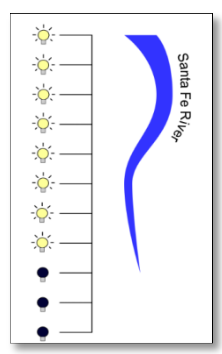

Figure 47: River Flow Notification Mock Up

7.1.3 River Flow Notification System

Implement LED system on existing Adopt-a-River signs to alert citizens of the present location of water in the river. As the water reaches the sign, LED lights will be turned on to notify citizens. A mock up can be seen in Figure 47.

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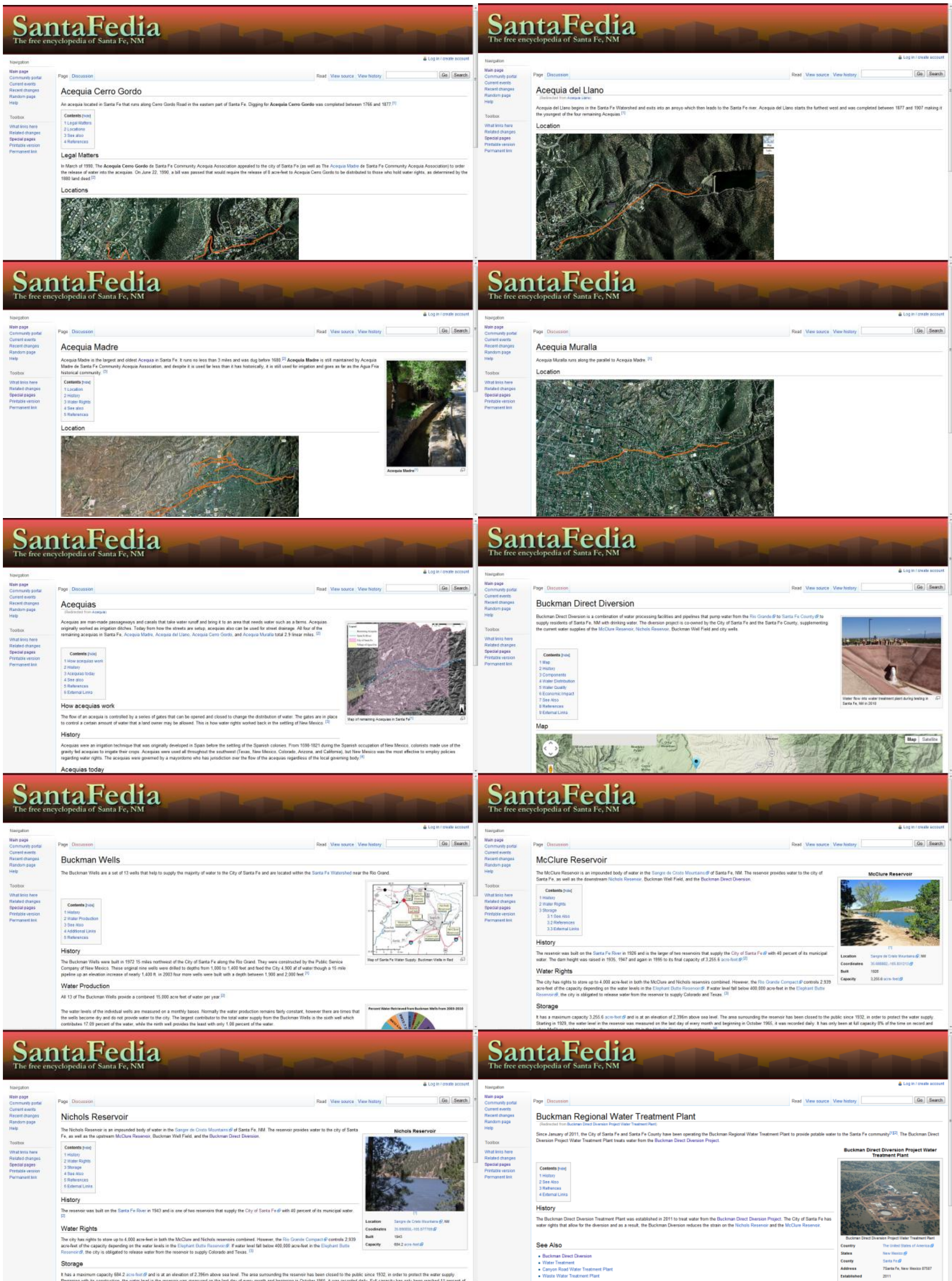
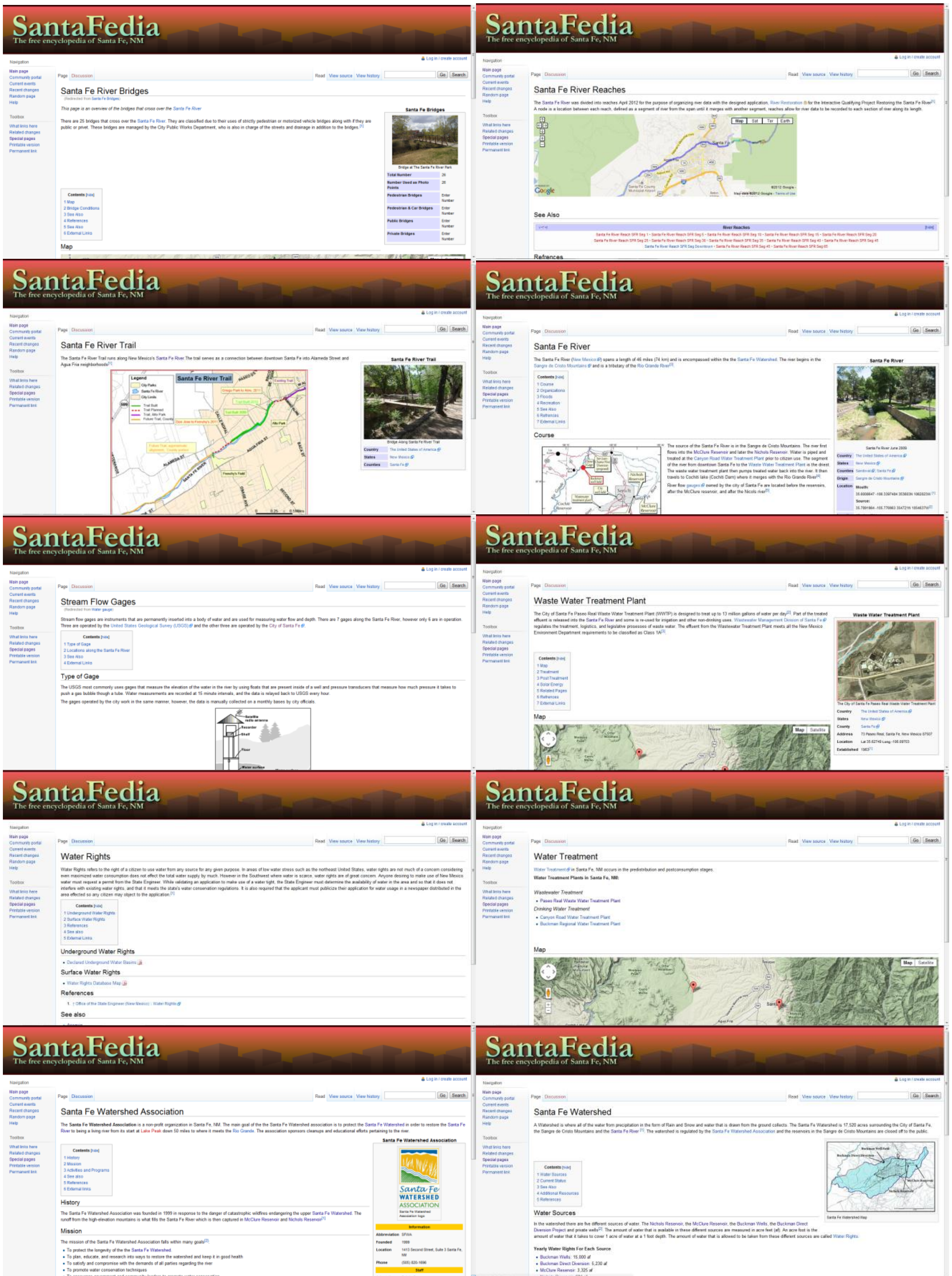
9 Appendices

9.1 Appendix A: Schedule of Project

March 19th: Meeting with advisors; Introduction to the Santa Fe Complex
March 20th: Meeting with Claudia; River Commission Meeting
March 21st or 22nd: Meeting with Felicity & Visit River Sites
March 23rd: Methodology Finalized
March 26th-April 4th: Edit Background & Finalize
March 30th: Wiki Page Outlines Created
March 31st: Wild Earth Guardians Santa Fe River Tree Planting Day
April 2nd-Apri 30th: Work on Executive Summary
April 9th: Finalize Deliverables
April 13th: Application Design & Database Finished
April 16th -30th: Write Results
April 26th: Alumni Event/ Poster Presentation Due
April 30th: Presentation
May 4th: Project Due

9.2 Appendix B: Santafedia Pages




SantaFedia
The free encyclopedia of Santa Fe, NM
Santa Fe River Bridges
Santa Fe River Reaches
Santa Fe River Trail
Santa Fe River
Stream Flow Gages
Waste Water Treatment Plant
Water Rights
Water Treatment
Santa Fe Watershed Association
Santa Fe Watershed

9.3 Appendix C: Photo Point Photos

E Alameda & Palace – Upstream (3/28/12)

E Alameda & Palace – Upstream (4/10/2012) | **E Alameda & Palace** – Down (4/10/2012)

E Alameda – Upstream (3/28/12) | **E Alameda –** Upstream (4/10/2012)

E Alamado & Delgato – Upstream (3/28/12)

E Alameda & Delgado – Upstream (4/10/2012) | **E Alameda & Delgado** – Downstream (4/10/2012)

E Alameda & Paseo De Peralta – Upstream (3/28/12)

E Alameda & Paseo De Peralta–Upstream (4/10/2012) |**E Alameda & Paseo De Peralta**–Downstream (4/10/2012)

El Castillo – Upstream (3/28/12)

El Castillo – Upstream (4/10/2012 | **El Castillo** – Downstream (4/10/2012)

Brothers Lane Bridge – Upstream (3/28/12)

Brothers Lane Bridge – Upstream (4/10/2012) | **Brothers Lane Bridge** – Downstream (4/10/2012)

E Alameda & Old Santa Fe Trail – Upstream (3/28/12)

E Alameda & Old Santa Fe Trail–Upstream (4/10/2012) | E **Alameda & Old Santa Fe Trail**–Downstream (4/10/2012)

E Alameda & Shelby – Upstream (3/28/12)

E Alameda & Shelby – Upstream (4/10/2012) | **E Alameda & Shelby** – Downstream (4/10/2012)

W Alameda & Don Gaspar – Upstream (3/28/12)

W Alameda & Don Gaspar–Upstream (4/10/2012) | **W Alameda & Don Gaspar**–Downstream (4/10/2012)

W Alameda & Galisteo – Downstream (4/10/2012) | **W Alameda & Galisteo** – Upstream (4/10/2012)

W Alameda & Sandoval – Upstream (3/28/12)

W Alameda & Sandoval – Upstream (4/10/2012) | **W Alameda & Sandoval** – Downstream (4/10/2012)

W Alameda & Guadalupe – Upstream (3/28/12)

W Alameda & Guadalupe–Upstream (4/10/2012) |**W Alameda & Guadalupe**–Downstream (4/10/2012)

W Alameda & Defouri – Upstream (3/28/12)

W Alameda & Defouri – Upstream (4/10/2012) | **W Alameda & Defouri** – Downstream (4/10/2012)

550 W Alameda – Upstream (4/10/2012) | **550 W Alameda** – Downstream (4/10/2012)

Santa Fe River Park – Downstream (4/10/2012) | **Santa Fe River Park** – Upstream (4/10/2012)

W Alameda & St Francis – Upstream (3/28/12)


W Alameda & St Francis–Upstream (4/10/2012) | **W Alameda & St Francis** – Downstream (4/10/2012)

E Alameda & Camino – Downstream (4/10/2012)

9.4 Appendix D: Application Mock-Up

Figure 48: Flow Chart of Application Mock Up

The full application mock up can be seen in a flow chart in Figure 48.

Title Page of Application

The home page, seen in Figure 49, has five different options that will allow the user to add different information about the river that will be uploaded to the corresponding website. It will also allow the user to view some of the data that has been uploaded and learn more about the river.

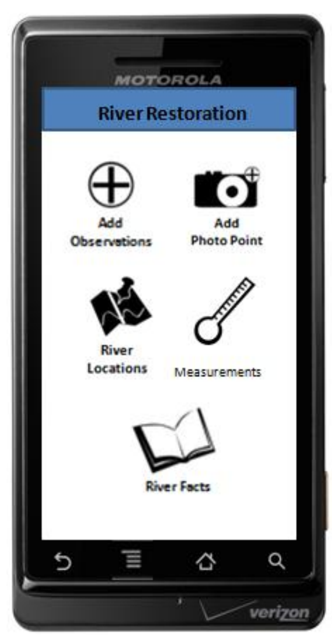


Figure 49: Phone Application Main Page

Add Observations

The first option is the *Add Observations*, which houses the different qualitative observations that can be taken without the use of external devises.

Add Photo Point

The *Add Photo Point* camera is used to add a new photo point to the list that has already been compiled. This part of the application is based off of the Digital Earth Watch application

River Locations

River Locations shows, though the use of a map and list, where the different data points are located along the river and helps to guide the user to the locations. There are two different types of data points; the first is a fixed photo point where the user needs to go to that location to take the photos. The other type is an observation which is shown though qualitative and quantitative observations.

Measurements

Measurements leads to imputing quantitative data through the use of interactive probes or other measurement devises. This section will be used by more than just the average citizen, but one who has more of a scientific background.

River Facts

The home page, seen in figure 1, has five different options that will allow the user to add different information about the river that will be uploaded to the corresponding website. It will also allow the user to view some of the data that has been uploaded and learn more about the river.

Add Observation

The Add Observation, shown in Figure 50, allows for qualitative data to be taken. The three different types of observations that can be taken is if there is litter present in the area, if there is water present and if the water is flowing. The user will input the data by selecting yes or no bottoms. The user is also able to take a picture if the area, allowing them to not have to take photos at the specific photo points. They are able to take pictures of notable litter and water in the area.

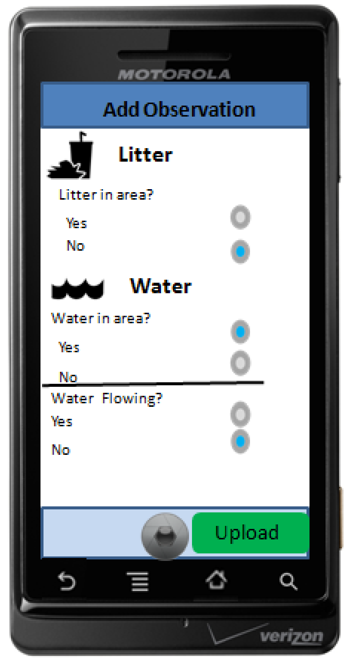


Figure 50: Add Observation Page

Add Photo Point

The add photo point function will allow the user to establish a new photo point at a location that has not already been established. The user will perform this function by first imputing the new name, description, location and the date of creation of the photo point. This menu is in Figure 52, Then the user would be prompted to take the first photo points in four different directions; upstream, downstream, the river bed and the sky. As each photo is taken the compass in the corner with the four different directions will change color as that direction is

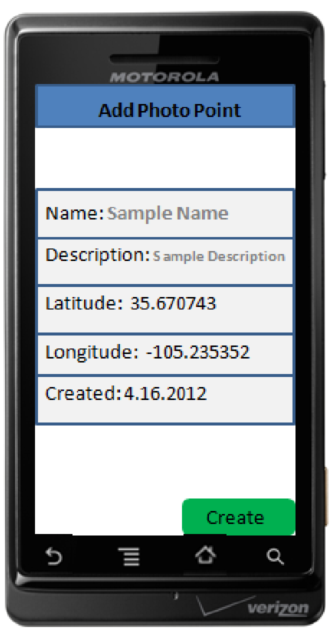


Figure 52: Add Photo Point Information Page

Figure 51: Add Photo Point - Upstream

Figure 53: Add Photo Point - Downstream

Figure 55: Add Photo Point - River Bed

taken. The original photos taken are show in Figure 51, Figure 53, Figure 55 and Figure 54. The photo points will show the changes in the vegetation and river flow over time. The image of the sky will allow the overhead foliage changes to be viewed.

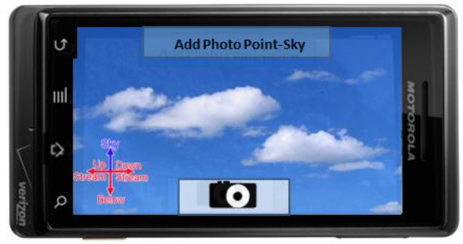


Figure 54: Add Photo Point - Sky

River Locations

Figure 58: Map - List View

The first option that will pop up is the list view of the different photo points (Figure 58). It will contain photos of the area along with an address and the distance of that photo point from the users' current location. The other that can be seen is the map view which shows where the photo locations are on the map. Shown in Figure 56. If that photo point is selected on either the list or map view, a bubble will pop up showing the options to add photos to that photo point, Figure 60seeing the facts and data that was taken at that location and the option to get directions to that photo point though the phone's map system shown in Figure 59. Another option that the user will have is to be able to view different maps that contain the different data points that have been taken. To get to this view they will open up a menu that will allow them to switch views (Figure 57). It will only show the points taken in the last ten days. This will encourage the user to take data points at different locations than those that have already been taken allowing for more data points to be taken. This will also allow the user to be able to add their own data points directly from that page. The different page options are seen in Figure 61.

Figure 56: Map - GPS View

Figure 60: Bubble Options

Figure 57: Map Switch to Different Options Page

Figure 59: Map Directions to Location

Figure 61: Different Map Views of Data Points

Measurments

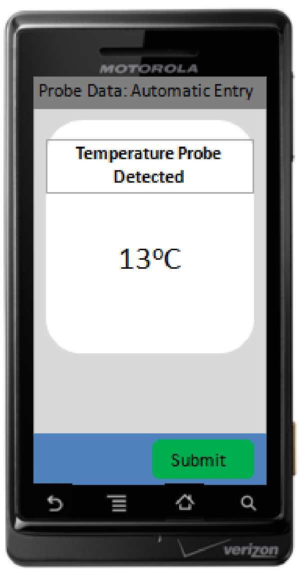


Figure 62: Measurements - Automatic Entry

This function of the app allows for quantitative data to be taken about different sections of the river. These observations include pH level, river depth, flow speed, dissolved oxygen, temperature, conductivity, turbidity, water quality colorimeter and an option that allows for addition data to be added.

There are two different ways this function works. The first is through the use of a probe that connects to the phone though the headphone jack or through a blue tooth connection. These probes will allow the data to automatically input the numbers into the phone before it is uploaded, shown in Figure 63 For those users who are able to take the measurements though other hand held devices they will have the ability to manually input the numbers. First the user will select the data they wish to enter from the screen in Figure 63. The data can be either typed into the bar or the slide rule moved to the corresponding area that produces the correct number. Also in the input page will be a description of the type of data that is being taken. This will help in the educational aspect of the application (Figure 64). We hope that schools will use our application and the students will be able to realize exactly what type of data they are taking. All of the different measurement screens can be seen in Figure 65.

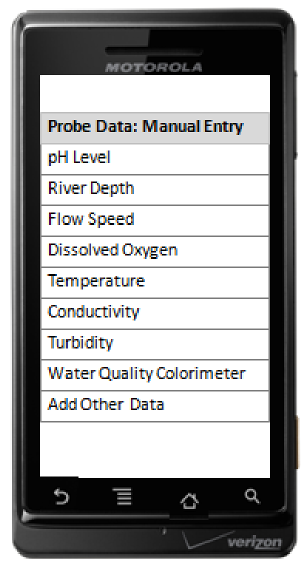


Figure 63: Measurements - Manual Entry

Figure 64: Measurements - Data Entry Page

Figure 65: All Measurements

River Facts

Figure 66: River Facts - Use Current Location

All of the information that is uploaded and sorted through the website is then able to be accessed through the application so the user can see a slideshow of the photo history along with the average measurements of the river reach that the photo point is a part of. This information will allow the user to be able to learn more about the river.

To access the information they will click on the river facts area and it will prompt the user to select the location of the data that they wish to view, the screen is shown in Figure 66. After the river location is selected the river data is presented with a slideshow of the photo history along with the average measurements of the data taken in the river reach that the photo point is a part of (Figure 67).

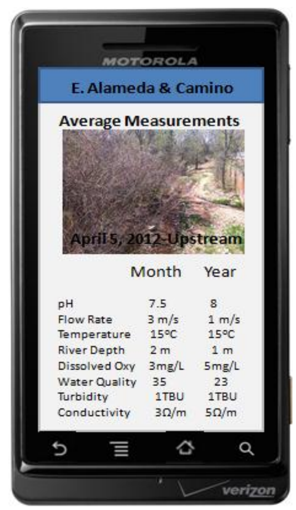
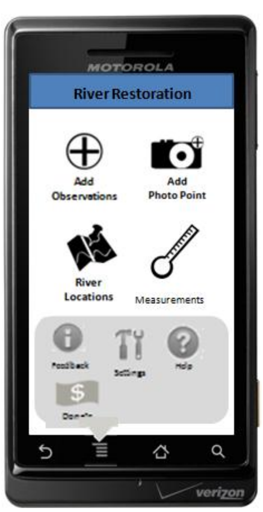


Figure 67: River Facts Page

Extra Menu



To access the extra menu the user must select the menu button on the application selection bar and the options of feedback, settings, help and donate. These functions will allow for a more personalized experience and can be viewed in Figure 68

Feedback

The feedback allows the user to input their opinion about the river and about the application

Figure 68: Extra Menu

Settings

The settings offer personalized experiences and control the user profile along with favorite locations and alerts. It also ensures that the GPS location device that is automatically in the phone is turned on. 7.3 Help The help function explains what each of the different symbols in the applications do and how to perform each of the functions

Donate

The user will have the option to donate directly from their phone to the Santa Fe Watershed Association.

Feedback

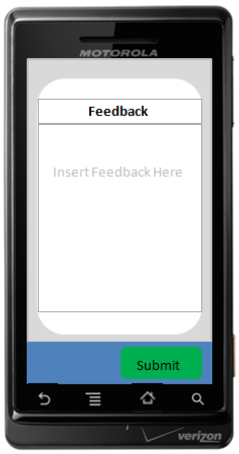


Figure 70: Feedback Page

The feedback menu will allow the user to write what they think about the application and about what they want to be done with the river in the format presented in Figure 70. This will encourage the users to have a voice about putting water back into the river. The feedback will go directly to the Santa Fe Watershed Association so that they can help be the voice of the citizens and push for more improvements to the river.

Settings

In the settings section there are four different options that will allow the user to personalize their experiences. On this menu (Figure 69) they have four different options to personalizing their application.

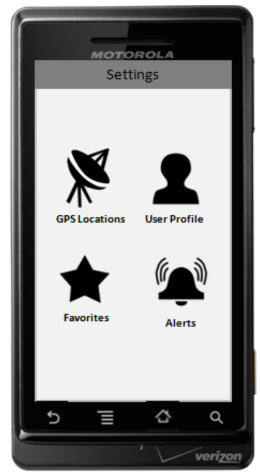


Figure 69: Settings Page

GPS

Figure 71: GPS Settings

The GPS settings, Figure 71, allow the information that is uploaded to have the location attached to it and allow for accurate results. It is used to ensure that the location is accurately recorded without the user having to provide more information. Once the data is uploaded to the website it will be sorted by the GPS location that it was taken at.

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User Profile

Figure 72: User Profile Registration

The user profile works to connect the phone and website together. The user creates a profile with their full name, a username, password and their e-mail on the screen in Figure 72 and logged-in in Figure 73. This login allows the user to view the data that was uploaded from the application on the online website. The user can then see if their data was accepted or rejected. The reasons that the data can be inaccurate is due to reading instruments wrong and photo points can be too blurry or of the wrong location.

Figure 73: User Profile Signed In

Favorites

The favorites option allows the users to bookmark their favorite locations for data points and river feedback. To add a favorite location the user selects the add favorites button in Figure 75 and it shows a list of the different photo points. The user then selects from these points which location they would like to add to their favorites.

Once a favorite is added, they are able to just select the favorite and have the option to add data, view the river data at that location and a take me there option (Figure 74).

Figure 75: Favorites Home Page

Figure 74: Favorite Options

Alerts

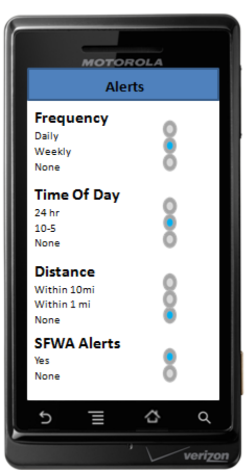


Figure 76: Alert Options

The alerts option encourages the user to take more photo points by allowing the application send alerts to remind the user to take data points. The user can select to have these alerts occur at different frequencies, time of day, distance from the river or if there are special Santa Fe Watershed Association (SFWA) alerts by selecting them in Figure 76. The alerts would go out when there are notable changes in the river, an example being when water is released to flow down the river.

Help

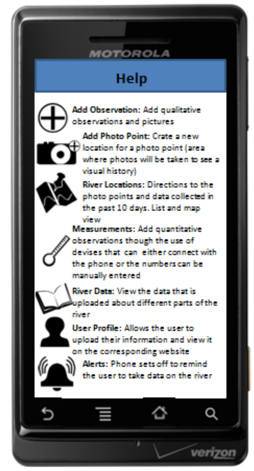


Figure 78: Help Options

The help function is fairly self-explanatory; it shows a list of the different icons and walked the user though using the application (Figure 78).

Donate

Figure 77: Donate Page

The users are able to donate to the Santa Fe Watershed Association to help benefit the river. The Santa Fe Watershed Association was chosen over the City of Santa Fe Water Division because one is able to donate to the SFWA online while the City of Santa Fe has to be donated in person. The application will redirect the user to the Pay Pal section of the SFWA website depicted in Figure 77.

Upload Notification

Once a user hits the upload button the same notification will show up, telling them that their information has been uploaded. Figure 79 shows this page that will also have an option to encourage the user to Donate to the Santa Fe Watershed Association.

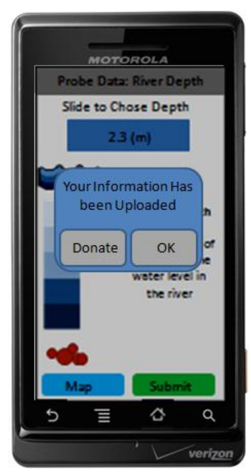
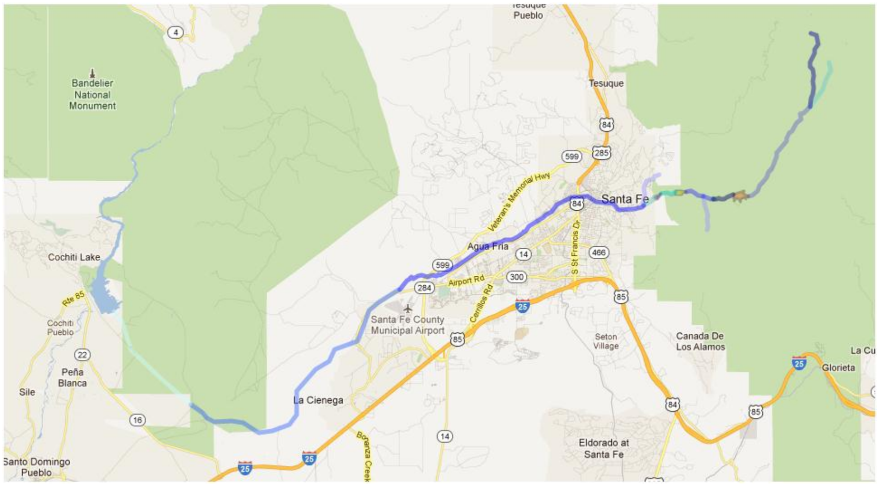


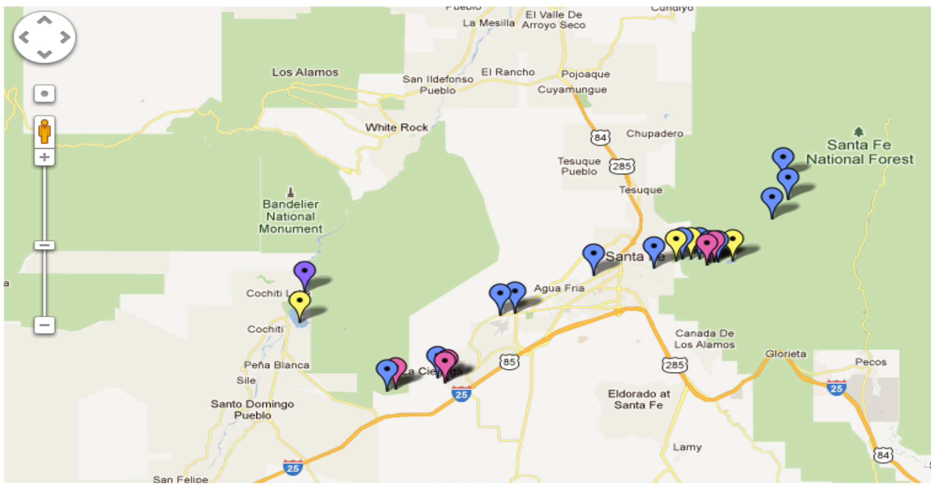
Figure 79: Data Entered Bubble

9.5 Appendix E: Google Maps

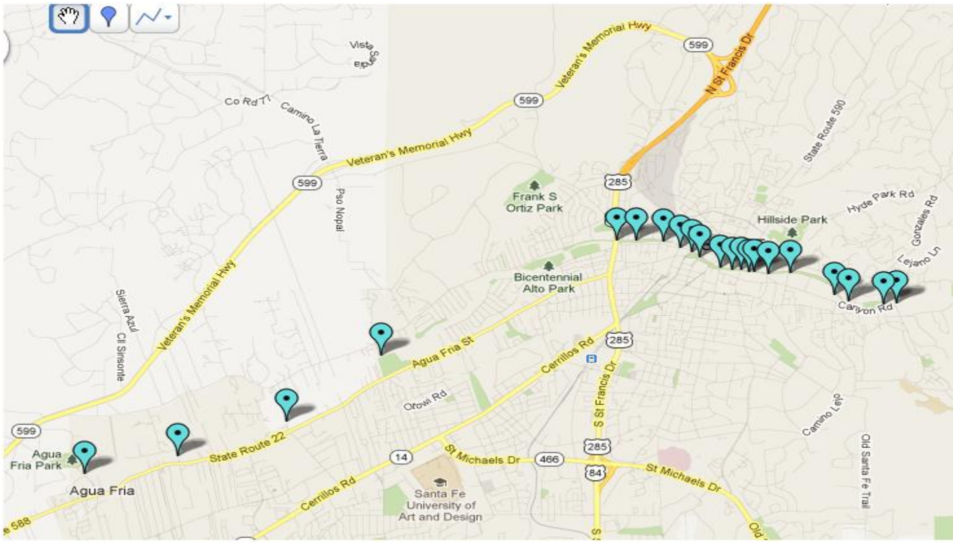
Santa Fe River Segments



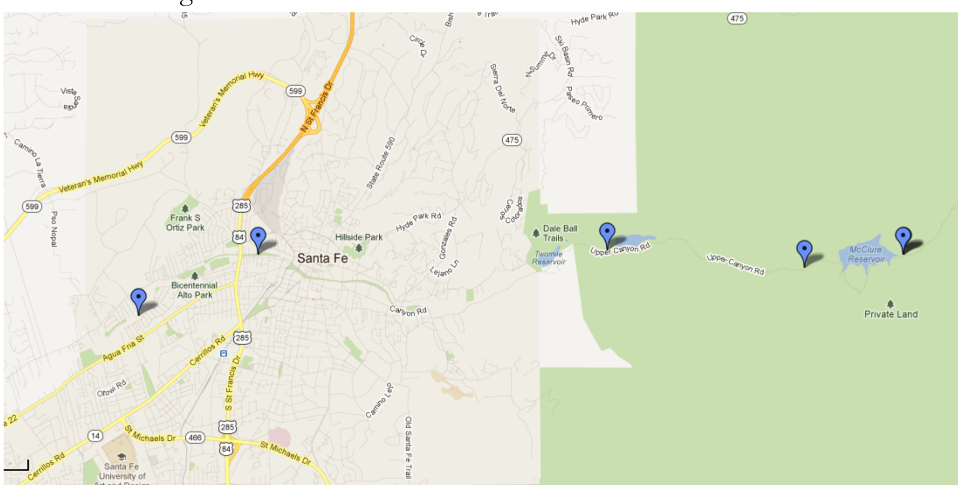
Santa Fe River Nodes



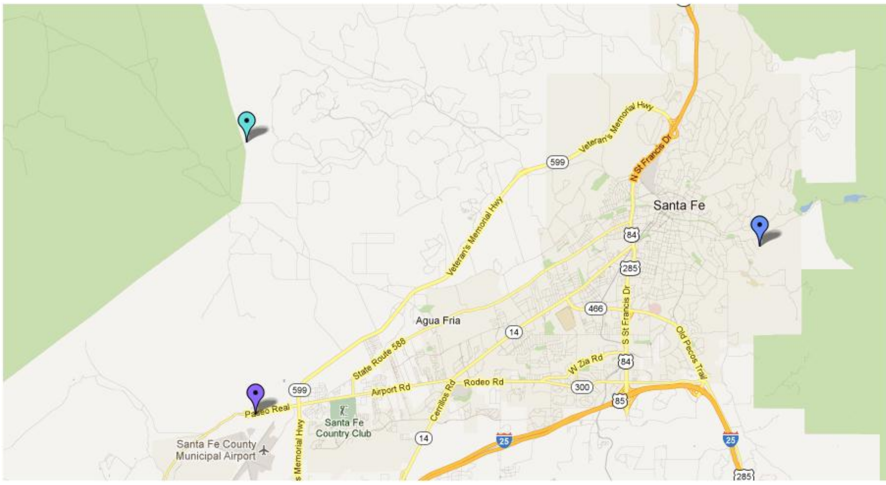
River Restoration Application Photo points



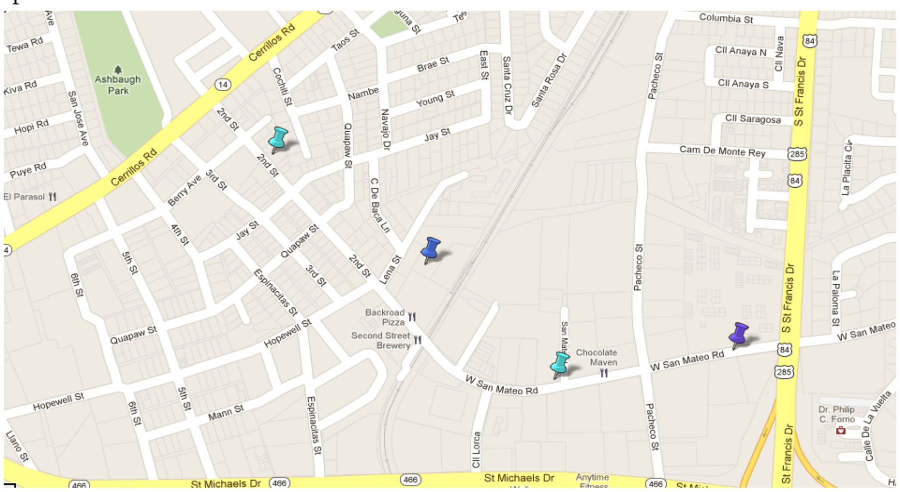
USGS River Gages



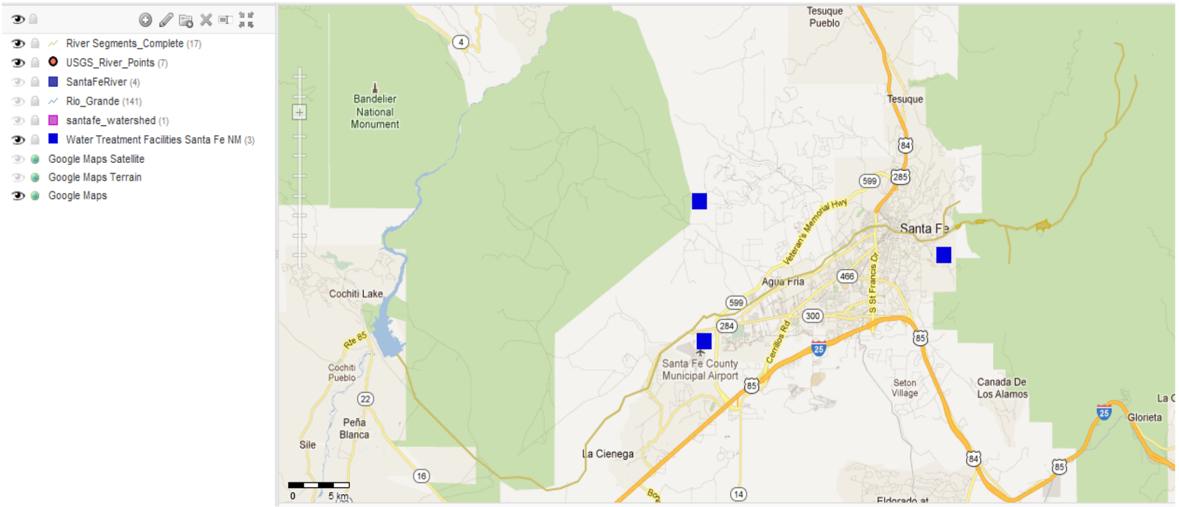
Water Treatment

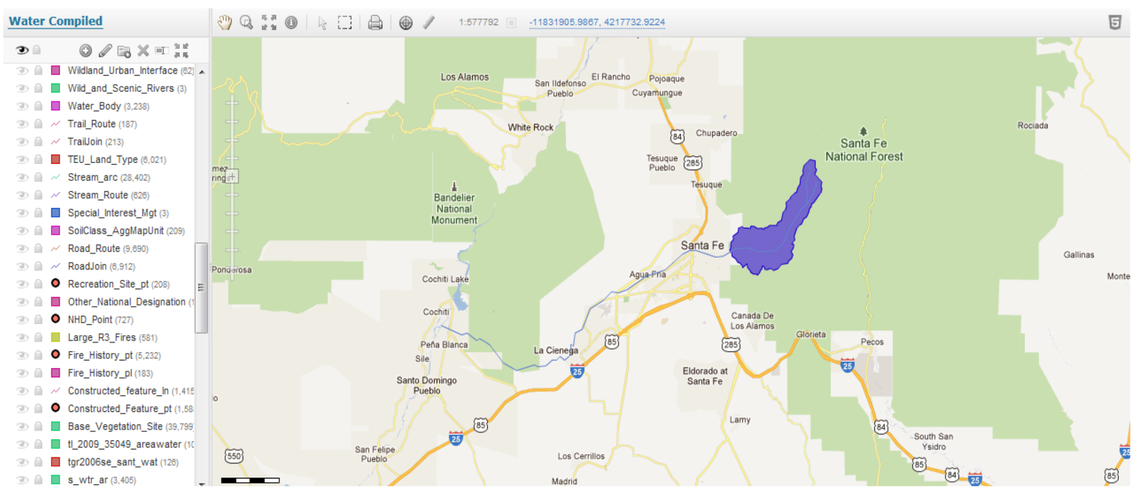


Sponsors



9.6 Appendix F: GIS Cloud Maps





9.7 Appendix G: Companion Website

Figure 80: Home Page

The website is designed with an intuitive interface (Figure 80) that will allow users to view photos, data, maps, as well as downloading the application that will help them contribute to the site.

Users can view their profile (Figure 81) which has been established through the app to view their contributions of data and photos. User data is moderated to keep out inaccurate material. A user can view the status of their submissions to see if they are approved or if they have been rejected and require revisions.

Figure 81: User Profile

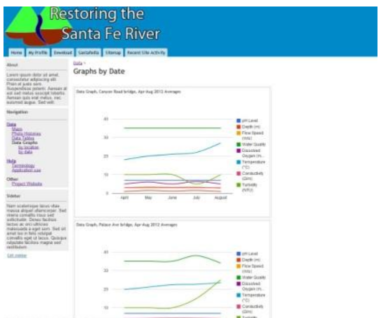


Figure 82: Graphs Page

The site will remain updated for every bit of information that is gathered and approved. This data can be viewed as tables and graphs (Figure 82). For instance the data table in this example shows five of the bridges that cross the Santa Fe River starting at Canyon Road and various types of data that was taken there. These pieces of data are factors such as pH level, depth, flow velocity, dissolved oxygen amount, temperature, conductivity, and turbidity, otherwise known as cloudiness. These are all aspects that measure the quality of water and the status of the river's health.

The website also contains a couple of help pages (terminology and application use) to help users learn how to use the application. The Terminology page (Figure 83) should cover a variety of words such as turbidity and pH Level that the average citizen might not know the meaning of. On the terminology page are links to Wikipedia entries about these terms to give the user better insight to their meaning and importance. The other page should be a video tutorial instructing the user on the proper use of the application.

Figure 83: Terminology Page

Figure 84: Home Page

The home page (Figure 84) is where a user can access everything. This is where they can find their profile, download the app, view photo histories and data as well as maps, and receive help.

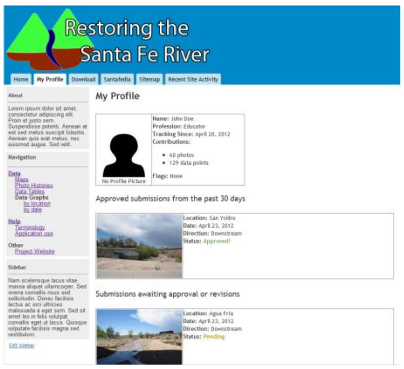


Figure 85: User Profile

The user profile (Figure 85) is where the user can view the current status of their submissions. Any submission is either approved, pending approval, or rejected. If a submission is approved, it will be viewable on the site by everyone and is part of the database. If it is pending approval, it is still on the site, but only the submitter and moderators may view it. If a submission is rejected it will queued for removal and will otherwise only be viewable by moderators and the submitter.

Figure 86: Download Page

Among the top tabs and the front page links is a location (Figure 86) to download the application. The application can be downloaded by using the barcode scanner app available on Android to scan the QR code which should bring you to a download prompt on your phone.

Figure 87: Data Page

The Data Page (Figure 87) will give the user a directory of visual representations of data as maps (Figure 88, Figure 93, Figure 89), in tables (Figure 92), graphs by locations (Figure 90), and graphs by date (Figure 91). Most of this data is available via the application, but is organized in a more aesthetically pleasing and easier to read manner on the website.

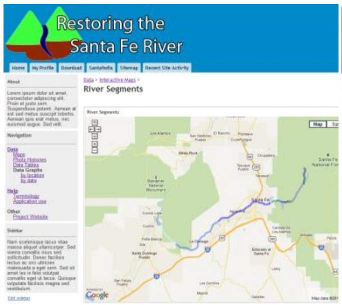


Figure 88: River Reaches Map

Figure 89: Photo Points map

Figure 90: Graphs by Location

Figure 91: Graph by Date

Figure 92: Data Table page

Figure 93: Interactive Maps Directory

Figure 94: Photo Histories Directory

The Photo Histories Directory (Figure 94) allows the user to look at various points along the river using photos taken by users. These pages (Figure 95, Figure 96, Figure 97, Figure 98) will showcase a current photo with basic details including whether or not there's water and/or trash. To make clear which trait is positive or negative, the "yes" or "no" is green if it's a positive trait, and red if negative. These pages also feature a backlog of photos to provide the previously mentioned photo history if available.

Figure 95: A Photo Point

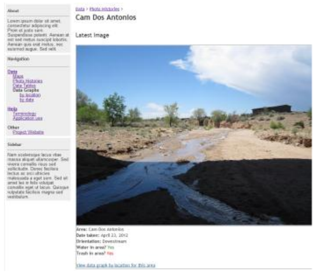


Figure 96: A Photo Point

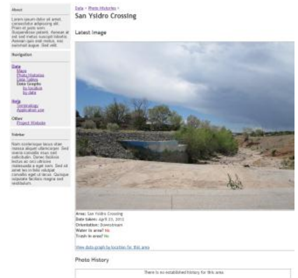


Figure 97: A Photo Point

Figure 98: A Photo Point

Figure 99: Help Directory

To help users who may be unfamiliar with certain terminology or features of the app, there exists a help directory (Figure 99) on the site. At the moment there are two help pages; a terminology page(Figure 100) which hosts a list of wikipedia entries that can help some one who is not familiar with terms such as pH level or turbidity. The other help page(Figure 101) is a tutorial on how to use the application which would have a video or tutorial showcasing the app's features and how to use them.

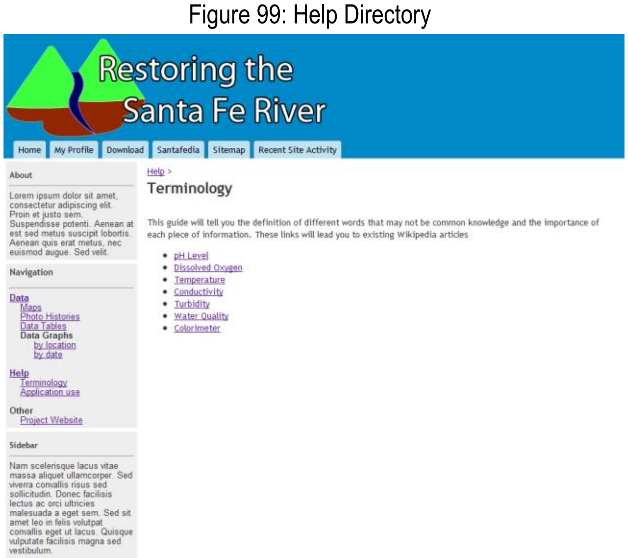


Figure 100: Terminology Page

Figure 101: Application Use