The Bear River

Utah's Last Untapped Water Source

CACHE COUNTY
WATER MASTER PLAN

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CEE 6440

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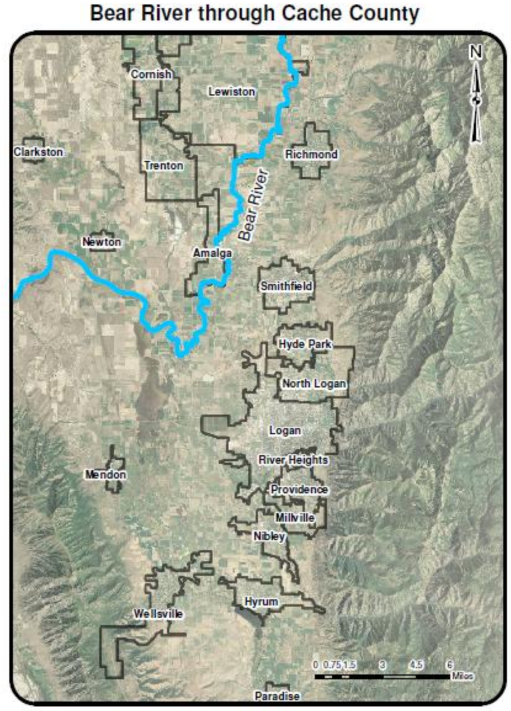
Introduction and Background

The Bear River has often been called Utah's last untapped water source. The reasons behind this statement as well as how Cache County can tap into this water resource are the focus of this project.

Living in a dry climate, every drop of water is crucial to sustainable development. While Utah continues to develop at a rapid rate, the availability of water supply remains relatively constant. As water becomes more and more scarce, sources previously overlooked are now being scrutinized to assess possible utilization.

Bear River through Cache County



The Bear River in particular, has long been a source of irrigation water for farmers in Northern Utah and Southern Idaho. As shown in the image to the right, the majority of the Bear River corridor is cropland. Eventually the Bear River empties into the Great Salt Lake, where as the name suggests, the water is no longer usable for irrigation due to the salinity.

Each year, 1.2 million Ac-ft of water travels down the Bear River into the Great Salt Lake (*Bear River Basin Planning for the Future, 2004*). The communities in Northern Utah are currently scrambling to figure out how they can put some of this excess water to beneficial use before it becomes salt water.

In 1991, the Utah Legislature passed the Bear River Development Act. This Act allocated 220,000 Ac-ft of water to be developed for use in Northern Utah. 60,000 Ac-ft of this water was allocated to Cache County. However, the amount of water committed to each of the communities is contingent upon the communities showing that they have a need for the water, and a plan to put the water to beneficial use.

Cache County has undertaken a water master plan to determine how much water they currently use, how much they will need in the future, and possible ways to develop the 60,000 Ac-ft of water from the Bear River in the future.

Purpose and Objectives:

As many of the decisions dealing with the development of the Bear River will require approval of the general public, educating the people of Cache County to the findings of the water master plan will be equally as important as any of the data itself. Even the best data will be wasted unless the public understands it enough to make the best decision for Cache County's future.

The main purpose of my academic project is to combine water use data, water supply, and population projections into a series of easily interpreted maps for Cache County.

One of my objectives is to provide clear data to the public, so that in seconds, the viewer will understand when additional water is needed in Cache Valley communities. Increasing public education will increase the possibility that the best decision is made, not just the easiest.

A second objective of my project is to show possible solutions to utilize additional Bear River water.

The outcome of these objectives will (hopefully) be that when election time comes, the average voter will understand when additional water is needed in Cache County, and how we can utilize it.

Data Sources

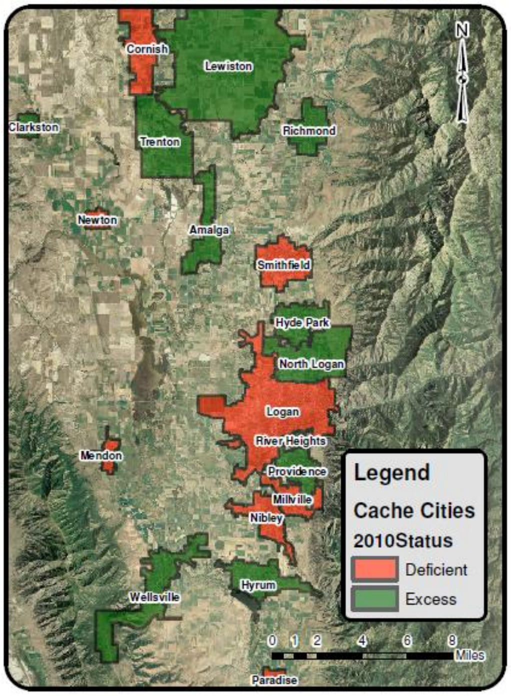
Current and projected populations for the communities in Cache County were provided by the Bear River Association of Governments (BRAG). Water use data as well as the reliable source data were gathered from the Utah Division of Water Resources (DWRe). Water rights data were gathered from the Utah Division of Water Rights (DWRi). Miscellaneous GIS data was gathered from the Utah GIS portal (gis.utah.gov) including but not limited to roads, city boundaries, watersheds, aquifers, water bodies, soil data, dams, DEMs, and aerial imagery.

Method

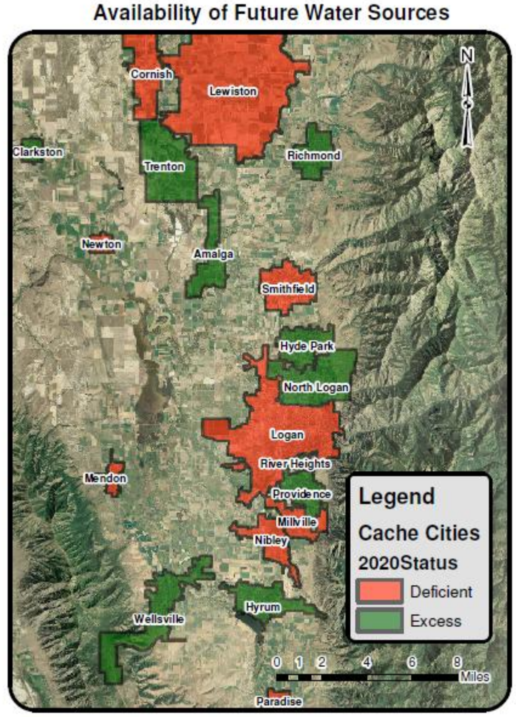
The first steps of data manipulation were performed using excel. The growth projections were combined with the per capita water usage in each of the communities in Cache County. These numbers were plotted against the reliable source of each of the respective communities to determine when the projected growth will exceed the reliable source capacity.

The resulting tables were then imported to GIS using the join function to associate the data with a feature class representing each of the communities. Maps were then created illustrating in ten year intervals when each of the communities will need additional water. The communities were each shaded either red if during that time interval they exceed their reliable source capacity or green if they still have excess capacity. The resulting maps are shown below.

Availability of Future Water Sources



Availability of Future Water Sources



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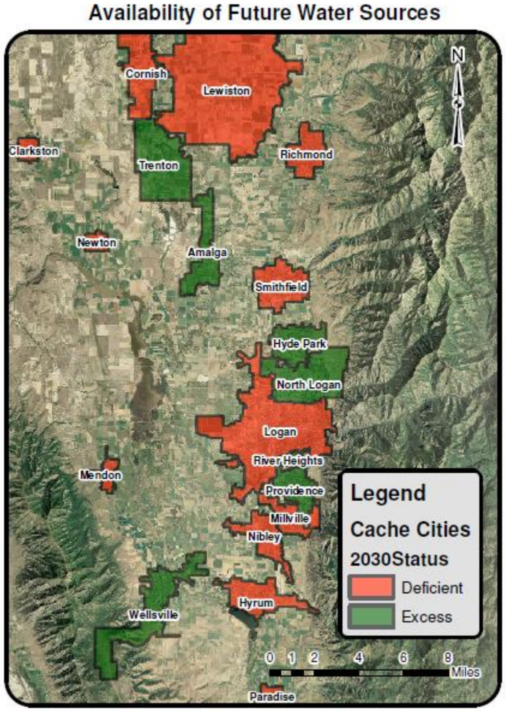
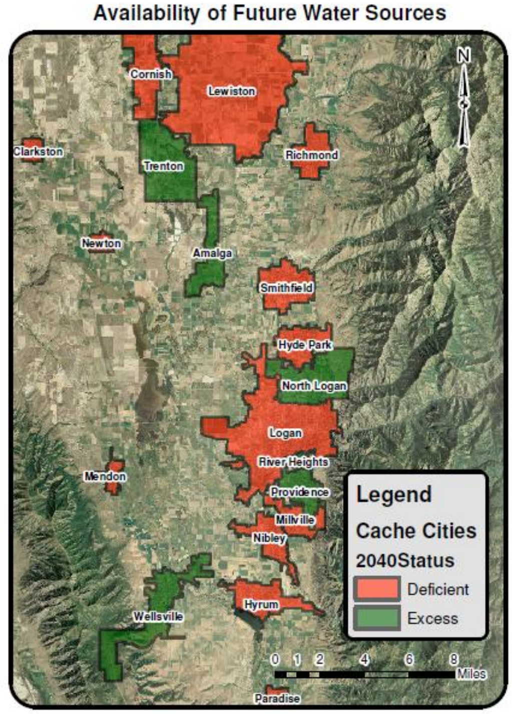
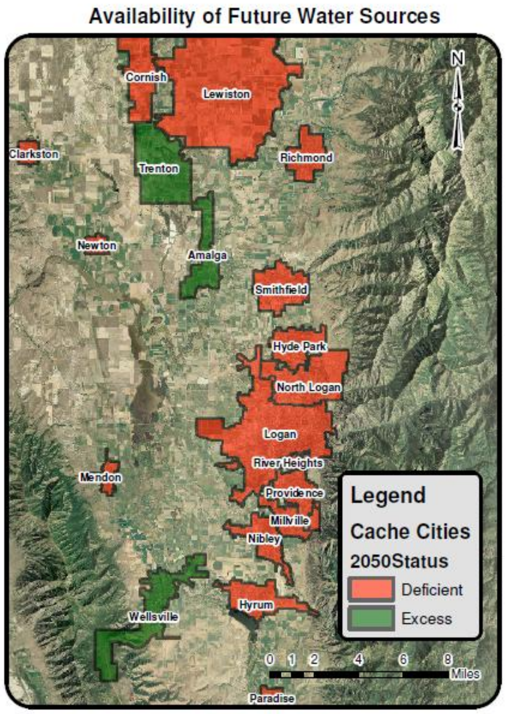
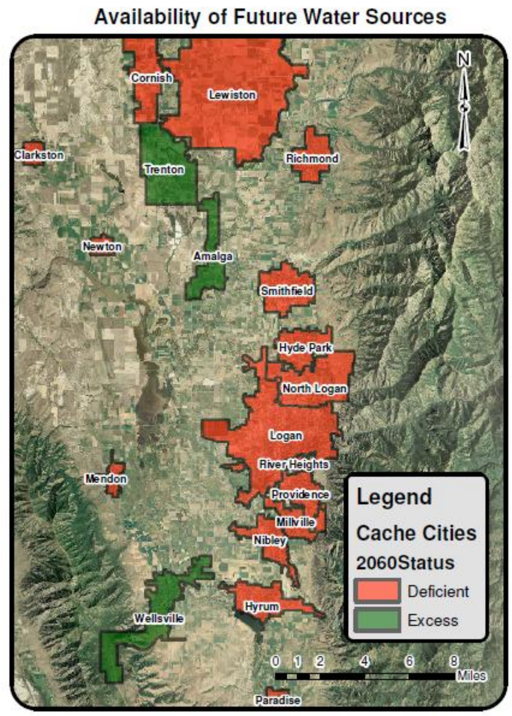


Availability of Future Water Sources



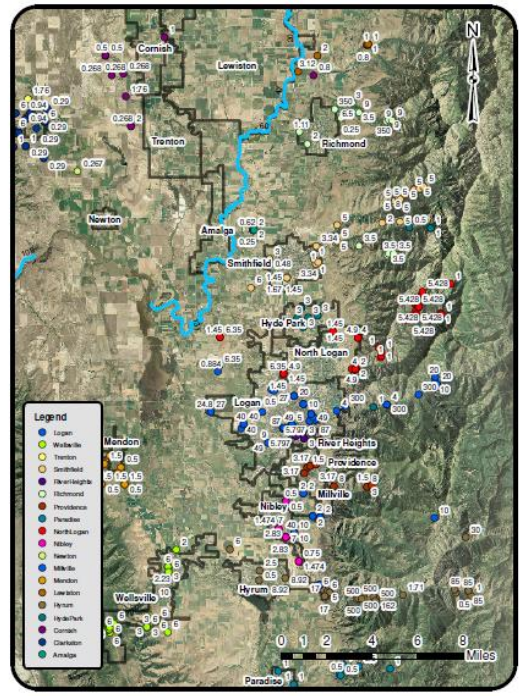




One might ask why a map is any more useful than a simple graph saying when the blue line crosses the red we're out of water. The added benefit a map offers is the ability to see an overview of the entire County, and analyze possible interconnects of water systems. For example, if two neighboring communities see that one of them is flush with water and the other is already high and dry, projects can be developed between the communities to share their water systems via an interconnect.

For the purpose of understanding what water rights each community currently owns, I also created a map of the City owned water rights with their associated allowable flow rates in cfs, utilizing water right data from the DWRi, shown on the right.

Existing Water Rights



If maps can help citizens understand when their communities will need additional water, the next step in the process will be to understand what the possible options for acquiring additional water are.

Part of the challenge faced in Northern Utah, and in many mountainous regions is we receive most of our precipitation in the form of snowfall. The rivers swell and often flood in the spring as the snow melts. However a large portion of this surge of water flows un-retained into the Great Salt Lake. If we want to continue sustainable growth, in one way or another this volume of water needs to be retained in locations where it will be needed during hot summer months for irrigation purposes.

As it relates to the Bear River development Act, two of the main options being analyzed for water retention are constructing surface reservoirs to hold the additional water, or utilizing the storage capacity of the aquifers through a developing technique known as Aquifer Storage and Recovery (ASR). Each of these options will be discussed in greater detail.

There were 45 potential reservoir sites in northern Utah identified by the DWRe. For the purpose of my academic project, I selected one of the sites I have particular interest in, and analyzed the possible development of a surface reservoir in Temple Fork of Logan Canyon.

Using the DEM data and the "Surface Volume" tool in the GIS 3d Analyst toolbox, I initially determined that the designated area could hold approximately 36,000 Ac-ft of water with a surface area of 371 Acres. Being familiar with the streams running down Temple Fork, I suspected that there would never be sufficient water to sustain such a large reservoir. In order to determine how large of a reservoir the stream could effectively fill each spring after being depleted for irrigation the previous summer, I delineated the Logan River watershed using the tools available through the Taudem software. The steps taken to complete this delineation are briefly summarized in the following paragraphs.

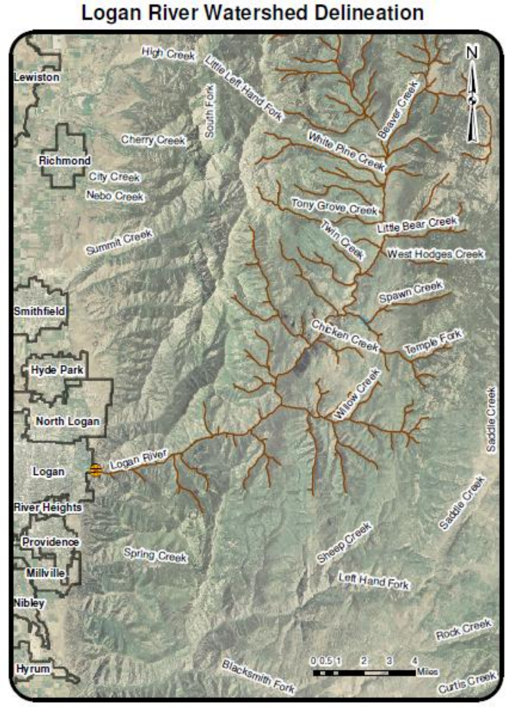
A Digital Elevation Model (DEM) of the Logan River watershed was downloaded and projected into GIS. A series of Taudem tools were then used to prepare the surface for delineation. The first step is to remove the pits in the DEM to ensure that the watershed does not have unintentional sinks. The pit remove function is used to bring the sink elevations up to the elevation of the lowest neighboring cell.

Next, the flow direction for each of the cells in the DEM are calculated using the D8 Flow direction tool through Taudem. This function analyzes the slope of the surrounding cells and assigns a flow direction based on the steepest surrounding slope.

The next function used is D8 Contributing Area. This Taudem function calculates the number of cells that are draining to the cell of interest. For example, if the properties of a cell in the resulting raster indicate a value of 10, this indicates that 10 cells size 30 x 30 meters are draining to this specific cell. An outlet location must first be specified for this function to execute. This is very useful in determining the amount of runoff expected at any given point in the watershed.

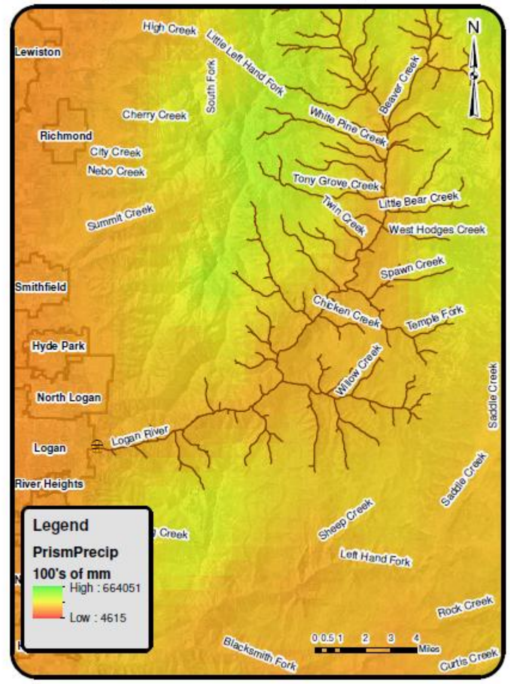
Finally, to cleanup the map and create the stream networks, the "Stream Definition by Threshold" tool is used. This tool connects the cells that meet the specified threshold, or number of cells draining into them. For this delineation, the threshold was set at 1000 cells. To finish this connection process, the "Open Stream Reach and Watershed" function is used. This creates shapefiles of the different reaches of the stream, and links them to the subwatersheds contributing to the respective streams.

Logan River Watershed Delineation



The main purpose in performing this delineation was to know the contributing area to the proposed reservoir location. Once this was determined, I then needed to know how much runoff could be expected from the area contributing to Temple Fork.

Logan River Watershed Precipitation



PRISM annual precipitation data was downloaded from Oregon State University. This data was downloaded in an ASCII format and the GIS ASCII to Raster tool was used to import the data. Once the projection was defined correctly, the precipitation data for the Logan River watershed was extracted using the GIS “zonal statistics as table” tool. The exported table identifies the minimum, maximum,and mean precipitation over the Logan River Watershed. The mean annual precipitaion is 940.25 mm/year.

The runoff ratio (r=q/P) was then calculated by dividing the mean annual discharge (flow in the Logan River) by the Precipitation over the watershed. The river flow value Q is divided by the watershed area to determine the runoff per unit area amount q. The mean annual discharge amount from the Logan River was found to be 233.35 cfs (USGS Stream Gauge 10109000). Since the watershed area is in meters, the flow was converted to 6.61 m^3/s, then divided by the area of 588 km^2 to determine the runoff per unit area q=1.18 E-8 m/s, or 1.18 E-5 mm/s. In order to divide q by the annual precipitation data, q must be converted to units of mm/year. The resulting value is 373.71 mm/year. Finally, the runoff ratio can be calculated by dividing the runoff per unit area q by the mean annual precipitaion P. Therefore q/P = 374.71 / 940.25 = 0.3975, or 39.75%.

Since there are not any stream gauges on the temple fork of the Logan River, I assumed the same runoff ratio applied for the subwatershed analyzed for the potential reservoir location. The D8 Contributing Area to the Temple Fork Dam Location is 44,921 30m x 30m cells. This results in an area of 40,428,900 m^2, or 4.04 E 13 mm^2. This is then multiplied by the runoff per unit area q = 373.71 mm/yr to calculate the annual stream discharge of 1.51 mm^3/yr, or 0.48 m^3/s (16.92 cfs).

At such a flow rate, the reservoir would accumulate approximately 1,000 Ac-ft per month. The river continues to flow through the winter, but the majority of the runoff will come during the spring months. If the reservoir had four months to fill before the irrigation demand increased, the storage volume would be 4,027 Ac-ft.

It is possible that with additional water piped from the Logan River, the reservoir could retain enough water to consider investigating the site in greater detail. In order to have an understanding of the potential reservoir sizes and volumes, I used various tools in the 3d Analyst extension, as well as the raster calculator as described below.

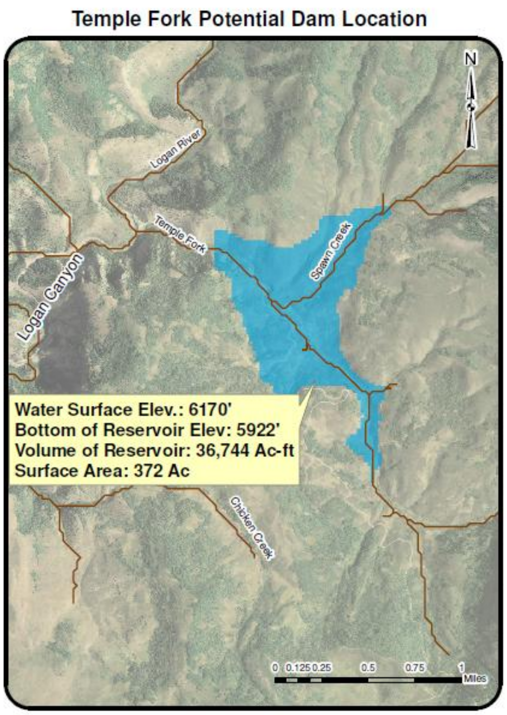
Using the “surface contour” tool in the triangulated surface GIS toolbox, I first created contours to determine preliminarily what the water surface elevation could be to maximize the storage volume in Temple Fork.

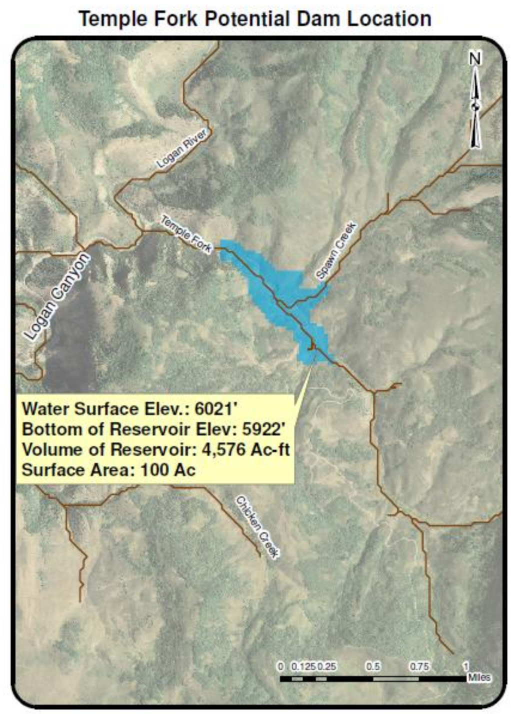
Once the preliminary water surface elevation was determined, a new raster of constant elevation was created using excel to plot the values, then exporting the data as a tab separated text file, then importing to GIS using the “ASCII to Raster” tool in the conversion toolbox. The imported raster dataset as well as the base raster were then clipped to a polygon surrounding the site of interest to speed up the future raster calculations. Using the raster calculator tool, I took the difference between the constant elevation raster and the base raster. This would obviously produce negative values as well, so I performed another raster calculation to identify only the positive values. This function returns a 0 for the negative values, and 1 for the positive values. In order to see the actual differences in elevation, the “zonal statistics as table” tool was used. The largest reservoir possible (without spilling over into the adjacent canyon) was modeled using a water surface elevation (WSE) of 6168’. This resulted in a surface area of 372 Ac, and volume of 36,744 Ac-ft.

The surface area and volume were checked using the “surface volume” tool in the functional surface toolbox. The results were within 1% of each other, which gave me a higher confidence level that I was using the tools correctly.

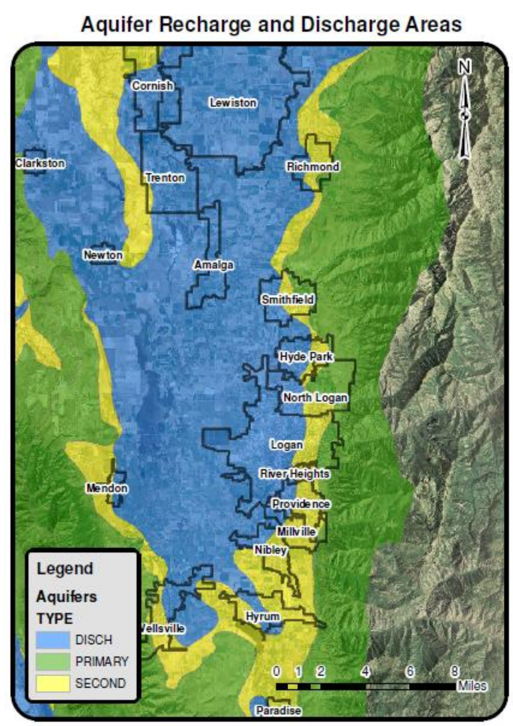
The sequence of operations was repeated again to determine the surface area needed for the smaller reservoir previously discussed. It was found that a WSE of 6021’, a volume of 4,576 Ac-ft could be produced, requiring a surface area of 100 Ac. Theoretically, this is the volume of water I believe could be sustained from the stream discharge of Temple Fork alone.

The resulting water bodies are shown in the two images below.



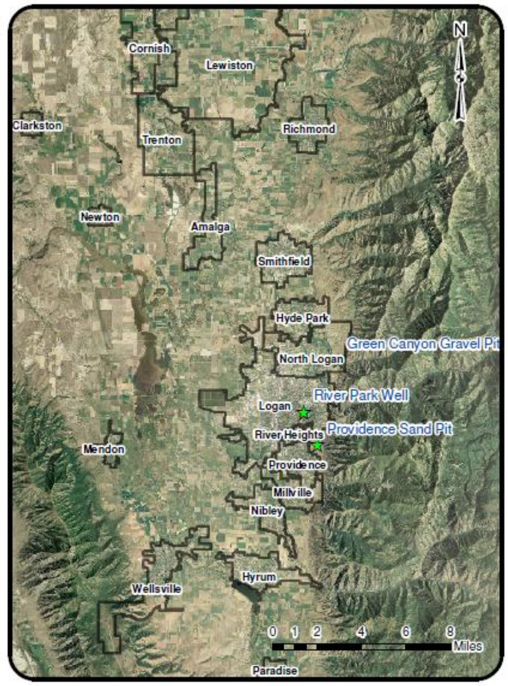


The second option considered for developing the additional water available from the Bear River is to utilize the Aquifers, or underground reservoirs that already exist. Using aquifer data from the Utah GIS portal, I created a map illustrating the main aquifer in Cache County. The map shows the primary and secondary recharge areas, as well as the discharge area, where the water from the aquifer enters streams, water bodies, and become surface water.



A newly developing technology is known as Aquifer Storage and Recovery or ASR. The principle of ASR is to utilize the available water during off peak months such as the fall and winter, and inject it into the confined aquifer below. As the water from the Bear River is not drinking water quality, an exchange would be developed to utilize the Bear River water for secondary irrigation, and in turn utilize the culinary water sources to inject treated water into the aquifers. A study performed in Cache County (*Principal Aquifer Storage and Recovery Site Assessment: Phase I, 2010*) identified three potential sites well suited for ASR in Cache County. They are shown in the figure on the right. As the Green Canyon and Providence Sand Pit sites lie within the aquifer recharge zone, it is possible to utilize surface infiltration to recharge the aquifer. The River Park Well would require pumping to inject the water into the confined aquifer. Further studies are currently being completed to look at the sites in more detail.

Potential Aquifer Storage Recovery InjectionSites



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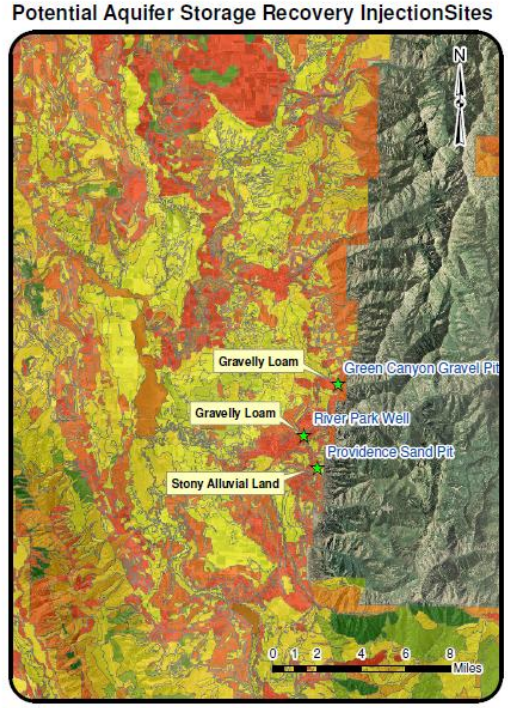

Soil data from the NRCS (SURGO) was downloaded to analyze the soil conditions at potential ASR locations. As you would probably expect, the three sites identified, and shown in the figure on the right, are located in gravelly loam, and stony alluvial land, ideal for surface infiltration.

Conclusion and Summary

In summary, water resource projects are heavily dependent on public education. Without public buyoff, even the best data will be ignored and the “right solution” will never be selected, unless it is the easy solution. The purpose of my project was to create a series of maps that will help the public easily understand the water situation in Cache County, and understand the possible options for further developing water to provide for our future sustainable growth.

References

Division of Water Resources. *Bear River Basin Planning for the Future*. Rep. 2004. Print.

Thomas, Kevin, Robert Q. Oaks, Jr., Paul Inkenbrandt, Walid Sabbah, and Mike Lowe. *Cache Valley Principal Aquifer Storage and Recovery Site Assessment: Phase I*. Rep. Cache County, 2010. Print.