How Much Water: Determining Current Water Needs and Usage -- Spring City, Utah

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Contents

Introduction

Spring City, Utah is a small town in central Utah located within the Sanpete County valley. The approximate current population of the city is 1,000 people. Spring City is on and at the base of an alluvial fan, which consists primarily of varying types of Silty Clay Loams. Despite large areas of poor farming soil, the land around Spring City has been developed into producing agricultural fields. The ability to produce in this area is due to the hard work of local farmers and the implementation of a pressurized irrigation system.

This irrigation system is managed by Horseshoe Irrigation Company, further referred to as the HSIC, which was created as a non-profit organization to manage the established water rights area. The HSIC provides water for an irrigated area of 5,820 acres. The pressurized systems consists of 9 regulating ponds and approximately 85 miles of underground pipe. The company is limited in its storage capacity and is currently experiencing frequent system failures.

Objective

The purpose of this project is to determine if current system failures are caused by a lack of water storage or caused by not enough water for the current system demand. Assuming the HSIC had all water rights and storage capabilities necessary, this project considers the question; if water storage volumes are increased to meet the amount of water supplied by the local watersheds, is there currently enough water on an average year to meet demand.

Method

To accomplish the objective of this project, studies for the agricultural demands and the watersheds supply are done. First calculations for water needs and second calculations for watershed water supply. Throughout this project ArcGIS is used to determine these characteristics of the water supply and demand.

Water Demand Calculations. To determine the approximate annual consumptive demands a shapefile from UDWR (2015), “Water Usage Land Data”, is used to define the types of crops upon the irrigated sections of land. The shapefile is added to the ArcGIS map showing the crop data from 2015. It is assumed that any variations over time of agricultural land type is negligible. This assumption is due to the same consistent use of agricultural land within the Sanpete Valley for livestock feed and because the agricultural land type is to be used only in the creation of an approximated value of water consumption needs.

The “Water Usage Land Data “shapefile consists of over 33,000 polygons covering western states. To narrow down the amount of data the Select Layer by Attribute tool is used to select only those crops within Sanpete County and the land that is irrigated. This selection and deletion narrows the polygons amount over 16,000. Second, a selection and deletion of all polygons greater than a distance of 10km away from the local delineated basin is done to further taper the data to only 1774 polygons. There is a variability of the HSIC system locations, and no existing shapefile from the HSIC Images from the H.I.C website are used for the selection of all irrigated polygons over the HSIC This selection is done by visual inspection and individual hand selection. Further deletion of non-irrigated polygons, dry crop farming polygons, and idle shrubland polygons cleans up the data, and establishes new shapefile consisting of only 746 polygons. Now that the data is ready the calculation of needed water demands can be completed. The resulting shapefile is shown in Figure 1.0

Figure 1.0 shows the HSIC and its associated shape file narrowed down to the crops and polygons that are used in the calculations of a mean annual water consumption need.

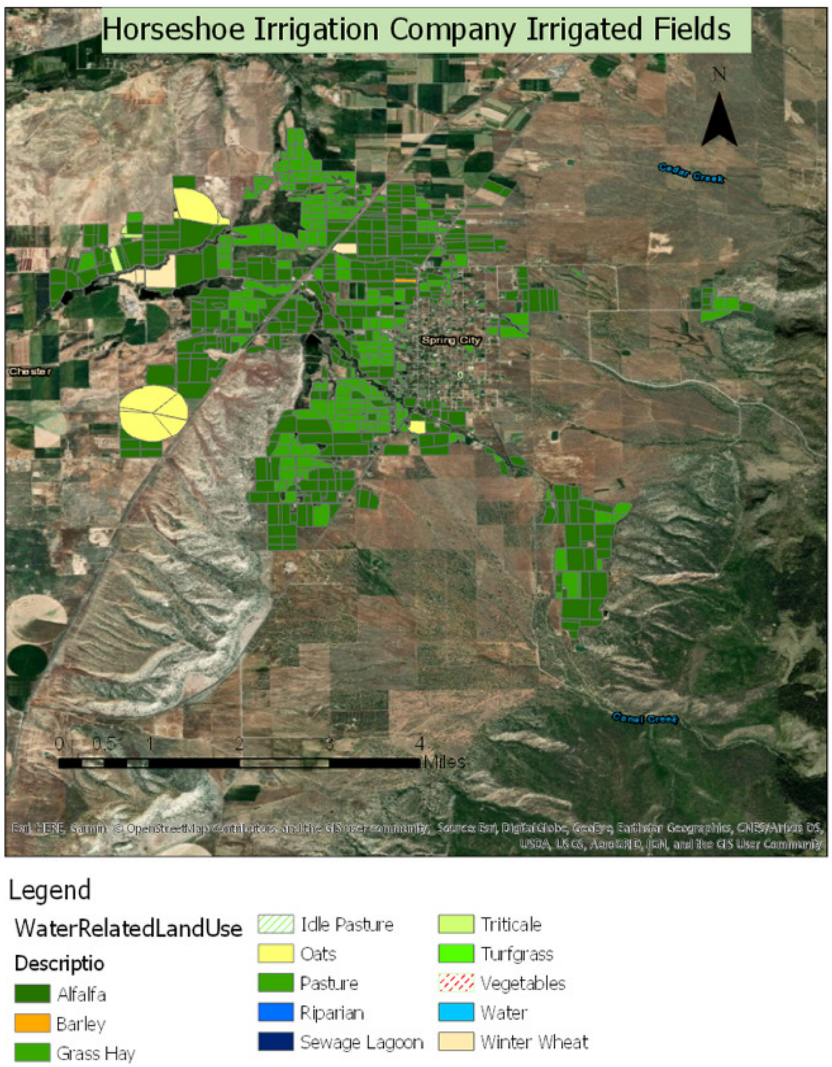

Figure 1.0 Horseshoe Irrigation Company Land Usage Polygons by Type

The land use descriptions in the polygons are used for the assignment of a consumptive use coefficient for each given land/crop type. These consumptive use coefficients are in

Consumptive Use and Water Requirements for Utah, (Huber A. L. et al., 1982), found using the Blaney-Criddle equation. The Blaney-Criddle Equation (1.0) uses a crop specific water usage coefficient (K) and multiplies that coefficient by a local factor (F). Because Huber calculates these local factors (F) in Utah, in areas with similar climate, valley, and soil characteristics the resulting Blaney-Criddle coefficients (U) are considered as sufficient to use for this project.

$$U = K(crop\ type) * F(location) \qquad \textbf{(1.0)}$$

Table 1.0 shows the resulting Blaney-Criddle. Each crop type has a calculated coefficient value that reflects the needed mean annual number of inches needed for a crop. Calculating the required volume of water for mean annual consumption is taking the area of a land/crop type and multiplying that area by the corresponding coefficient resulting in an acre-feet per year value.

Table 1.0 Blaney-Criddle Coefficients

Labels	**(U)Coeff. (Inches/year)**
Alfalfa	25
Grass Hay	25.59
Urban Grass	32
Grains	17.5
Pasture	25
Riparian	0
Vegetables	21.6

The calculations for the water demand per each polygon are done in ArcGIS. Using the attribute table for the new shapefile several new fields are created. A Blaney-Criddle coefficient field is added as well as a Water Needs field. Inputting the Blaney-Criddle Coefficients the Calculate Field tool is used to assign coefficients to description types. This is done using a sequence of if statements as shown in Figure 2.0.

```
if($feature.Descriptio=="Alfalfa") {return 25};
if($feature.Descriptio== "Grass Hay") {return 25.59};
if($feature.Descriptio== "Turfgrass") {return 32};
if($feature.Descriptio== "Pasture") {return 25};
if($feature.Descriptio== "Oats") {return 17.5};
if($feature.Descriptio== "Triticale") {return 17.5};
if($feature.Descriptio== "Winter Wheat") {return 17.5};
if($feature.Descriptio=="Barley") {return 17.5};
if($feature.Descriptio== "Vegetables") {return 21.6};
```

Figure 2.0 Sequence of Code Used in ArcGIS Calculate Field Tool

The Water Needs field is calculated and filled using the same Calculate field tool using the area multiplied by the Blaney-Criddle coefficient which is divided by 12 to convert inches to feet. See Equation (2.0). The new Water Needs field is summed to determine an approximation for the annual agricultural water demand for the HSIC.

$$WaterNeeds = Acres * \frac{U}{12inches} \quad \textbf{(2.0)}$$

The results for the annual agricultural demand analysis are shown within the results section showing the total amount needed for the HSIC system. Due to the complexity of producing a Penman-Monteith time function value for evapotranspiration and the Blaney-Criddle Coefficients already taking into account the local climate and environment evapotranspiration is assumed negligible. (Allen R. et al. 1998)

Watershed Water Availability. The next stage in this project is finding an approximation of an average annual amount of water to be supplied to the HSIC from the local watersheds.
Two methods are used to determine these approximations. First a description of the characteristics of the local watersheds and the assumptions used.

The two watersheds that are considered are the two HUC12 watersheds with identifiers #160300040301 and #160300040302 as shown in Figure 2.0. These watersheds are from Region 16 of the Hydrologic Unit Maps created by the USGS. These HUC12 watersheds are used to calculate the approximate annual amount of water supplied by these watersheds. This data is added to an ArcGIS base map and the Select by Attribute and Locations tools are used to trim the other watersheds within Region 16.

San Pitch River Watershed HUC12 Spring City, UT

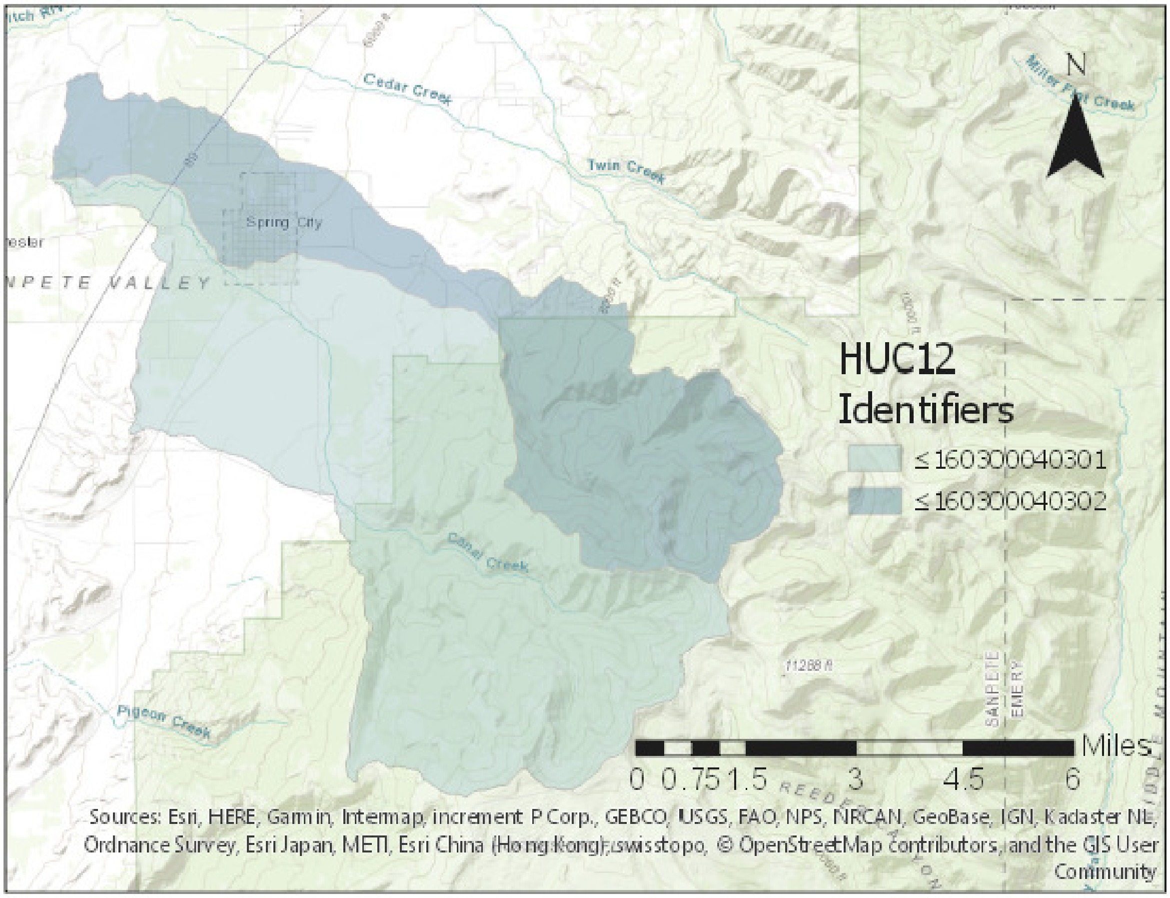

Figure 2.0 HUC 12 Watersheds, Identifiers #160300040301 and #160300040302

ArcGIS is used to calculate Digital Elevation Model Watersheds as shown in Figure 3.0. Because the actual stream flow counts were not desired, only a yearly volume amount, the DEM watershed wasn't used in the analysis. Additionally, because it was desired that the valley be included in the watershed to consider the precipitation on the fields, attempts were made to delineate the watersheds into the valley. These attempts proved to be unsuccessful. Because of the unsuccessful attempts at in valley watershed delineation it was determined that the HUC 12 watersheds should be used to achieve a more accurate result.

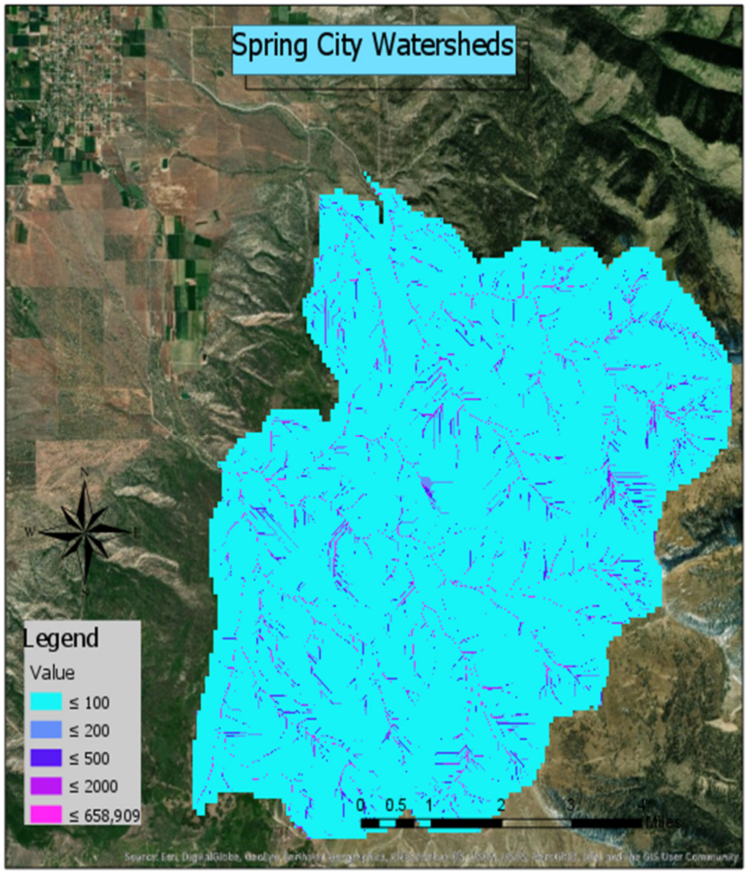

Figure 3.0 DEM Watersheds Following Canal and Oak Creeks

In determining the approximate annual water supply some assumptions are made. The total computed amount of precipitation rate over the watershed area is a mean yearly value. When considering precipitation, it is assumed that the watershed boundaries include most of the HSIC's boundaries, and therefore, the precipitation on the fields is considered in the water availability section of this study rather than being subtracted from the water needs section.

Another important assumption for the watershed water availability approximation calculation comes from a hydrological and aquifer study done by the Utah Division of Natural Resources (DNR), and the United States Geographical Survey (USGS) (Wilberg, 2002). From the study it is determined that the local aquifer is recharged from stream flows at a rate of 50 percent. This recharge rate means that 50 percent of the water that travels in the streams is lost too seepage into groundwater. Therefore, it is assumed that the 20 mile stretches of the Canal Creek and Oak Creeks lose 50 percent of their water (Wilberg, 2002). Canal Creek is associated with HUC12 #160300040301 and Oak Creek is associated with HUC12 #160300040302 (See Figure 2.0). This loss coefficient is assumed for the values of the water volume supply calculations.

The first method used for calculations is from the USGS and Utah DNR study. This method only uses the area constructed by the two HUC12 watershed polygons and equation (3.0) (Wilberg, 2002). Equation (3.0) was developed by creating a linear regression equation for five gaged streams within the Wasatch Platea and used for calculating the average annual streamflow for streams. The Q variable being the average annual streamflow in acre-feet per year, and the variable A referring to the drainage area in square miles. ArcGIS is used to calculate a new field value of watershed flow (Q), using the Calculate Field tool.

$$\ln(Q) = 8.40 + 0.06 * (A) \quad \textbf{(3.0)}$$

The second method of calculation is a simple method using the area of the watersheds and multiplying that area by a mean annual precipitation rate (4.0). The mean annual precipitation rate is found by PRISM (2010) (See Figure 4.0). The mean annual precipitation found is 13.4 inches. This value is less than the Utah mean annual average of 18.58 inch, but is considered sufficient as it is deemed better to have a smaller value than a larger value for the objective of this project. A smaller value adds a factor of safety in determining the supply will meet demands, because if the smaller precipitation value meets demands a larger will exceed them.

PRISM Time Series Data
Location: Lat: 39.4935 Lon: -111.5096 Elev: 5748ft
Climate variable: ppt
Spatial resolution: 4km
Monthly 1981-2010 Normals
Dataset: Norm81m
PRISM day definition: 24 hours ending at 1200 UTC on the day shown
Grid Cell Interpolation: Off
Time series generated: 2018-Nov-20
Details: http://www.prism.oregonstate.edu/documents/PRISM_datasets.pdf

Date	ppt (inches)
January	1.04
February	1.1
March	1.25
April	1.24
May	1.23
June	0.87
July	0.74
August	0.85
Septembe	1.22
October	1.52
Novembe	1.09
Decembei	1.26
Annual	13.4

Figure 4.0 – Calculation of Mean Annual Flow (PRISM)

The calculation of the watershed area by precipitation uses ArcGIS and implements equation (4.0) in the Field Calculation tool. An attribute table with the resulting values is created and is exported to excel for convenient manipulation.

$$Q = Area * MeanAnnualPrecip \quad \textbf{(4.0)}$$

The values for the total watershed are supply are summed for the USGS and Precipitation methods, and the values are shown in the results section.

Results

The results of the water demand and the water supply are synthesized. Water demand as a single acre-feet per year value. Water supply has two values calculated from the two methods and then those values are reduced by a seepage reduction factor.

Water Demand. For the water demand the water needs for each polygon in GIS were calculated and then a sum of those values is found. The approximate total amount of water needed is rounded up to 9,200 acre-feet per year. In addition to a value of 9,200 acre-feet per year calculated, Figure 5.0 is made to show the water needs for each polygon in the HSIC system boundaries.

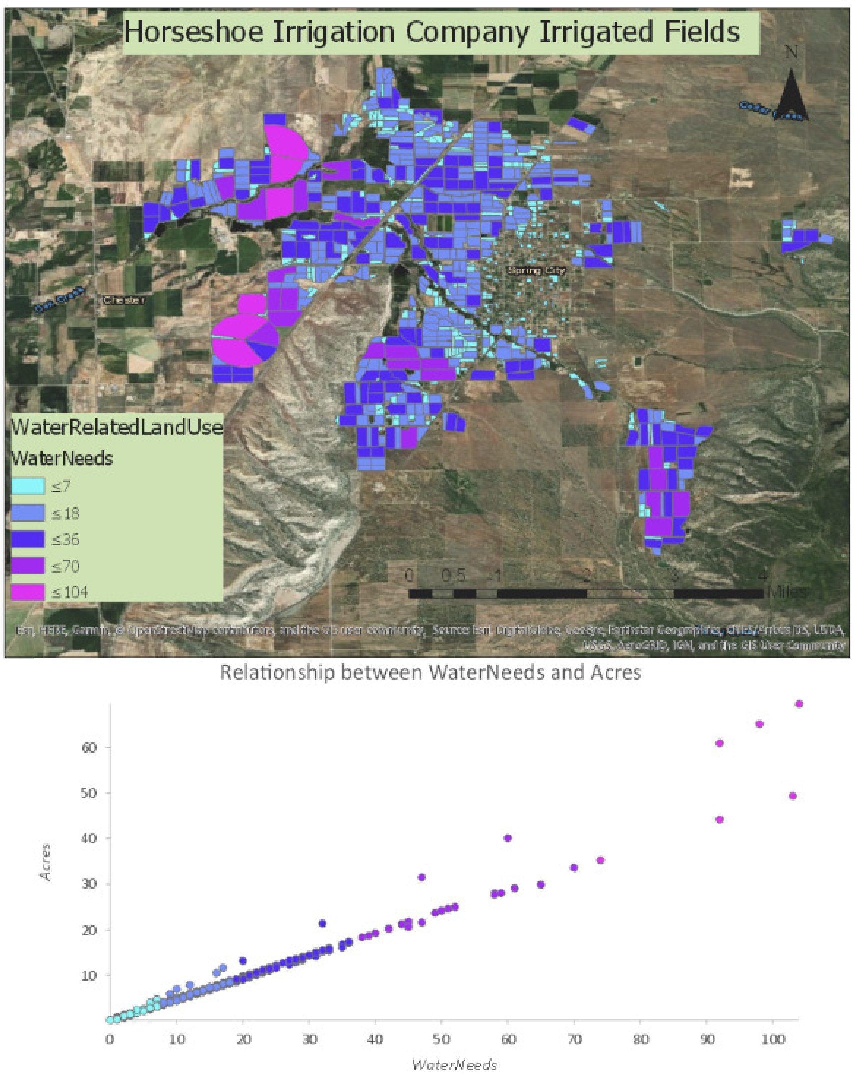

Figure 5.0 Individual Polygon WaterNeeds Values

Water Availability. The results of the water supply analysis are shown in Table 2.0 and Table 3.0. The seepage reduction factor of 50% is used in the calculation of Table. 3.0.

Table 2.0 Watershed Characteristics and Sum of Water Supply from ArcGIS

OBJECTID	HUC_12	HUC_12_Name	ACRES	SquareMiles	WaterSupply_Q_USGS	WaterSupplyPrecip	Units
1364	160300040302	Upper Oak Creek	11330.76	18	8103	12653	acre-feet
1377	160300040301	Canal Creek	19427.33	30	22026	21694	acre-feet
				Total:	30130	34347	acre-feet

Table 3.0 Watershed Characteristics and Sum of Water Supply from ArcGIS with 50% seepage factor

OBJECTID	HUC_12	HUC_12_Name	ACRES	SquareMiles	WaterSupply_Q_USGS	WaterSupplyPrecip	Units
1364	160300040302	Upper Oak Creek	11330.76	18	4052	6326.5	acre-feet
1377	160300040301	Canal Creek	19427.33	30	11013	10847	acre-feet
				Total:	15065	17173.5	acre-feet

To further analyze the watershed supply we can consider Figure 6.0 with the yellow and gray bars showing the original calculated total water supply and the orange and blue bars showing the same methods after the 50% reduction factor.

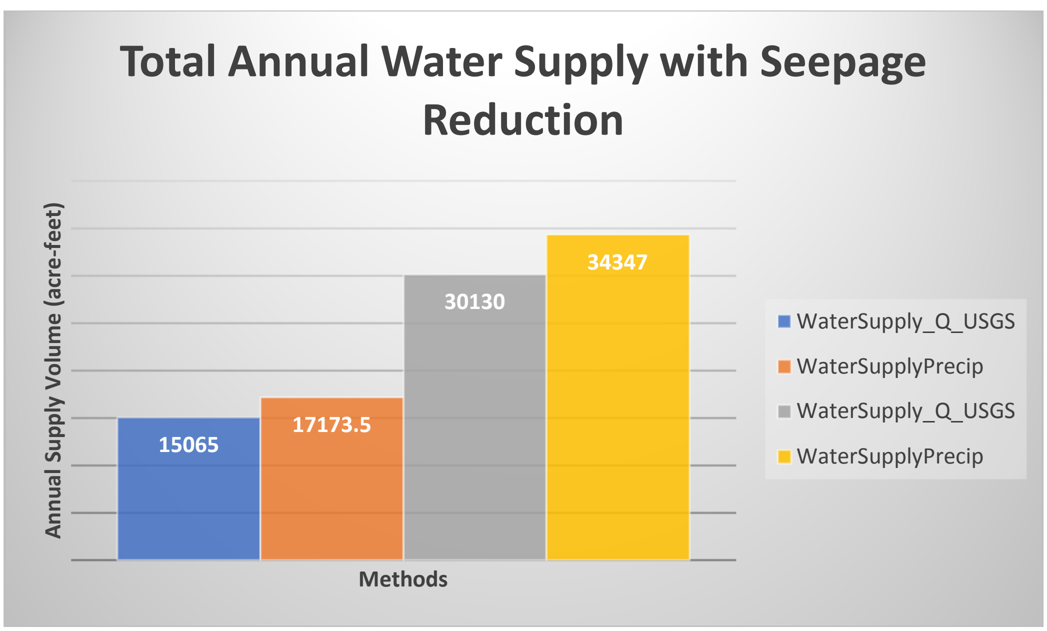

Figure 6.0 Approximations of Total Annual Water Volume Available

From the water supply calculations, the water supply using the USGS method seen in equation (3.0) calculates a more conservative value or approximately 15,000 acre-feet per year. Because this value is more conservative it is the value compared to the water demand.

Discussion

Considering the results from both the Water Demand and the Water Supply, the demand of 9,200 (acre-feet per year) is less than the supply of 15,000 (acre-feet per year). Because the demand is less than the supply, an educated assumption can be made that the HSIC has enough water supply in their watersheds, and yearly precipitation to accommodate for their needs. The approximate supply value is over 5,000 (acre-feet per year) larger than the demand. Therefore, because the supply value is significantly larger than the demand that any errors in the method are negligible.

In the project it was assumed that the precipitation for the valley would be considered in the supply source of the data. A problem with this assumption is that it does not consider precipitation during the non-growing season. This non-growing season accounts for half of the year. Another study of just the growing season months for valley precipitation should be done to correct this. For this project due to time constraints, and because the difference in values is based on approximated values and is found 50% larger than the approximated demand the error is considered as negligible.

A major factor that cannot be considered in this project is the assumption that the water users would only apply the amount of water needed per crops type. Water users especially agricultural users use the water they have even if the crop does not need it. A common view in the area is the phrase, Use it or loss it. Therefore, there is a lot of overwatering. Additionally, not only does the culture affect the amount of water used, so does the irrigation technique. The irrigation technique meaning what type of irrigation method, such as wheel lines verses pivots. The irrigating efficiency is a significant factor in water usage, but as stated in the objective of this project the scope of this project is to determine if the water supply could in a perfect system provide enough water for the current irrigation system.

Conclusion

In conclusion, it is found that based on conservative approximations Spring City, Utah has enough water supply to meet approximated water demands. It is found that if 50% of a conservative approximation of total precipitation over a period of 12 months were able to be stored the HSIC's agricultural water system would no longer have system failures. The system would always have enough water to supply the needs of water users.

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