RAINWATER HARVESTING IN THE UNITED STATES

A Sizing and Feasibility Study

Abstract: This report develops a methodology, using ArcGIS, to determine the sizing of a cistern for rainwater harvesting systems across the United States based on catchment area and monthly usage.

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Introduction:

Rainwater Harvesting is a method of gathering potable water that has been in use for thousands ofyears. "There is archeological evidence that attests to the capture of rainwater as far back as 4,000 years ago, and the concept of rainwater harvesting in China may date back 6,000 years" (Board, Texas Water Development). Today in the United States as water resources become scarce in many locations, the capture of rainwater for everyday use is on the rise. The highest cost of most rainwater harvesting systems is typically the storage cistern. This is also the most critical portion of any rainwater harvesting design, as an appropriately sized cistern will ensure that the system will handle the demand placed on it by the users. Virtually any area in the United States can harvest rainwater, however, in some areas the cistern or catchment area required, due to limited rainfall, can be very large and thus make rainwater harvesting unfeasible. Through this study, individuals will be able to determine if rainwater harvesting is a viable option for their total water needs, non-potable needs, or not an option at all.

Objectives:

The objectives of this project are to develop a GIS Model with inputs of catchment area and monthly water usage that produces an end of month and end of year water storage representation across the entire United States for those given parameters.

Methodology:

Data Resource:

The first step in developing this rainwater harvesting model was to find an accurate and useful dataset of rainfall data across the United States. When conducting rainwater harvesting analysis, it is typically best to utilize monthly average rainfall data because most water usages are better assessed on a monthly basis. The most accurate data available for this project was located at the Prism Climate Group website. http://www.prism.oregonstate.edu/

Figure 1. PRISM Data

The PRISM website has a compilation of data published by Oregon State University. The precipitation data is arranged such that one can either download individual yearly data, monthly data, and monthly average precipitation data from 1971 to 2000 across the nation. The data is packaged in a gzip file which was developed from the GNU project. By going to their website and downloading the program, the dataset can be easily unzipped and converted into an ASCII file.

Calculating Monthly Water Usage:

The next critical piece of data required is a water usage term for the household being designed for. There are many excellent programs online that can calculate this for when the user inputs usage into the programs and the Texas Manual on Rainwater Harvesting also has a step-by-step method for this. The USGS recommends several, but one that is easy to use is located at the "Computer Support Group", and on-line site that offers free calculator tools for public use http://www.csgnetwork.com/waterusagecalc.html. This calculator takes into account indoor use by estimating bathroom use, toilet water use, facet use, dishwashing and laundry use. To determine outdoor use, the calculator looks at the amount of irrigation utilized by a specific household.

When using this or any of the other calculators, it is critical to be honest in the assumed usage and think of all eventualities. For example when many people are over to visit, or how long one truly uses the water at the faucet. By applying good water conservation measures, many individuals can bring down their water usage to lower than 1,000 gallons per user per month.

Sizing Catchment Area:

To calculate the amount rain that can be captured, an accurate estimate of catchment area, or roof size, is critical. One easy way to do this is via ArcGIS online using the satellite imagery from the base map options and the area calculation tool as depicted in figure 2. Once in ArcGIS online at http://www.arcgis.com/home/ choose the Map option. Then using the address bar, you can input your home address in the "find address of place" bar. This will zoom the map in directly to that location. The user can then toggle between different maps and satellite imagery to get a nice view of the catchment area or rooftop by choosing the "Basemap" button. Once at the desired location, the "measure" tool can then be used to outline the catchment area and by changing the units arrive at the total area measurement.

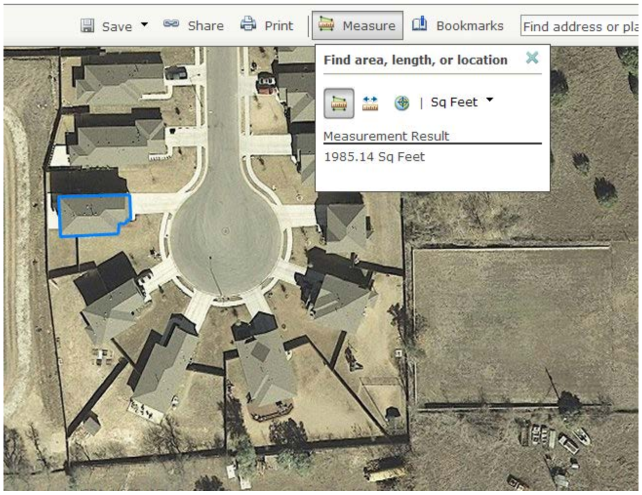

Figure 2. ArcGIS Area measurement Tool

Deriving the Storage Term Equation

Once all of the necessary data has been collected, the next step to developing the model was to derive an equation dependent on catchment area and monthly usage that could convert the raw rainfall data from PRISM into gallons of storage. The following equation was utilized to conduct this conversion for all of the raster data:

$$S = \frac{PV(100mm)}{\frac{1000mm}{cm}} * \frac{.394ft}{12cm} * \frac{7.4805gal}{ft^3} * \eta * CA * -M$$

Equation 1. Rainfall Storage Equation

Where:

PV=Prism Precipitation value(100mm)

CA=Catchment Area (ft^2)

M= Monthly water Usage(gal)

η =efficiency factor (.85)[1]

S= Storage available(gal)

The primary reason for utilizing monthly data versus annual data is that an individual user needs to know when they can expect peaks in storage and when their storage levels will drop. Thus a monthly projection allows the user to see during what months they may need to conserve water carefully and also when there will be plenty of water available. However, in doing this, the user would be required to make many timely conversions to this original data. Therefore a model was developed in ArcGIS that takes the input of PRISM data and generates a raster projection of storage values across the United States. A flow-chart diagram of the model developed is shown below.

GIS Model:

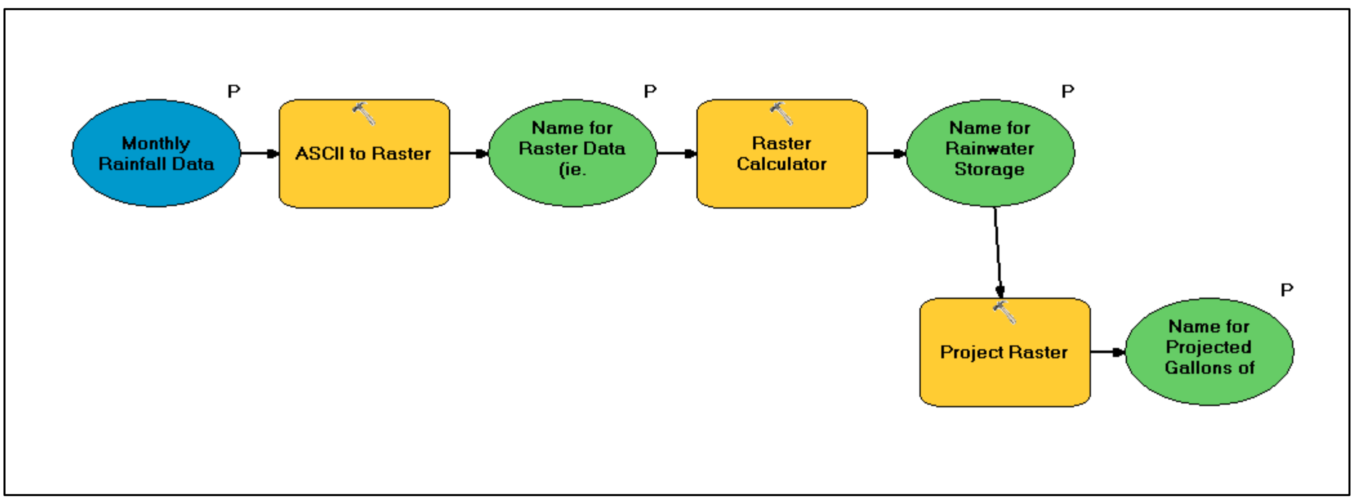

Figure 3. GIS Model Flow-Diagram

There are four parameters for the models, one input and three outputs. The first input parameter is the rainfall data. This takes the ASCII rainfall data and converts it into a raster

[1] (Board, Texas Water Development)

format. This then generates a named Raster that is then sent to the Raster Calculator where the Storage Equation from above is applied using the Raster Calculator tool, generating a raster of rainwater storage values for each raster. Those storage value raster's are then finally projected onto the GCS_North_American_1983 coordinate system for spatial reference that can then be viewed in ArcGIS. Lastly to group the data into recognizable terms, the symbology tools can be utilized to classify the values into unique bands of storage values within a given range of concern. For most rainwater harvesters, a tank between 4,000 gallons and 10,000 gallons is sufficient; however, it is beneficial to see how much water can be harvested in some areas. Therefore in the following figures output values of 1,000 – 6,000 gallon intervals were used at 1,000 gallon intervals and then bands at eight, ten, and over fifteen thousand gallons respectively.

Results:

The results from this model are displayed below in an example Raster output for the month of January. In this example a catchment area of 2,000 ft^2 was assumed and a monthly usage of 1,000 gallons per month. From this generated map, one can now easily see across the United States the water that could be captured through the month of January. With a single glance it is evident that the easiest areas to utilize rainwater harvesting are along the West Coast of the United States and in the South East. Anyone living in the Central part of the country will not be successful at harvesting rainwater without an extremely large catchment area.

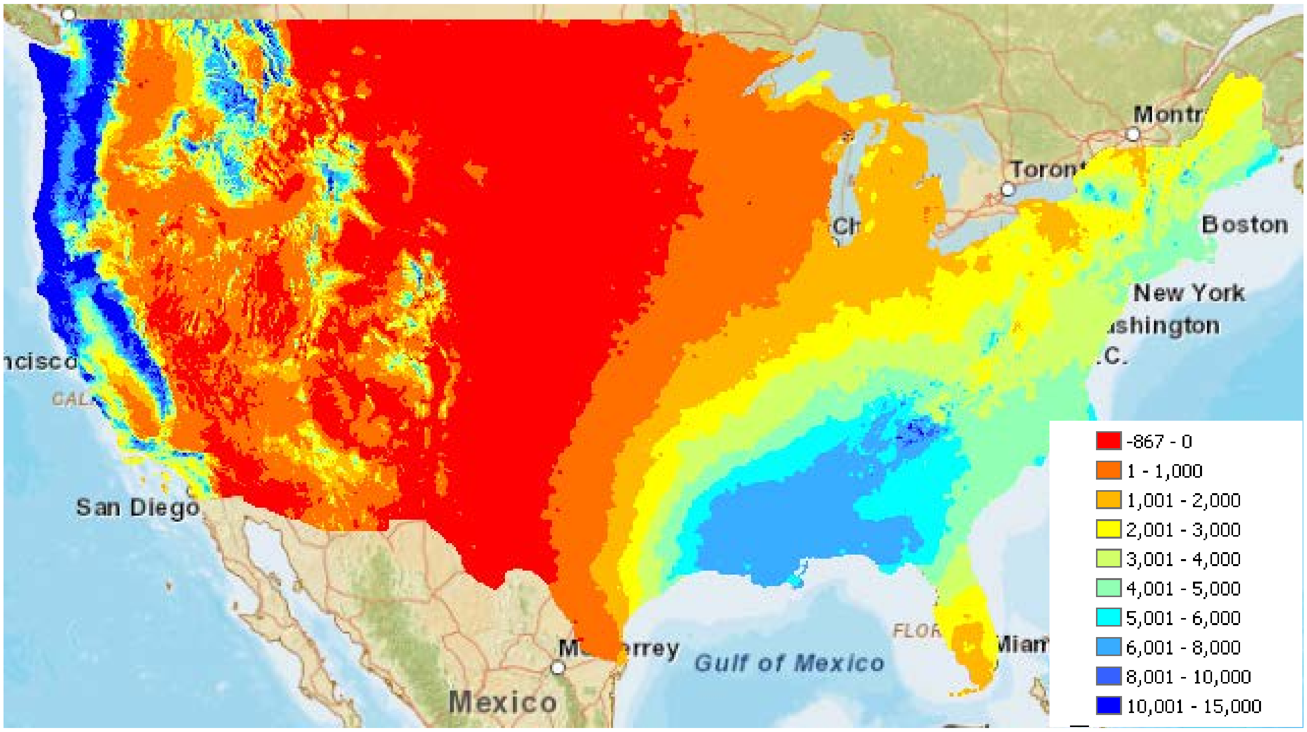

Figure 4. January End of Month Storage available with 2,000 ft^2 Catchment Area and 1,000 gallons per month of usage.

This process can be accomplished for all months such that an individual can see the amount of storage they can expect to gain, or loose, in a single month. By then using map algebra, all of the months can also be added together to yield an end of year storage map such as the one below.

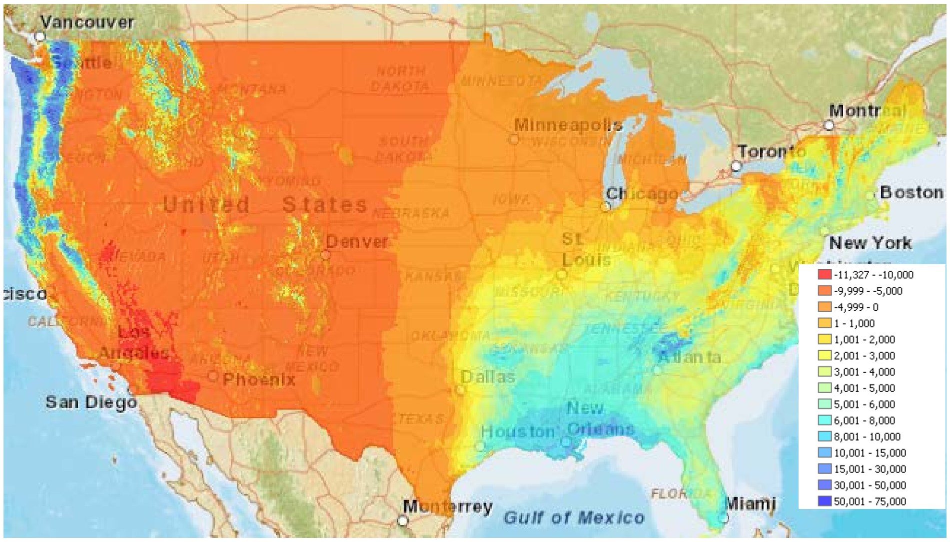

Figure 5. January End of Month Storage available with 532 ft^2 Catchment Area and 1,000 gallons per month of usage.

One advantage of this program also is that by changing the transparacy of the storage display, a user can easily zoom into their location using the many basemaps in ArcGIS and determine not just the rainfall in their region, but down to their specific location.

Conclusion:

This project attempted to determine an efficient way to determine rainwater harvesting feasibility and sizing across the United States of America using ArcGIS and publicly available rainfall data. It was determined that utilization of ArcGIS and monthly mean precipitation data can be very useful for individual users, rainwater harvesting companies, and individuals studying rainwater harvesting and is a very efficient way to conduct such studies and analysis. By locating the appropriate data, many other studies could be accomplished to determine storage that would be available in drought years, heavy rain years, or any other myriad of options by selecting other data from the PRISM website and applying the same methodology.

Additionally, with the appropriate data, similar studies could be conducted for other countries globally for determination of whether rainwater harvesting is a viable option in other areas that struggle to find viable sources of water.

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