Analysis and design of a rainwater cistern system for providing water for wildlife

By Ariel Ortega

INTRODUCTION

The objective of this problems course was to design a properly sized animal watering tank for wildlife in the Jemez Mountains region. These watering tanks are placed into the ground and provide animals with drinkable water. The tanks collect rainwater from water collecting surfaces built close to the tanks.

The Rainmaker Wildlife Corporation[1] sells these types of tanks of various sizes and water capacities built out of plastic. Depending on the size of the tank they can come with a built-in tapered side in the top of the tank that allows the animals to get to the water when the tank is not full. The other side of the top is covered to reduce loss of water to evaporation and is barrel shaped to provide structural strength that prevents the cover from sagging. These types of water collecting tanks are called guzzlers.

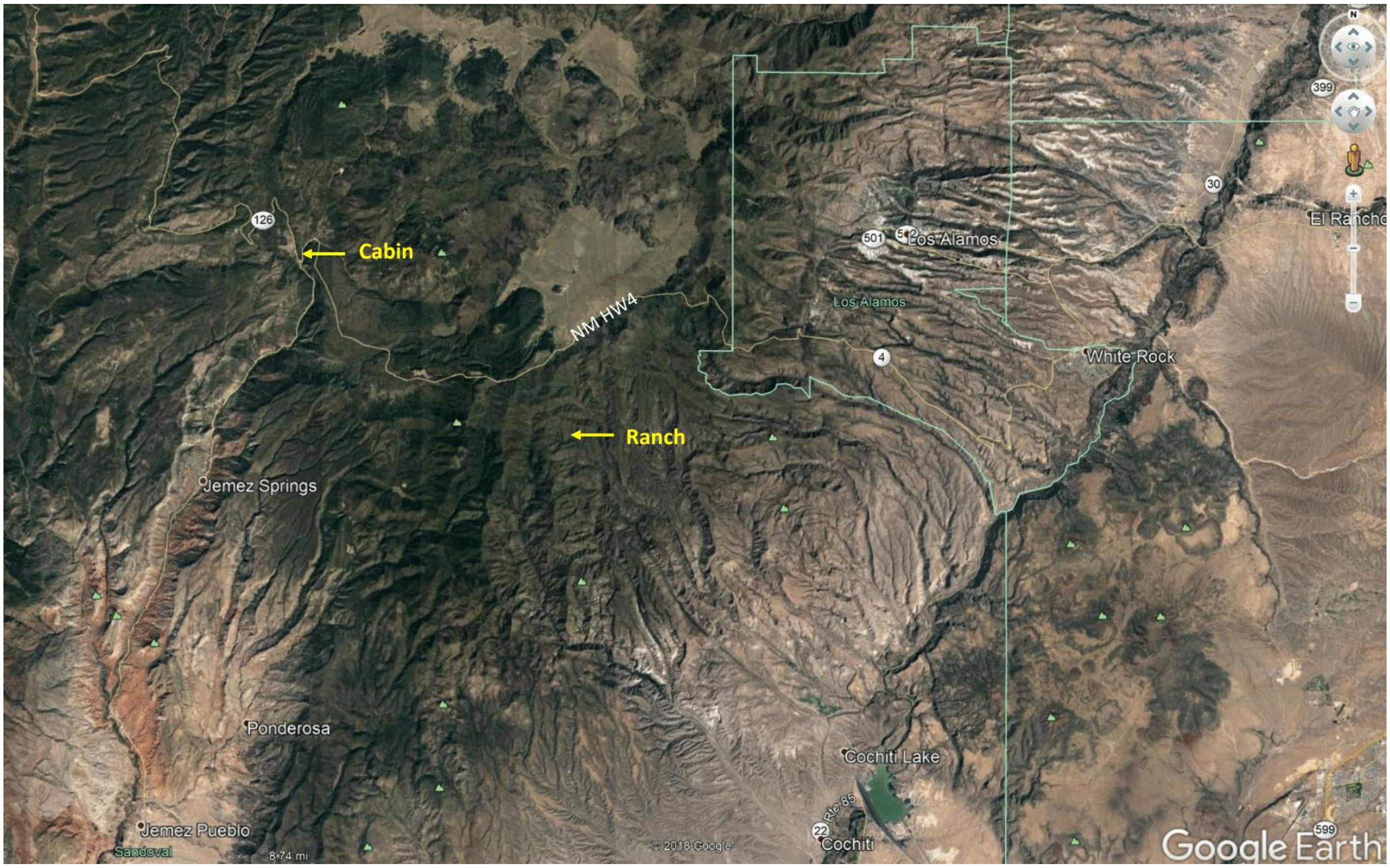
500-gallon guzzler provided by Rainmaker Wildlife
https://www.rainmakerwildlife.com/products/dome-top-500

This work was conducted to meet the requirements of Engineering Problems Course 495, supervised by Research Associate Professor Dave Menicucci, of UNM ME Department.

1000-gallon guzzler provided by Rainmaker Wildlife
https://www.rainmakerwildlife.com/products/dome-top-500

These guzzler models were considered for use early on, but I waited till I had a more concrete understanding of what I needed in terms of sizes before deciding on what to use for the tank. For now, I knew we needed watering tanks that would attract animals to two properties for the purposes of observing and hunting, a cabin and a ranch both located in the Jemez mountains region. The cabin is in a rural community about 5 miles north of Jemez Springs. The ranch is in a remote forested area about two miles south of the Valles Caldera national Preserve.

These tanks would need to have a water collecting surface build close to them so that they can collect rainwater throughout the year. For the cabin location, the water collecting surface would be the roof of the cabin itself, as the roof is made of medal panels that direct waters to two gutters which would be connected to the tank. For the ranch location a water collecting surface would need to be built close to the tank.



Map 1, Location of cabin and Ranch Watering Tank Sites
https://www.google.com/maps/search/google+maps/@35.7664576,-106.6119858,46520m/data=!3m1!1e3

These Guzzlers would be built next to a water collector so that they can be naturally refill by the rain and provide water for various wild animals throughout the year. There were three problems that needed to be addressed to realize this project.

- The first problem to addressed was the sizing of the watering tanks. The Rainmaker Wildlife Corporation[1] offers various tanks of different sizes. I wanted a tank that best fits the size for the location, the number of animals that will visit the tank, and the amount of rainwater the location receives.
- The second problem was the sizing of the rainwater collectors. A water collector is needed that is big enough to maintain water in the tank throughout the year given the amount of rainwater the area gets, but not so big that it would be too cumbersome to build.
- The last problem I addressed was the implementation; getting and placing the tanks into the ground, and building the water collecting surfaces. In order to address these problems, I relied on a variety of resources and collaboration from others that helped determine appropriate sizes and provide the manpower to finish the project.

TANK SIZE

To appropriately size the tank, I needed to understand primarily two things, the amount of water being deposited into the tank by rain, and the amount of water the animals would be drinking from the tank. Too small a tank would not be able to accommodate a large quantity of animals before it dries out, and it would not be able to gather a large enough amount of rainwater to remain operational in-between rain events. A too large tank would be quite difficult to install, and it could turn out to be unnecessary big in order to provide water throughout the year given the amount of rain the area receives.

The general size of the watering tank would depend primarily on the animals that would be coming to drink form it. Given that we were dealing with large animals, primarily deer, I knew I didn't want something too small to begin with, Rainmaker Wildlife offered guzzlers at the 200, 500 and 1000 gallon capacities, so I decided to analyze those three values as a starting point to see which would be more appropriate. To analyze which watering tank size is better I needed to understand how much water would be available from rain and how much water would be consumed by animals. Combining the amount of rainwater available given a certain water collector size, the amount of water being consumed by animals, and the size of the tank into a type of model would provide me with a tool to be able to evaluate different watering tank and collector sizes and how they might operate in various weather scenarios.

The first thing I did was gather data on both precipitation and number of animals in the region. I used the data, along with the different tank sizes and water collecting surface sizes, to build a data model in excel that would show which tank size is more appropriate to use. A data model makes quantitative prediction based on a set of given assumptions. It's a way to see mathematically how all these different variables affect one another and which combinations of inputs are better for my purposes. The model allowed me to analyze the options available and to explore the different design options without having to build and rebuild in real life. What is key is that the model needed to be reasonably accurate or else it could give the wrong prediction which we based our construction on. To that end the model needed to be worked on extensively and every variable needed to be thoroughly analyzed.

The model was based on daily data inputs as that is the best resolution that can be expected. Obtaining data in increments smaller than a day for so many different variables would be too difficult and data in increments larger than a day would be too general to make a precise conclusion form.

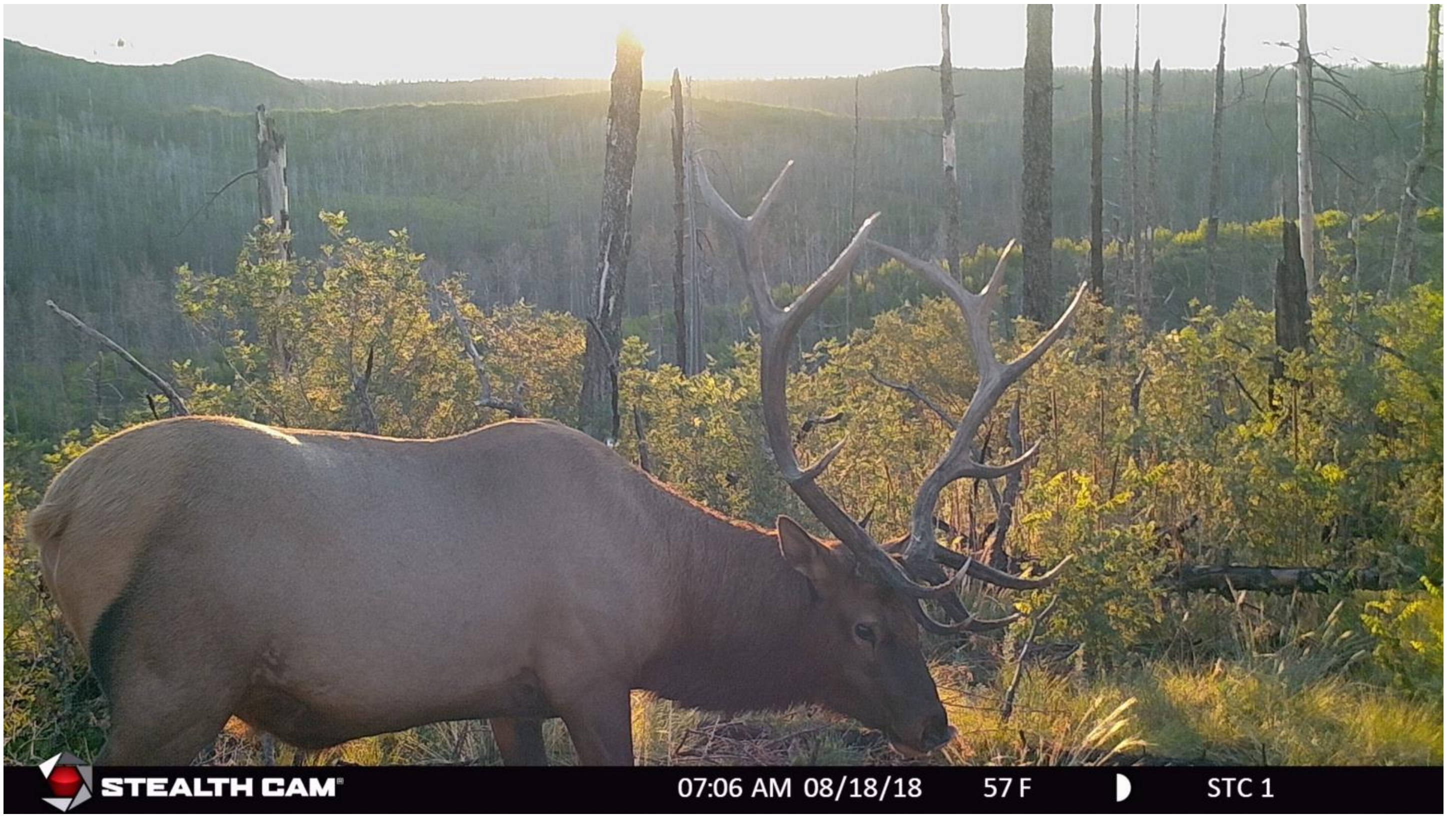
Animals

Gathering data for the number of animals that would visit the tanks proved to be quite difficult. There was no empirical data on the precise number of different animals that would visit the tank at different times, nor could there be, as the nature of wild animals can be quite unpredictable and measuring their numbers and habits is quite challenging. I build the model based on qualitative data from Professor Menicucci who had extensive knowledge and experience with the native animals. He also had thousands of dated photos from trail cameras of the many wild animals found in both locations. After analyzing various photos of the kinds of animals and discussing their habits, I implemented 4 different variables of animal water consumption into the model.

After some discussion, I assumed that these animals would be visiting the tank once a day to drink one third of their daily water consumption. I estimated that the amount of water each animal could drink by comparing their weight to the weight and water consumption ratio of cattle. For example, a beef cow weighing 900 pounds drinks about 10 gallons of water a day. So, then an adult elk weighing 450 pounds would consume 5 gallons of water a day. If that adult elk is going to the tank to drink one third of his daily water consumption, then that would be about 1.7 gallons every day. I did the same estimates with the does weighting 175 pounds, and a fawn weighting 50 pounds.

Regarding the animal visitation schedule, I used animal photos and discussions with Professor Menicucci to assume the following:

Cow Elk-- Adults seem to travel alone and could drink about 1.7 gallons of water from the tank given that it only visits the tank once a day.
Does-- They seem to travel in groups of two or three and could drink each about 0.6 gallons of water from the tank given that they only visit the tank once a day
Fawns-- They seem to travel with their mothers in small groups and could drink each about 0.2 gallons of water from the tank given that they only visit the tank once a day.
Others-- These include all lesser and less common animals like, foxes, bears, rabbits, squires, birds, bighorn sheep, mountain lions, bobcats, cayotes and turkeys. These I decided combined to about 0.2 gallons of water from the tank every day, as their appearance wouldn't be as common as that of the deer.

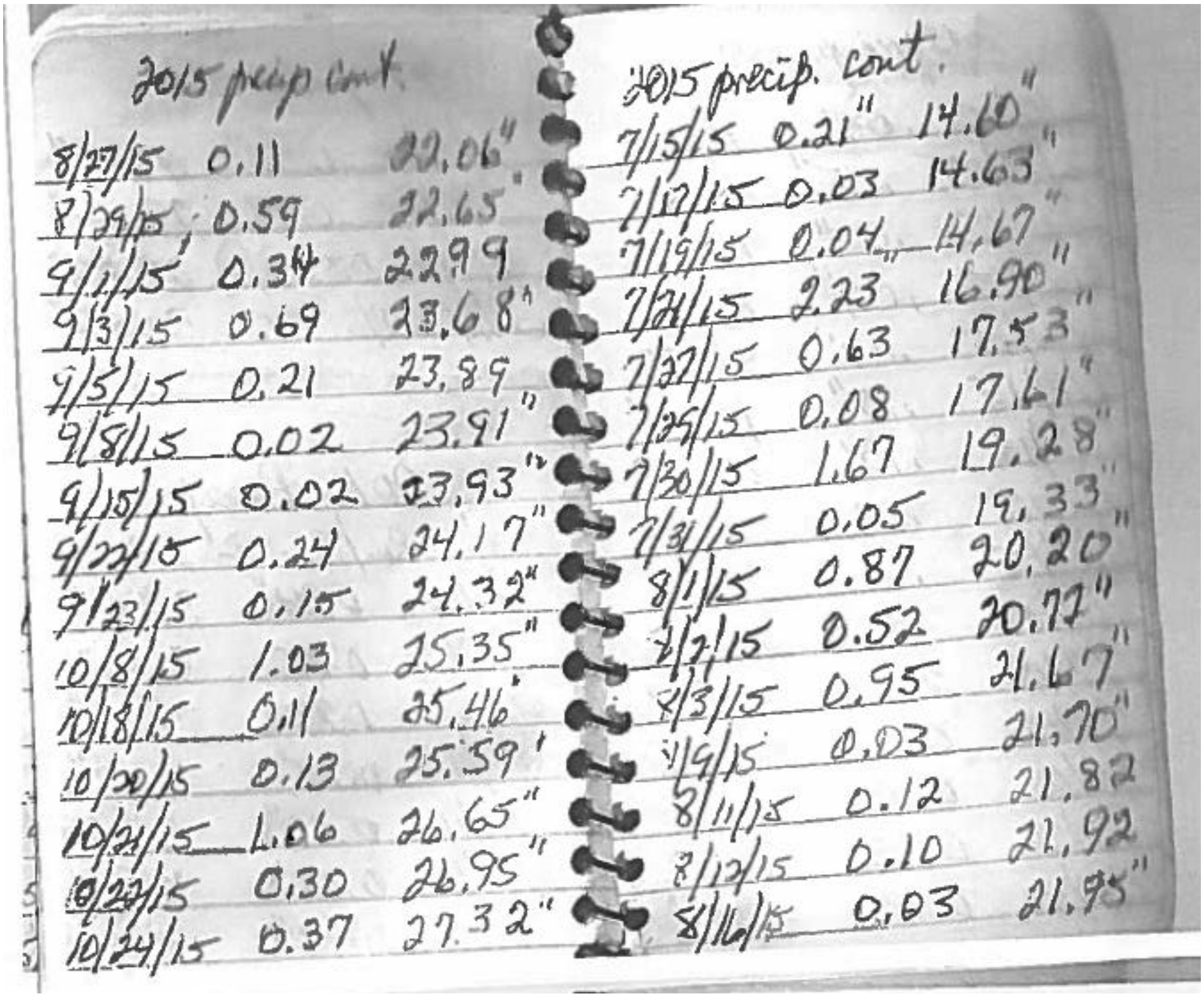


Photograph close to the ranch showing an adult elk by himself. Photograph was provided by Dave Meniccuci.

Photograph close to the cabin showing two elks, possibly two young males. Photograph was provided by Dave Meniccuci.

Precipitation

I gathered precipitation data 500 meters away from the ranch site, recorded at a neighboring ranch by a retired scientist who had been measuring precipitation and temperature for many years. I refer to this weather site as "Andy's data". Andy has a rain gauge that he uses to record daily rain precipitation in his notebook. He also records outside temperature using digital devises. The data included years from 2002 to 2017, however it did not include precipitation data for the winter.



2015 precip cont.

8/27/15 0.11 22.06"
8/29/15 0.59 22.65"
9/1/15 0.34 22.99
9/3/15 0.69 23.68"
9/5/15 0.21 23.89"
9/8/15 0.02 23.91"
9/15/15 0.02 23.93"
9/22/15 0.24 24.17"
9/23/15 0.15 24.32"
10/8/15 1.03 25.35"
10/18/15 0.11 25.46
10/20/15 0.13 25.59
10/21/15 1.06 26.65"
10/22/15 0.30 26.95"
10/24/15 0.37 27.32"

2015 precip. cont.

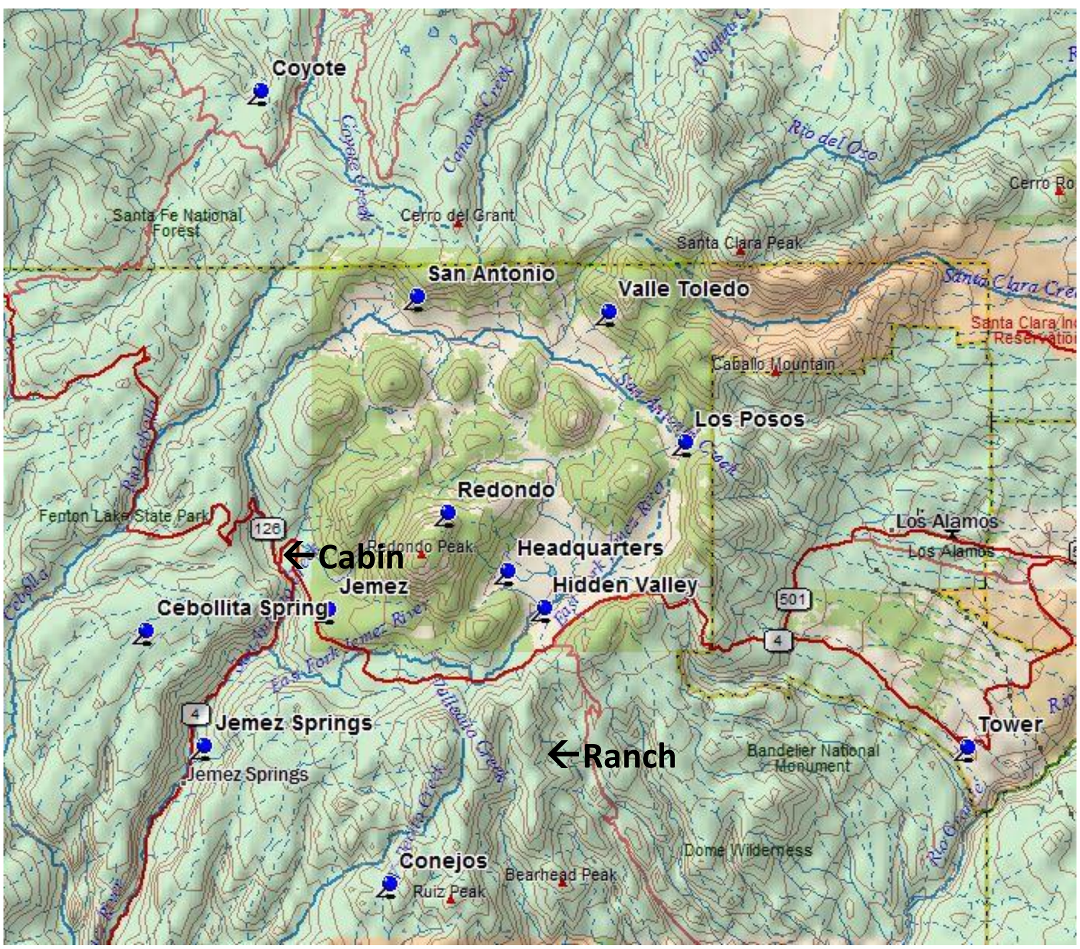
7/15/15 0.21" 14.60"
7/17/15 0.03 14.63"
7/19/15 0.04" 14.67"
7/21/15 2.23 16.90"
7/22/15 0.63 17.53"
7/25/15 0.08 17.61"
7/30/15 1.67 19.28"
7/31/15 0.05 19.33"
8/1/15 0.87 20.20"
8/2/15 0.52 20.72"
8/3/15 0.95 21.67"
8/9/15 0.03 21.70"
8/11/15 0.12 21.82
8/13/15 0.10 21.92
8/16/15 0.03 21.95"

Andy's precipitation data showing the date a measurement was made, the precipitation in inches for that day, and the total yearly precipitation up to that date.

Andy's precipitation data needed to be field in for the missing winter precipitation. I did this by using another set of data from the Valles Caldera National Preserve Climate Stations website[5]. I used the data from the Headquarters weather station because it was closest in its proximity and elevation to the ranch. The Headquarters weather station offered data on a verity of climate factors like precipitation, temperature, humidity and wind speed. These would be useful latter on in the model, but for now I only focused on obtaining the precipitation data to fill in for the winter precipitation in Andy's data. The data from Headquarters came in 10-minute increments so I had to convert it to daily totals so it would be compatible with Andy's data and my model.

Headquarters (VC) New Mexico							
:	LST	mph	Deg F	%	in		
: Date	Time	Wind	Av Air	Rel	Precip		
:YYYY/MM	hh:mm	Speed	Temp	Humidty			
1/1/2014	0:00	9.83	35.26	40.68	0		
1/1/2014	0:10	10.95	35.58	39.62	0		
1/1/2014	0:20	9.87	35.45	39.83	0		
1/1/2014	0:30	9.7	35.5	39.3	0		
1/1/2014	0:40	10.75	35.38	39.28	0		
1/1/2014	0:50	9.75	35.09	39.93	0		
1/1/2014	1:00	10.31	34.89	40.5	0		
1/1/2014	1:10	8.53	34.59	41.31	0		
1/1/2014	1:20	8.54	34.38	41.47	0		
1/1/2014	1:30	7.981	34.2	42	0		
1/1/2014	1:40	8.69	34.08	41.96	0		
1/1/2014	1:50	9.36	33.9	42.33	0		
1/1/2014	2:00	11.01	33.8	42.46	0		
1/1/2014	2:10	10.73	33.77	42.19	0		
1/1/2014	2:20	8.86	33.59	42.85	0		

Data sample from the Headquarters weather station.

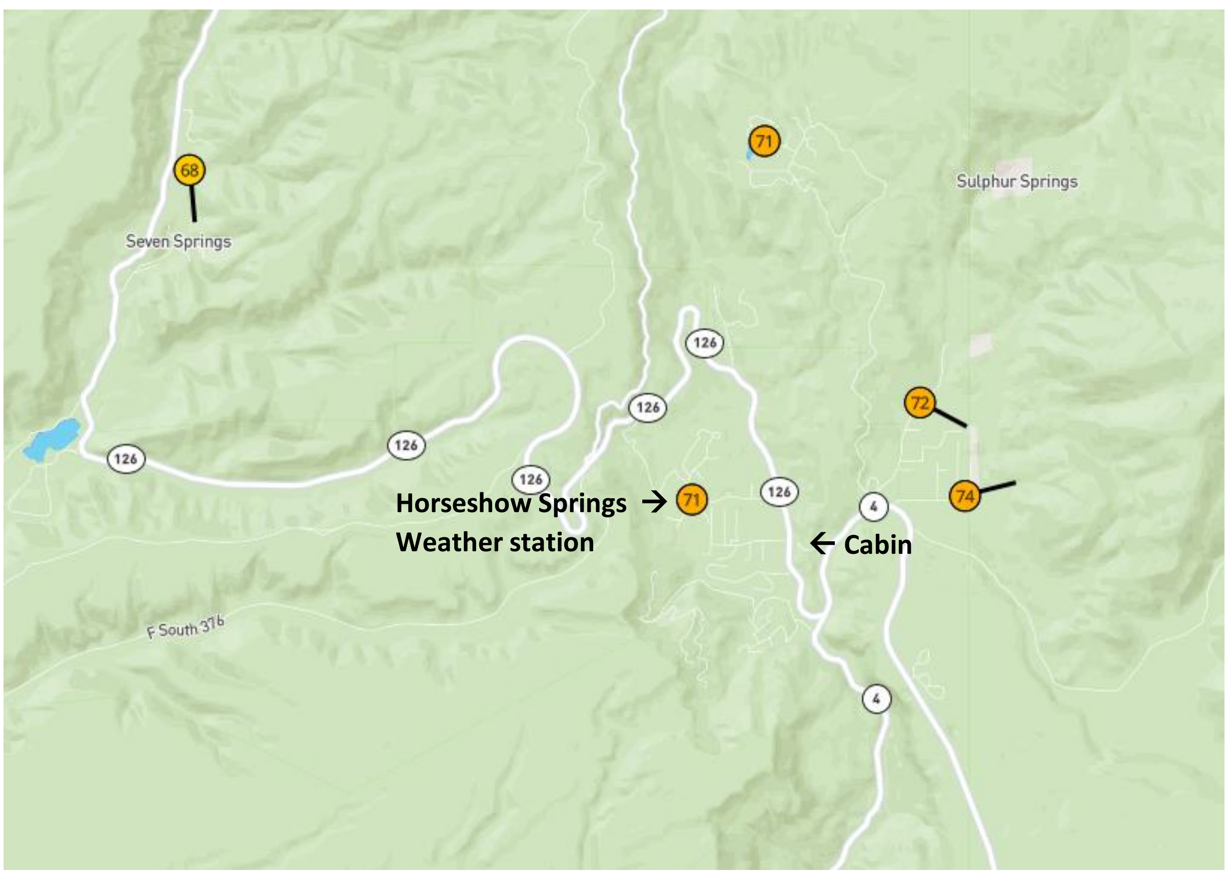


Map 2, Location of Cabin and Ranch relative to the Valles Calderas weather stations. https://wrcc.dri.edu/vallescaldera/

To obtain precipitation data closer to the cabin site I used a different weather data gathering website knows as Weather Underground[4]. I used the weather station Horseshoe Springs La Cueva because it was closest in its proximity and elevation to the cabin. Like the Headquarters weather station, it offered data on various climate factors.

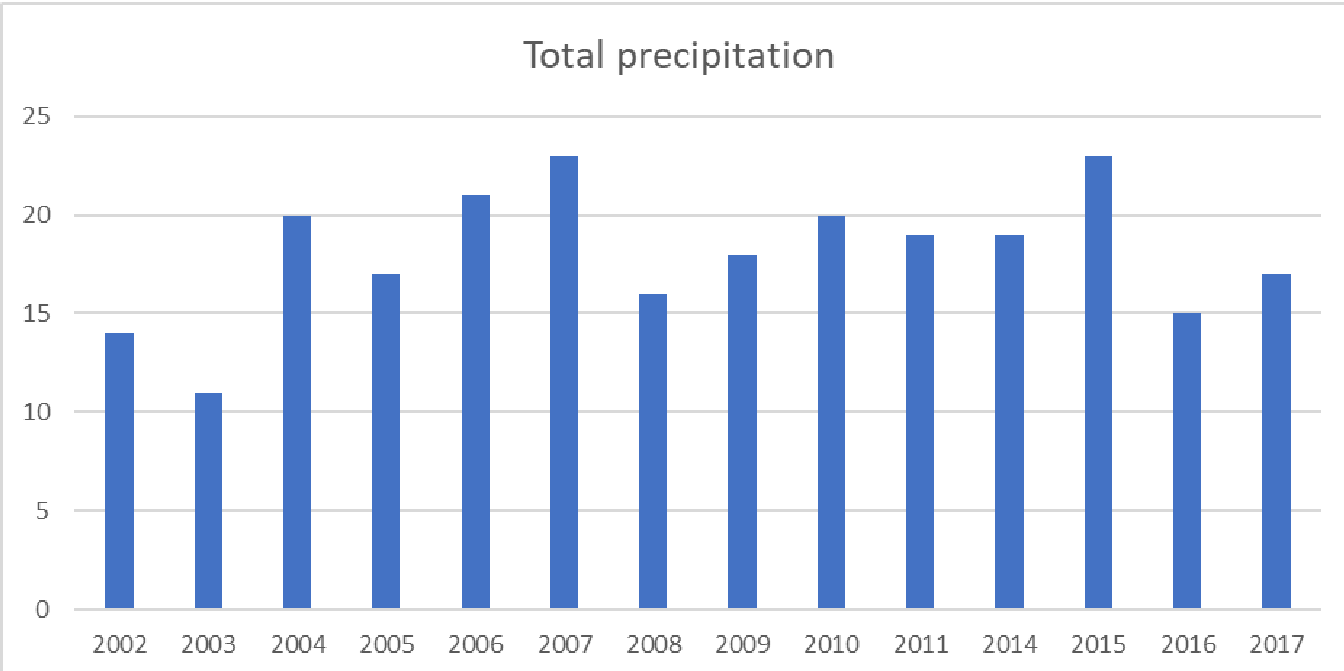
	Temperature			Dew Point			Humidity			Speed			Pressure		Precip Accum
Date	High	Avg	Low	High	Avg	Low	High	Avg	Low	High	Avg	Low	High	Low	Sum
10/1/2018	70.9 °F	58.4 °F	43.7 °F	45.1 °F	37.4 °F	30.7 °F	71.0 %	48.1 %	26.0 %	7.4 mph	0.4 mph	0.0 mph	29.9 in	29.9 in	0.0 in
10/2/2018	68.0 °F	55.2 °F	46.9 °F	57.6 °F	50.6 °F	45.0 °F	99.0 %	85.7 %	52.0 %	9.6 mph	0.6 mph	0.0 mph	29.9 in	29.8 in	0.0 in
10/3/2018	68.5 °F	57.6 °F	50.5 °F	54.5 °F	50.7 °F	46.6 °F	99.0 %	80.2 %	47.0 %	7.2 mph	0.3 mph	0.0 mph	29.9 in	29.8 in	0.0 in
10/4/2018	64.9 °F	53.7 °F	40.6 °F	53.4 °F	43.1 °F	33.3 °F	99.0 %	71.2 %	37.0 %	13.6 mph	0.6 mph	0.0 mph	29.9 in	29.8 in	0.0 in
10/5/2018	62.8 °F	47.1 °F	31.1 °F	38.1 °F	30.8 °F	22.1 °F	97.0 %	59.8 %	22.0 %	10.5 mph	0.6 mph	0.0 mph	29.8 in	29.7 in	0.0 in
10/6/2018	61.3 °F	48.6 °F	29.8 °F	40.1 °F	31.8 °F	23.5 °F	93.0 %	57.0 %	24.0 %	11.2 mph	0.9 mph	0.0 mph	29.7 in	29.6 in	0.0 in
10/7/2018	57.6 °F	50.0 °F	43.0 °F	49.6 °F	39.0 °F	33.6 °F	97.0 %	67.3 %	44.0 %	9.8 mph	0.8 mph	0.0 mph	29.6 in	29.5 in	0.0 in
10/8/2018	47.5 °F	39.2 °F	32.0 °F	40.3 °F	35.3 °F	28.9 °F	99.0 %	86.9 %	50.0 %	7.6 mph	0.2 mph	0.0 mph	29.6 in	29.5 in	0.0 in
10/9/2018	46.0 °F	38.7 °F	30.6 °F	38.5 °F	33.1 °F	29.3 °F	99.0 %	81.9 %	53.0 %	11.4 mph	0.3 mph	0.0 mph	29.6 in	29.5 in	0.0 in
10/10/2018	51.4 °F	41.3 °F	30.7 °F	37.2 °F	31.1 °F	25.0 °F	99.0 %	70.4 %	37.0 %	14.5 mph	0.5 mph	0.0 mph	29.8 in	29.6 in	0.0 in
10/11/2018	54.1 °F	42.3 °F	32.0 °F	46.0 °F	35.5 °F	29.5 °F	99.0 %	79.4 %	44.0 %	9.6 mph	0.5 mph	0.0 mph	29.8 in	29.7 in	0.0 in
10/12/2018	57.7 °F	46.4 °F	33.8 °F	41.2 °F	37.2 °F	32.7 °F	99.0 %	73.6 %	40.0 %	6.7 mph	0.3 mph	0.0 mph	29.8 in	29.7 in	0.0 in
10/13/2018	57.0 °F	45.5 °F	32.4 °F	38.8 °F	33.2 °F	27.3 °F	98.0 %	66.4 %	33.0 %	9.6 mph	0.6 mph	0.0 mph	29.7 in	29.6 in	0.0 in

Data sample from the Horseshoe Springs La Cueva weather station.

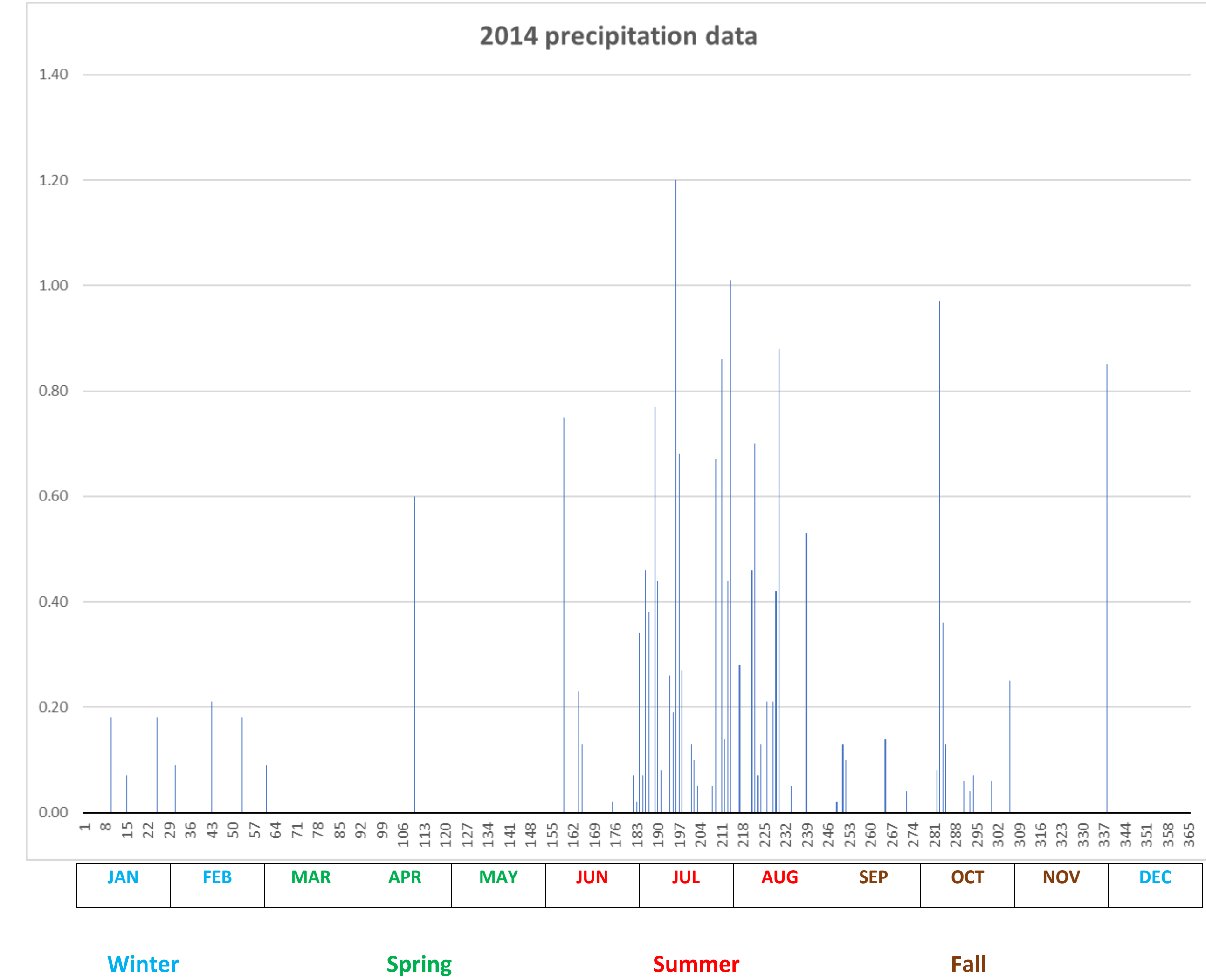


Map 3, Location of Cabin and Ranch relative to the Weather underground weather stations. https://www.wunderground.com/dashboard/pws/KNMJEMEZ4

For the data model I started with precipitation data from 2014 as this was the mean precipitation year that Andy's data indicated. All years indicate a pattern of heavy rain during the summer with periods of no rain in the spring and fall. Precipitation in the Winter varied depending on the year. Rain in the summer was abundant, but it was the periods without rain in the spring and fall that I needed to pay attention to in the data model. It was in these periods that the watering tank could be left extensively without any water.



Plot of the yearly rain precipitation sum from 2002 to 2007 (in inches). Data was provided by Andy Browman. Does not include winter precipitation.



Plot of the precipitation in inches close to the ranch in 2014. Data was provided by Andy Browman and Valles Caldera national Preserve Climate Stations.

WATER COLLECTOR

In order to build our model that would show the amount of water in the tank day by day given precipitation, animal consumption, and size of the collector, I needed to think about one last variable and that is the loss of water to evaporation. I needed to know how influential the water loss to evaporation would be in the model. If it was significant enough then the water collector would have to build so that it compensates for that loss due to evaporation.

Evaporation

Calculating the loss of water due to evaporation was complicated as I found multiple equations that would take in a multitude of variables to do so. In the end I put two different evaporation equations into the model. The first was the Stiver and Mackay Evaporation Equation used to measure the water loss in pools due to evaporation[2]. The second was a more general equation used commonly in engineering problems[3]. These equations require data on temperature, humidity, air speed and air pressure. To gather the data, I relied on the different weather stations from before. Weather Underground[4] and Valles Caldera National Preserve Climate Stations[5] provided all the data needed not only for the evaporation equations, but also precipitation data from many previous years which I used latter on to model for years that had little or large amounts of rain.

Stiver and Mackay Evaporation Equation

The following equation was developed by Warren Stiver and Dennis Mackay of the Chemical Engineering Department at the University of Toronto. It can be used to estimate evaporation from the surface of a pool of liquid that is at or near ambient temperature. Please note that the equation as been modified from its general form to be applicable to calculating evaporation from swimming pools.

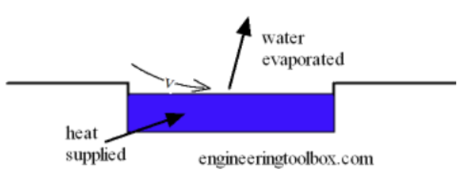
$$E = \frac{PAW}{T + 459.67}$$

Where:

- E = Evaporation Rate (Gallons/Day)
- A = Pool Surface Area (ft^2)
- W = Wind Speed Above Pool (mph)
- P = Water's Vapor Pressure (mmHG) at Ambient Temperature
- T = Temperature (°F)

First evaporation equation. Stiver and Mackay Evaporation Equation https://dengarden.com/swimming-pools/Determine-Evaporation-Rate-for-Swimming-Pool

Evaporation of water from a water surface - like an open tank, a swimming pool or similar - depends on water temperature, air temperature, air humidity and air velocity above the water surface.



The amount of evaporated water can be expressed as:

$g_s = \Theta A (x_s - x) / 3600$ (1)

or

$g_h = \Theta A (x_s - x)$

where

g_s = *amount of evaporated water per second (kg/s)*

g_h = *amount of evaporated water per hour (kg/h)*

$\Theta = (25 + 19 v)$ = *evaporation coefficient* (kg/m^2h)

v = velocity of air above the water surface (m/s)

A = water surface area (m^2)

x_s = *maximum humidity ratio of saturated air at the same temperature as the water surface (kg/kg) (kg* H_2O *in kg Dry Air)*

x = humidity ratio air (kg/kg) (kg H_2O *in kg Dry Air)*

Second evaporation equation. The Engineering ToolBox General Evaporation Equation https://www.engineeringtoolbox.com/evaporation-water-surface-d_690.html

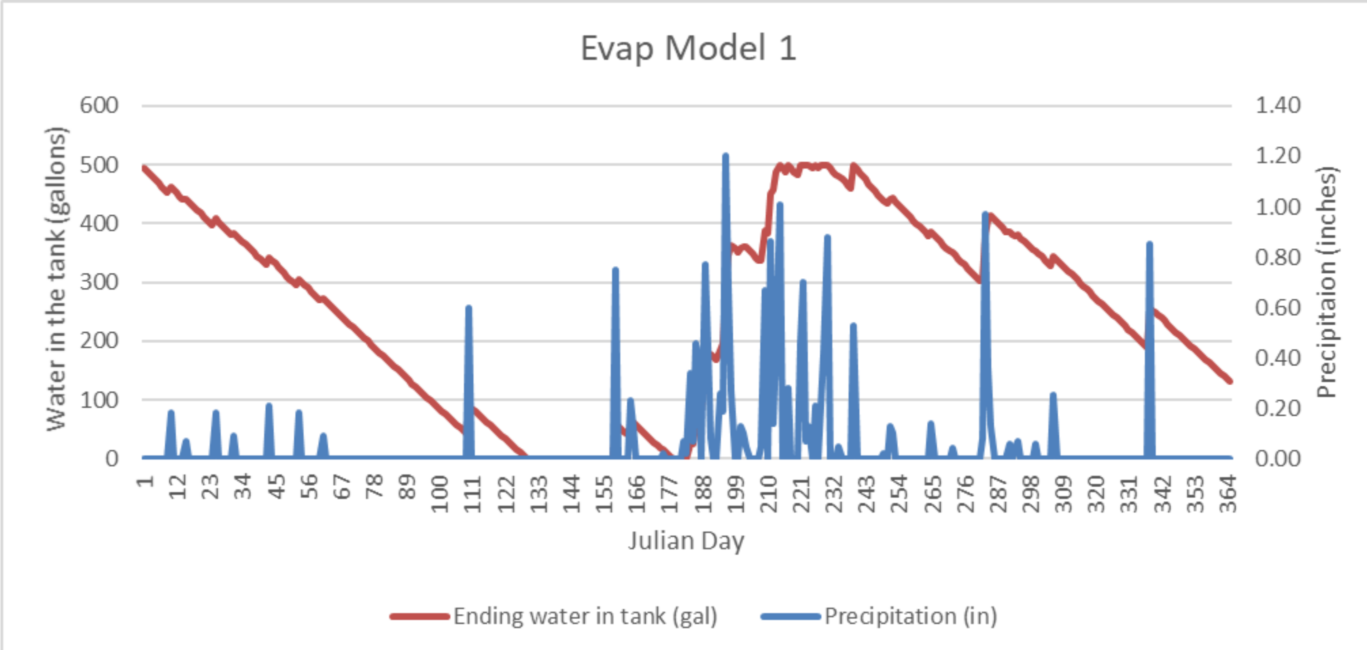
Model

Having all the data and variables gatherer I put it all together and build a model in excel that would intake all the following variables:

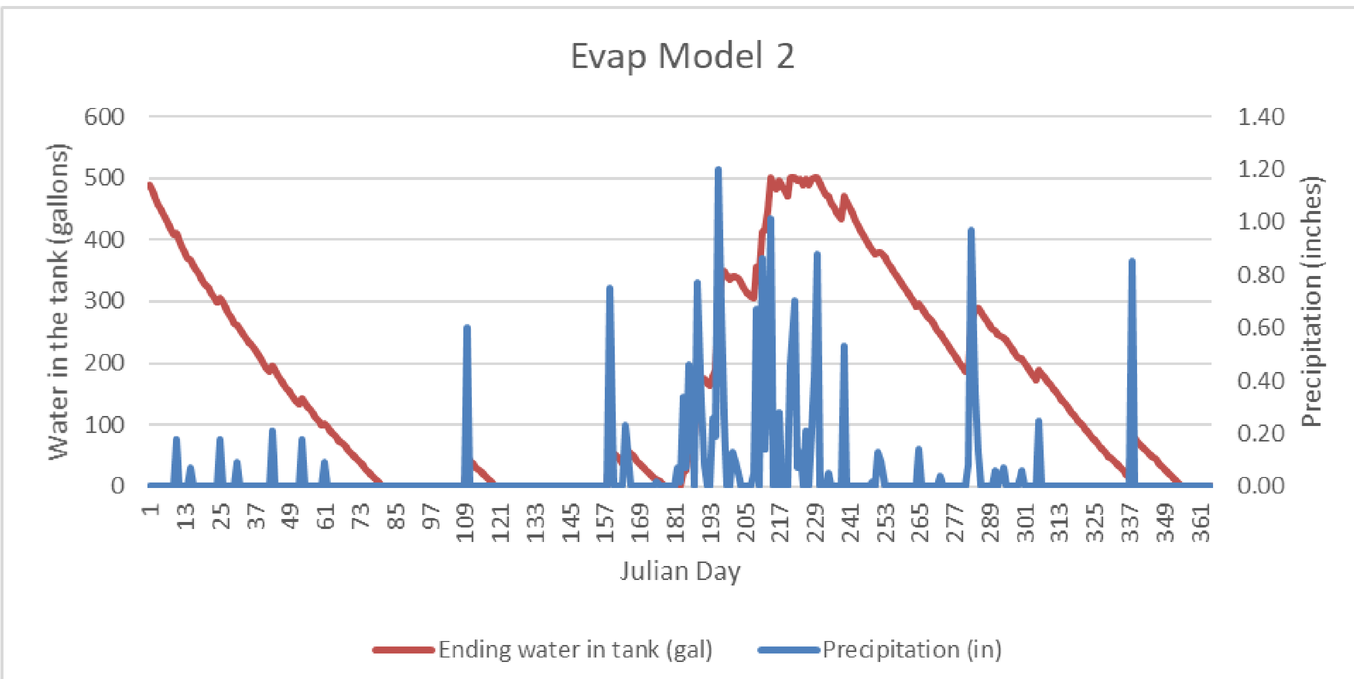
- Tank size (in gallons). This is the water holding capacity of the watering tank
- Number of Elk visits per day (assuming 1.7 gallons of water consumed every visit)
- Number of Doe visits per day (assuming 0.6 gallons of water consumed every visit)
- Number of Fawn visits per day (assuming 0.2 gallons of water consumed every visit)
- Other Animals (assuming 0.2 gallons of water consumed every visit)
  These are the animals that would be coming on average once a day to the guzzler to drink.
- Water gathering surface (in square yards). This is the size of the water collector. The bigger the value the bigger the collector which means the more water that can be collected per rain event, but it also makes the collector harder to build the bigger it is.
- Initial amount of water in the tank (in gallons). This is the amount of water in the guzzler as the model begins. It wouldn't always be empty as the amount of water in the guzzler at the begging in of the year is dependent on the previous year.
- Average temperature (Fahrenheit). This is the average air temperature above ground. This is used in the evaporation equations.
- Average Humidity (percent humidity). This is the average air humidity above ground. This is used in the evaporation equations.
- Average Wind Speed (miles per hour). This is the average air speed in the air above ground. This is used in the evaporation equations.
- Water gathering efficiency (percentage). This is the efficiency of the water collector. The collector won't be able to collect all the water that lands on top of it. For the models I used a water gathering efficiency of 90 percent.

The model would intake all the given variables and give the two separate amounts of water left in the tank every day, one for each evaporation equation. I then plotted the amount of water left in the tank for each evaporation equation against the precipitation measured every day. In order to do all this a fair amount of knowledge in how to use Excel was required.

The first thing I noticed when I ran the model was the difference in the water being lost to evaporation from the evaporation equations. Before I dealt with the appropriate size of the tank and water collector, I needed to address the difference in the evaporation equations which made a noticeable difference in the model.



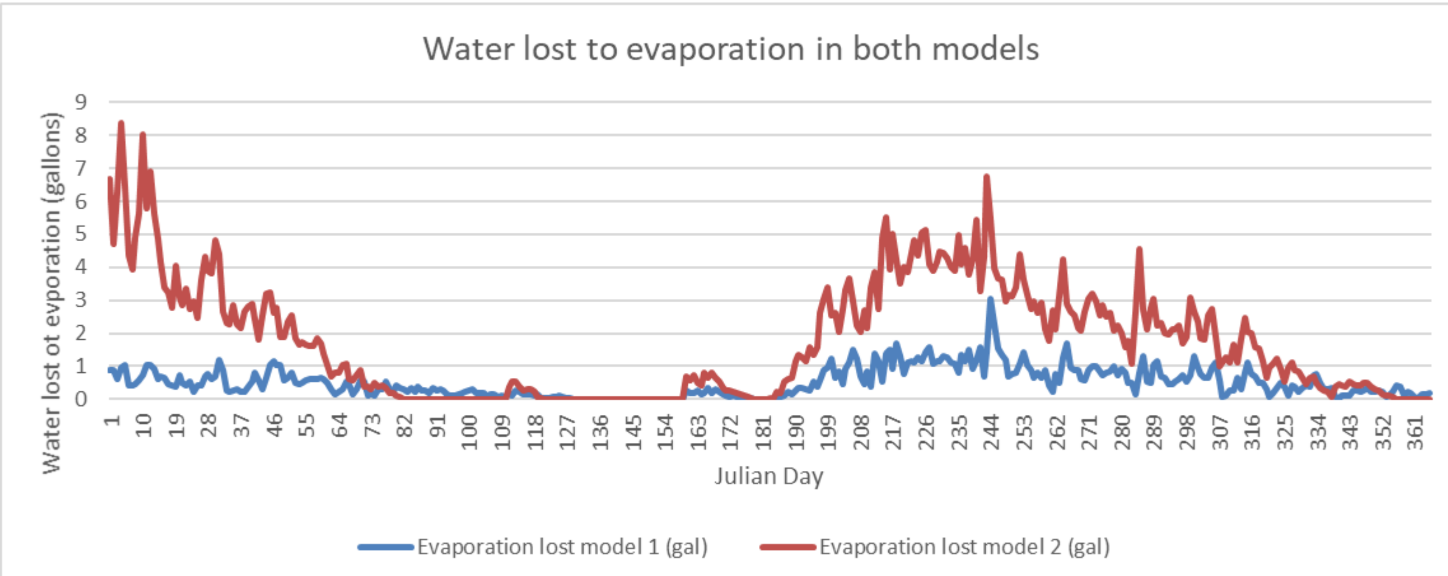
Excel 2014 water in the tank against precipitation graphs with 500-gallon tank and 20 square yards of water collecting surface. This Model used the first evaporation equation.



Excel 2014 water in the tank against precipitation graphs with 500-gallon tank and 20 square yards of water collecting surface. This Model used the second evaporation equation.

I also added to the model a way to calculate the number of days without water in the tank and the amount of water lost once the tank was full for both evaporation equations. This helped show the difference in values between both evaporation equations. The results were as follow for the 2014 year.

Total gallons of water lost in 2014 using the first evaporation equation	184.0318
Total days with no water in tank for 2014 using the first evaporation equation	33
Total gallons of water lost in 2014 using the Second evaporation equation	631.0082
Total days with no water in tank for 2014 using the Second evaporation equation	82

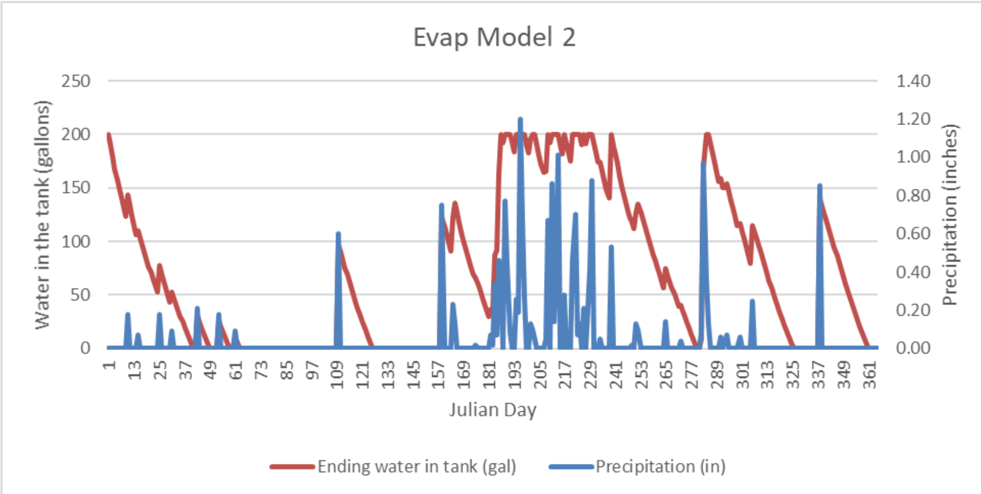


Excel 2014 graph showing the difference between the water lost due to evaporation from both evaporation equations.

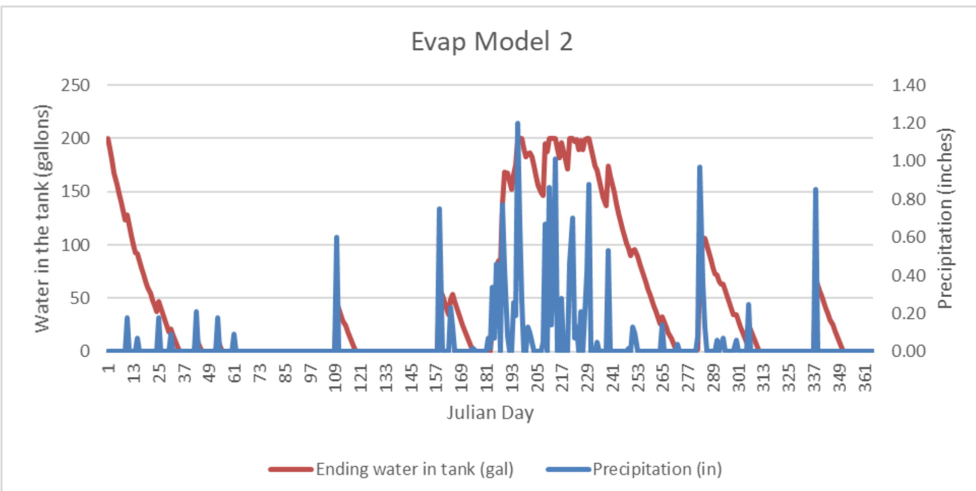
The difference in the water being lost to evaporation from the evaporation equations was noticeable. I didn't have enough time to analyze why exactly there was such a difference between the two different evaporation equations. I consulted Professor Menicucci about it and he recommended using the second evaporation equation that predicts the larger difference as is safer for our model and is an equation that is customarily used in engineering.

With the difference in evaporation lost addressed I could go back and begin running the model with different tank sizes and water collecting surface to see which would be more appropriate. For all future model scenarios I used the second evaporation equation.

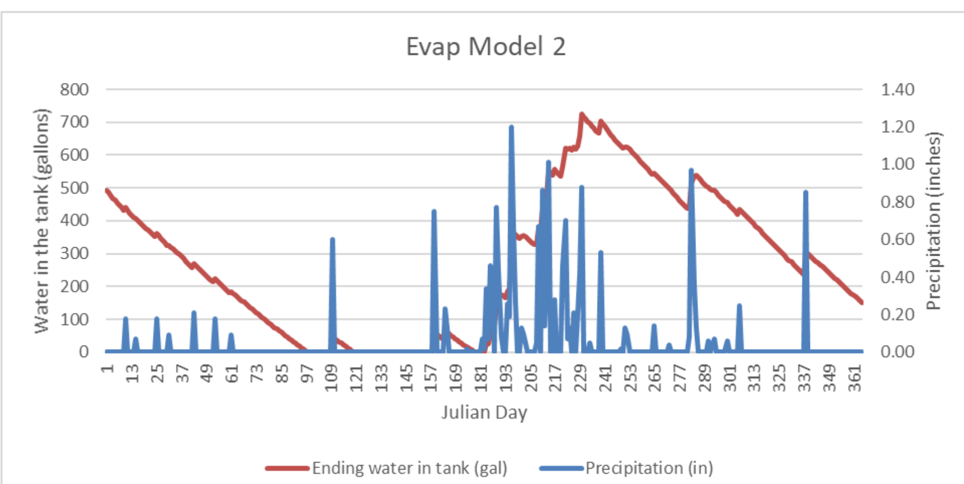
This first model scenario is for 2014 which I established earlier was a good average year in terms of precipitation. I ran the model with many different sizes for the water gathering surface and tank capacities of 200, 500 and 1000 gallons. After analyzing the many different model predictions, I decided that 20 square yards of water gathering surface was reasonable for a starting point for keeping the tank wet in an average precipitation year given a tank capacity of 500-gallons. A 200-gallon tank couldn't suffice for the amount of days without rain. A 1000-gallon tank would have been much more difficult to transport and place in the locations, it also didn't offer a considerable difference from the 500-gallon tank in terms of available water given the same size water collector.



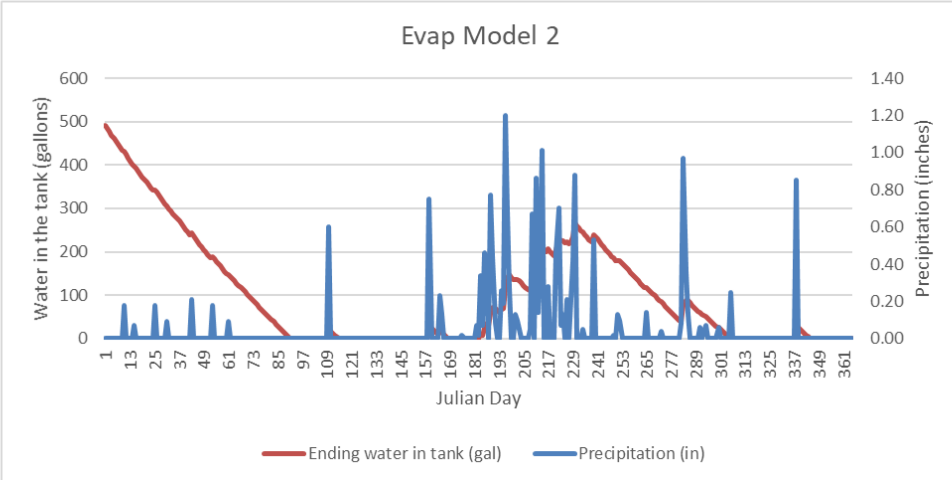
Excel 2014 water in the tank against precipitation graphs with 200-gallon tank and 40 square yards of water collecting surface.



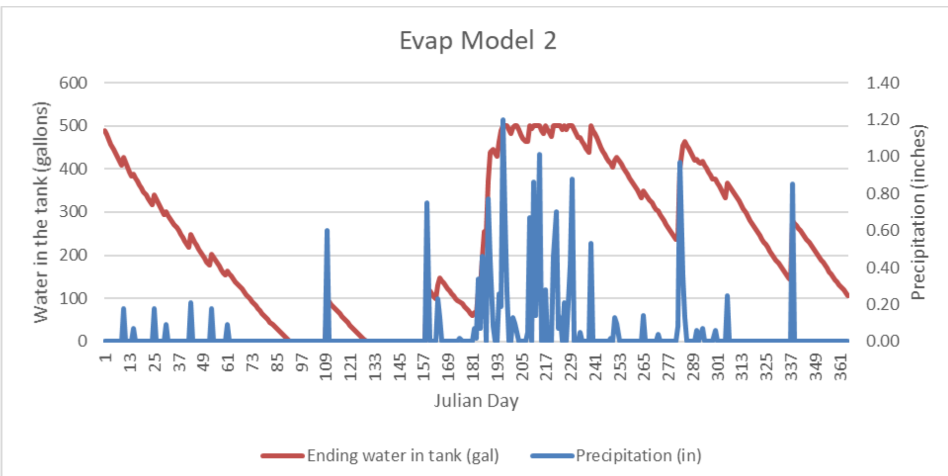
Excel 2014 water in the tank against precipitation graphs with 200-gallon tank and 20 square yards of water collecting surface.



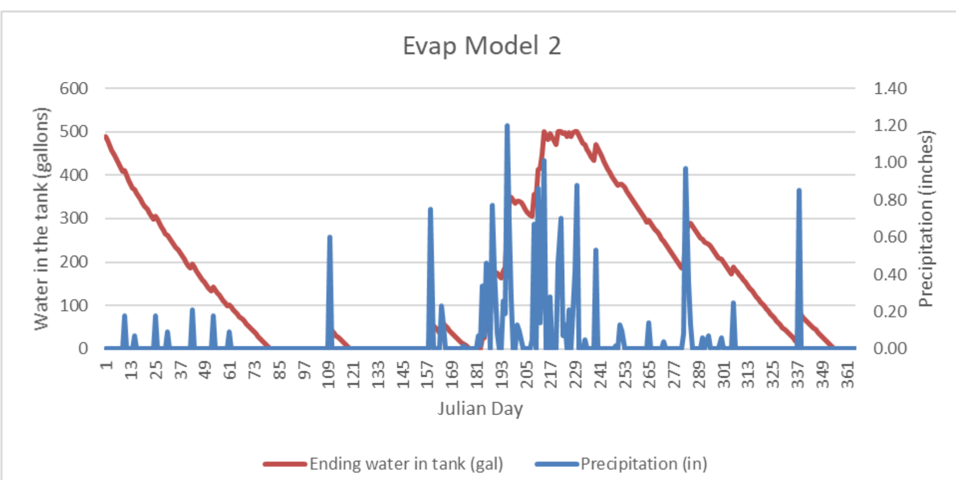
Excel 2014 water in the tank against precipitation graphs with 1000-gallon tank and 20 square yards of water collecting surface.



Excel 2014 water in the tank against precipitation graphs with 1000-gallon tank and 10 square yards of water collecting surface.



Excel 2014 water in the tank against precipitation graphs with 500-gallon tank and 40 square yards of water collecting surface.



Excel 2014 water in the tank against precipitation graphs with 500-gallon tank and 20 square yards of water collecting surface.

The size of the water collector needed to be balanced between providing the tank with enough water throughout the year, and cost efficiency. A too small of a collector wouldn't provide the require water to make the tank function, a too large of a collector would be difficult to build and costly. I went with the smallest collector that the model shows would work for a 500-gallon tank, and when we build it, we make it so that we could easily add further water gathering surface if required. The 500-gallon guzzler tank from Rainmaker Wildlife[1] would be used for both locations.

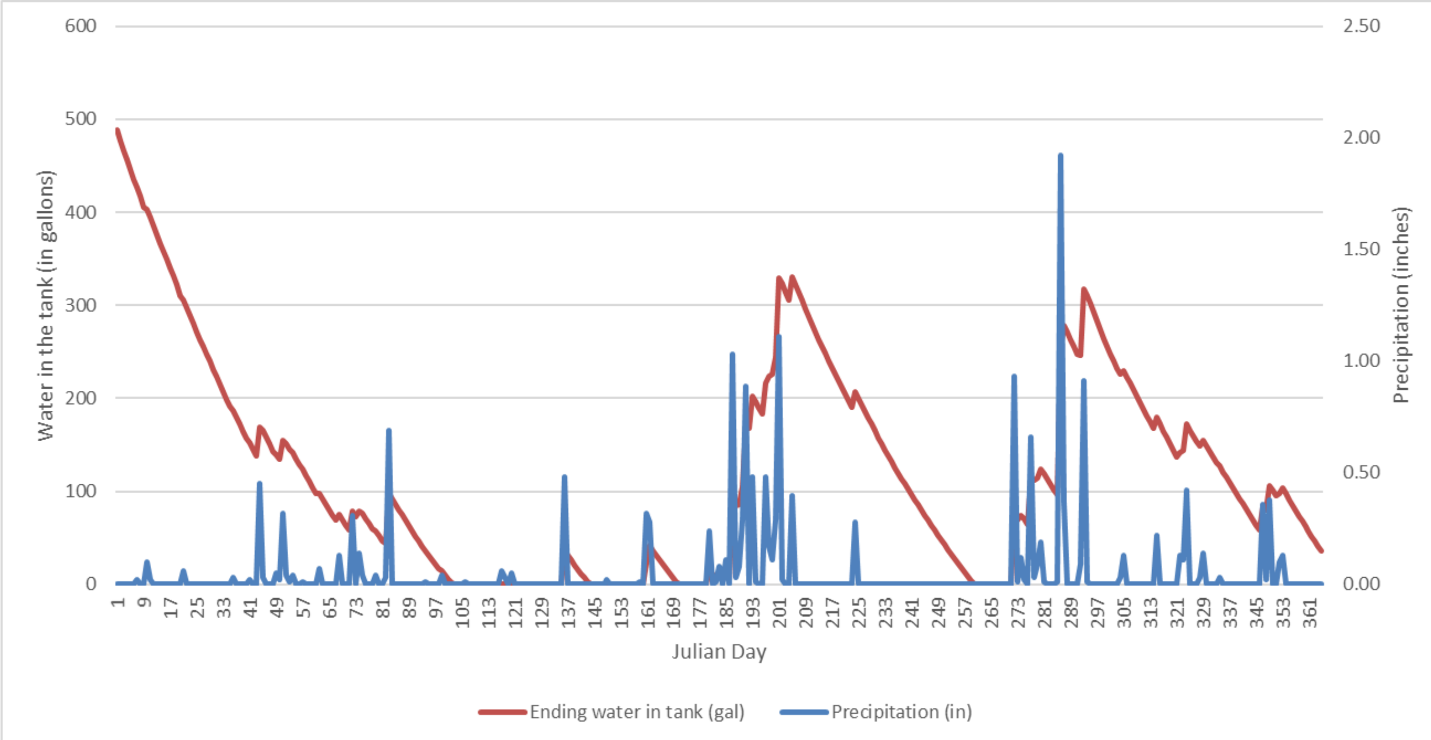
Z1

	A	I	J	K	S
1	Tank size (in gallons) (model dependent on 500)	500			
2	Number of Elk (consumes 1.7 gallons a day)	1			
3	Number of Doe (consumes 0.6 gallons a day)	3			Total gallons los
4	Number of Fawn (consumes 0.2 gallons a day)	3			Total gallons los
5	Others (consume 0.2 gallons a day)	2			Total days with
6	Water gathering surface (in square yards)	20	4.47214	square side	Total days with
7	Humidity ratio air (Mollier Diagram)	0.0025			
8	Initial amount of water (in gallons)	500			
9	Average temperature (Fahrenheit)	39.0595	Temp data taken from the Redondo site (https://wrcc.dri.edu/vallescaldera/)		
10	Average temperature (Celsius)	3.92193			
11	Average Humidity (change in humidity changes the Humidity ratio air)	53.155	Humidity data taken from the Redondo site (https://wrcc.dri.edu/vallescaldera/)		
12	Average Wind Speed (miles per hour)	4.76428	Wind data taken from the Redondo site (https://wrcc.dri.edu/vallescaldera/)		
13	Average Wind Speed (meters per second)	2.12976			
14	Water gathering efficiency	90			
15					

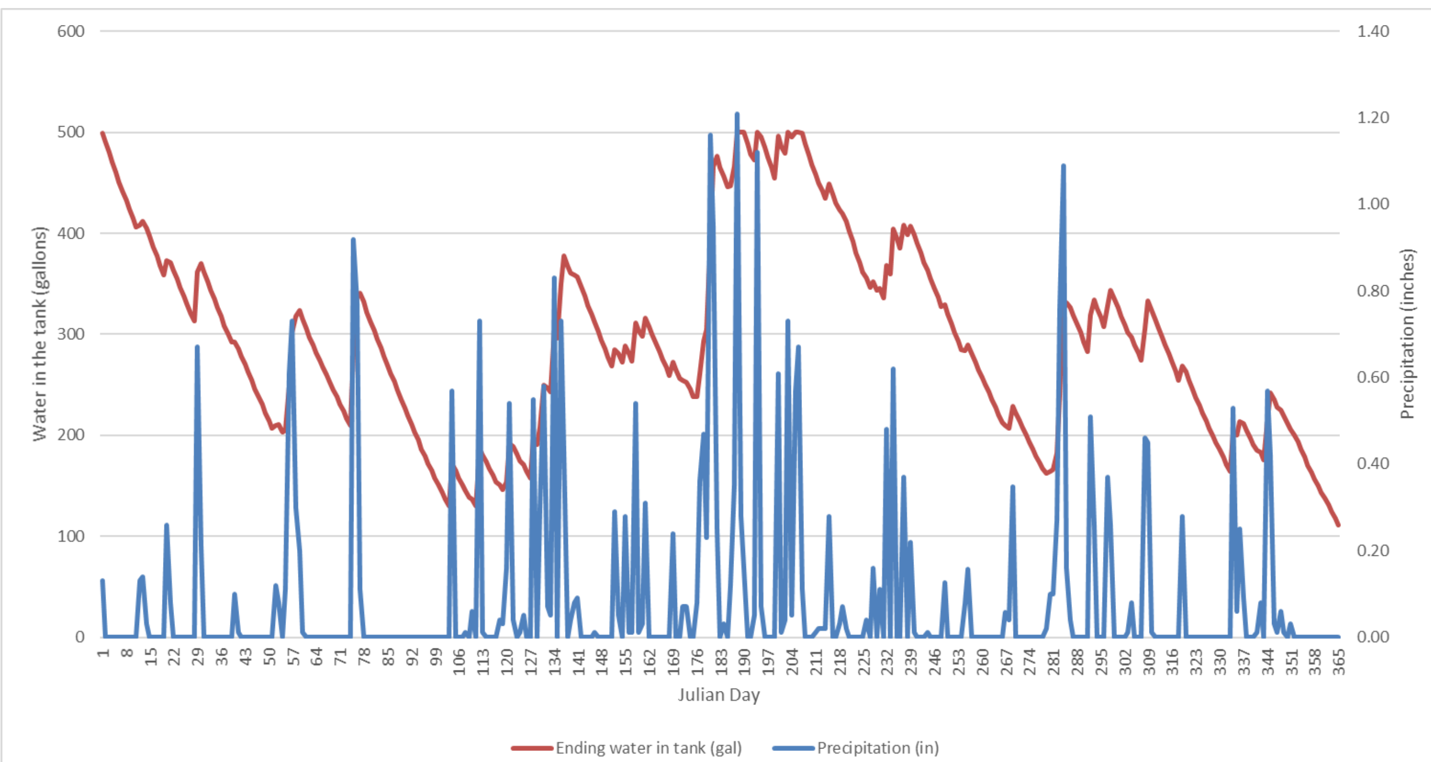
16	Day	Temperature (F)	Temperature (C)	Precipitation (in)	Wind speed (mph)	Wind Speed (mps)	Relative Humidity (%)	Precipitation captured (gal)	Starting water in tank (gal)	Evaporation lost model 1 (gal)	Animal consumption (gal)	Ending water in tank (gal)	Excess Water model 1		Starting water in tank (gal)	Evaporation lost model 2 (gal)	Max Saturation Humidity ration of Air	Ending water in tank (gal)	Excess Water model 2
17	1	25.9355	-3.3692	0.00	6.64305	2.96962	45.4665	0	500	0.89541	4.5	494.6046	0		500	6.66235	0.005044	488.8376	0
18	2	30.7518	-0.6934	0.00	3.99089	1.78404	17.5085	0	494.605	0.88575	4.5	489.2188	0		488.838	4.711581	0.005044	479.6261	0
19	3	29.441	-1.4216	0.00	6.52211	2.91556	19.055	0	489.219	0.62728	4.5	484.0916	0		479.626	6.31025	0.005044	468.8158	0
20	4	20.3666	-6.463	0.00	9.90939	4.42977	52.2499	0	484.092	0.96743	4.5	478.6241	0		468.816	8.375276	0.005044	455.9405	0
21	5	5.80745	-14.551	0.00	7.22908	3.23159	47.4617	0	478.624	1.03909	4.5	473.085	0		455.941	6.446657	0.005044	444.9939	0
22	6	20.7782	-6.2343	0.00	4.12858	1.84559	27.919	0	473.085	0.42529	4.5	468.1597	0		444.994	4.374162	0.005044	436.1197	0
23	7	26.5007	-3.0552	0.00	3.54467	1.58457	37.4912	0	468.16	0.43007	4.5	463.2297	0		436.12	3.932979	0.005044	427.6867	0
24	8	22.846	-5.0856	0.00	5.28187	2.36114	55.8781	0	463.23	0.45194	4.5	458.2777	0		427.687	4.889627	0.005044	418.2971	0
25	9	22.0119	-5.5489	0.00	6.76065	3.02219	56.481	0	458.278	0.58196	4.5	453.1958	0		418.297	5.642056	0.005044	408.1551	0
26	10	17.9378	-7.8123	0.18	11.2313	5.02068	71.2692	15.228	453.196	0.71404	4.5	463.2097	0		408.155	8.041498	0.005044	410.8416	0
27	11	30.2656	-0.9635	0.00	7.19199	3.21502	48.2988	0	463.21	1.03958	4.5	457.6701	0		410.842	5.787815	0.005044	400.5537	0
28	12	20.4719	-6.4045	0.00	9.44423	4.22183	59.1114	0	457.67	1.03913	4.5	452.131	0		400.554	6.896814	0.005044	389.1569	0
29	13	16.1741	-8.7922	0.00	7.44455	3.32792	55.7431	0	452.131	0.93922	4.5	446.6918	0		389.157	5.618938	0.005044	379.038	0
30	14	23.7015	-4.6103	0.00	6.31744	2.82407	38.626	0	446.692	0.62118	4.5	441.5706	0		379.038	4.879022	0.005044	369.659	0
31	15	28.1806	-2.1219	0.07	5.17939	2.31533	37.967	5.922	441.571	0.69239	4.5	442.3002	0		369.659	4.173557	0.005044	366.9074	0
32	16	28.4264	-1.9853	0.00	3.68157	1.64576	30.9992	0	442.3	0.6705	4.5	437.1297	0		366.907	3.378629	0.005044	359.0288	0
33	17	26.214	-3.2144	0.00	3.52658	1.57648	35.7718	0	437.13	0.47526	4.5	432.1545	0		359.029	3.228737	0.005044	351.3001	0
34	18	30.4444	-0.8642	0.00	2.73878	1.22431	39.0246	0	432.154	0.41508	4.5	427.2394	0		351.3	2.774559	0.005044	344.0255	0
35	19	29.2106	-1.5497	0.00	5.54385	2.47825	38.538	0	427.239	0.37179	4.5	422.3676	0		344.025	4.058426	0.005044	335.4671	0
36	20	29.9135	-1.1592	0.00	3.69288	1.65082	35.8913	0	422.368	0.7115	4.5	417.1561	0		335.467	3.094389	0.005044	327.8727	0
37	21	30.4546	-0.8586	0.00	3.32941	1.48834	21.5731	0	417.156	0.48018	4.5	412.1759	0		327.873	2.858693	0.005044	320.514	0
38	22	27.1058	-2.719	0.00	4.61556	2.06328	22.5066	0	412.176	0.4362	4.5	407.2397	0		320.514	3.367512	0.005044	312.6465	0
39	23	13.3678	-10.351	0.00	3.38298	1.51228	80.9206	0	407.24	0.52896	4.5	402.2108	0		312.646	2.749217	0.005044	305.3973	0
40	24	24.2636	-4.298	0.00	4.07987	1.82381	36.2819	0	402.211	0.22807	4.5	397.4827	0		305.397	2.981292	0.005044	297.916	0
41	25	33.4221	0.79005	0.18	3.04228	1.35998	26.7886	15.228	397.483	0.41099	4.5	407.7997	0		297.916	2.478605	0.005044	306.1654	0
42	26	28.7228	-1.8206	0.00	5.61644	2.5107	42.9262	0	407.8	0.43866	4.5	402.8611	0		306.165	3.642683	0.005044	298.0227	0
43	27	24.8616	-3.9658	0.00	7.52187	3.36248	52.3801	0	402.861	0.67545	4.5	397.6856	0		298.023	4.335102	0.005044	289.1876	0
44	28	21.723	-5.7095	0.00	6.70332	2.99657	38.2131	0	397.686	0.77508	4.5	392.4105	0		289.188	3.877564	0.005044	280.81	0
45	29	25.6904	-3.5053	0.00	6.83757	3.05658	39.1177	0	392.411	0.60643	4.5	387.3041	0		280.81	3.817633	0.005044	272.4924	0
46	30	30.4921	-0.8377	0.00	9.75913	4.3626	69.4741	0	387.304	0.70749	4.5	382.0966	0		272.492	4.811097	0.005044	263.1813	0
47	31	24.4966	-4.1686	0.09	9.09293	4.06479	80.4471	7.614	382.097	1.18687	4.5	384.0237	0		263.181	4.402999	0.005044	261.8923	0
48	32	14.2176	-9.8791	0.00	4.32514	1.93346	87.941	0	384.024	0.89264	4.5	378.6311	0		261.892	2.645878	0.005044	254.7464	0

Excel 2014 data model showing the ending water in the tank every day from both evaporation equations. In this model the tank size is 500 gallons and the water gathering surface is 20 square yards.

Now that I had a working model, I could go back and input data from other years to see how the 500-gallon tank with a 20 square yard water gathering surface would do in a year with little rain and a year with allot of rain. I ran the model scenario using data from 2018 which was a year with relatively low precipitation, as well as 2015 which was a year with high relative precipitation. Data for both years was gathered from the Headquarters weather station[5].

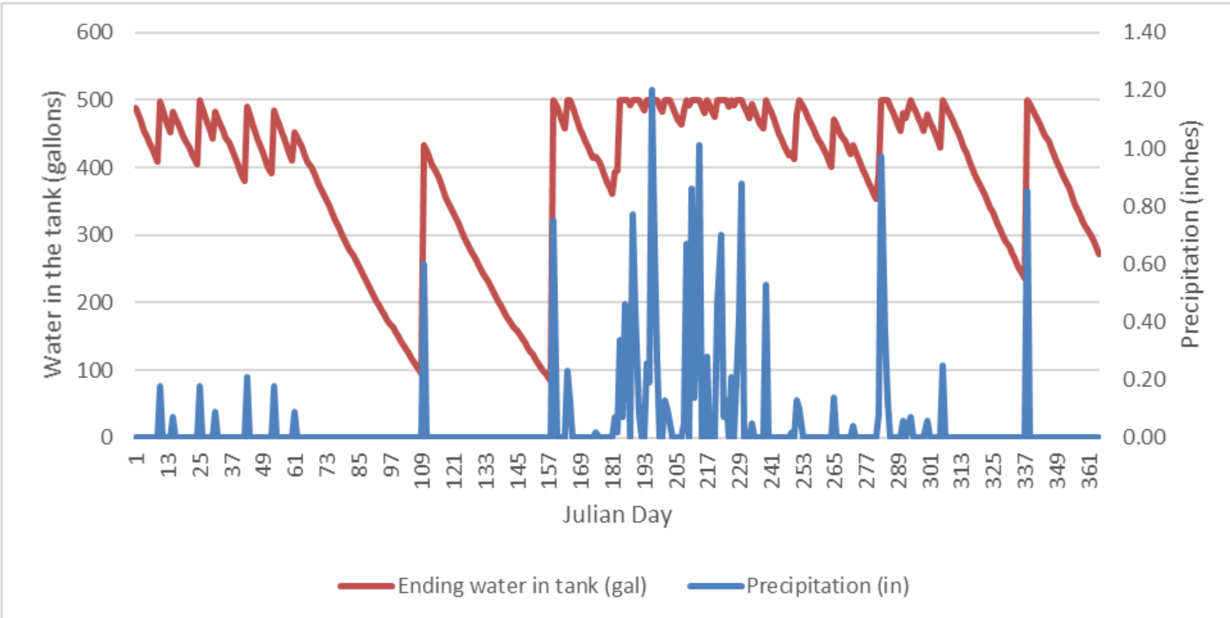


Excel 2018 water in the tank against precipitation graphs with 500-gallon tank and 20 square yards of water collecting surface.



Excel 2015 water in the tank against precipitation graphs with 500-gallon tank and 20 square yards of water collecting surface.

With the size of the tank and the water gathering surface figured out I could continue to the implementation portion of the project. The tank at the cabin was to use the two water gutters connected to the roof of the cabin. The water gathering surface of the cabin was about 135 square yards, and after running the model with that gathering surface for the average precipitation year of 2014, I decided that for now there was no need to reduce the water gathering surface for the cabin, but at certain times is possible that the size would need to be reduced. When that would the case the water gathering surface could be reduce to only half of the cabin roof by only connection one of the gutters to the tank. For the tank at the ranch a collecting surface of about 20 square yards needed to be built after the tank was placed at that location.



Excel 2015 water in the tank against precipitation graphs with 500-gallon tank and 135 square yards of water collecting surface.

IMPLEMENTATION

The Tanks

First, the tanks needed to get to their locations so that they could be installed into the ground. Rainmaker Wildlife delivered the tanks to the city and from there they were transported to the Jemez mountains in a truck. At 220 pounds each the 500-gallon tanks are not so heavy that they couldn't be handled with a few extra pairs of hands.

Once the tanks were at their desired locations, we started the labor-intensive work of fitting them into the ground. First, we needed to create an appropriate hole in the ground that would fit the tank dimensions. The hole needed to be leveled and flat to make sure the tank wouldn't suffer from uneven external pressure that could cause it to break once it got filed with water. Once the tank was placed, we put some wooden frames on the inside to provide it with some internal pressure as we covered the outer parts of the tank with dirt and rocks to give it stability.

Tanks on their way to the Jemez mountains.

One of the tanks being taken to the ranch.

Hole for the tank at the cabin being made, making sure that the base for the tank is even all throughout.

Getting ready to place the tank in the hole close to the cabin.

Placement of a brick wall in the water drinking side of the tank as to prevent debris from falling in.

Filling the sides of the tank with dirt and rocks to give it stability at the cabin.

Hole for the tank at the ranch being made, making sure that the base for the tank is even all throughout.

Filling the sides of the tank with dirt and rocks to give it stability at the ranch.

The Water Collectors

As mentioned before the water collector for the cabin tank are the gutters that collect rainwater from the roof of the cabin which offer about 135 square yards of water gathering surface. The two outflows of the roof gutters are extended and connected to reach the tank.

Connection between the water collector and the tank at the cabin.

For the water collect at the ranch the construction considers a couple of factors that could impact the guzzler. The amount of snow and ice that could build up on top of the collector can be an issue. A maximum live load of 5 feet of solid ice is calculated for the water collector. The wind is another factor to consider. The microburst of air at the mountains can reach speed of 150 miles per hour. This can create a dangerous uplift that could damage the water collector.

To solve for this, we build the collector just above the ground to eliminate uplift and provide additional stability. We chose to place the tank right next to a titled piece of land so that when we build the collector right on top of the ground it is naturally tilted to collect and place the water into the tank.

With both guzzlers installed, the final task was to address monitoring the performance and maintenance. Rain gauges were placed in both the cabin and ranch that will monitor the precipitation. The measured precipitation can them be compared to the amount of water in the tank to measure the performance of the guzzler like how the data model worked. To measure the amount of water in the tank a measuring line will be built along the inside of the tank, like with fuel tanks. Both the tank and water collectors will be periodically cleaned to make sure that there are no obstructions. If what is being measured from the guzzlers doesn’t reflect the results from the data model, then the appropriate changes to the water collector size will be made.

Field Calibration of Model

As it happens a short wile after the guzzler system at the cabin was finished, the tank got filed from a series of rain events measuring 0.8 inches of precipitation total. There was so much water overflowing when it happened that one of the roof gutters that connected the roof of the cabin to the tank got taken offline to reduce the amount of water coming into the tank. Too much water overflow and it could erode the berms around the tank.

I went back to the data model and recreated the scenario to see if it would predict the same result. The tank got field with about 100 gallons of water before the rain, and it was also too early for any animal consumption to have happened. So, I ran the model with 100 gallons of initial water in the tank, a water gathering surface of 135 square inches which was the approximate surface area of the roof, zero number of any animals visiting the guzzler, and a precipitation of 0.8 inches. The model showed that the tank would indeed get filled and that there would also be about 55 gallons of excess water that would overflow, confirming what was observed at the cabin with a good level of accuracy.

For now, the surface area of the water gathering surface at the cabin will remain half of its capacity. Once grass grows around the tank and solidifies the land there will be no need to worry about overflow and the water gathering surface can return to its full size.

SUMMARY

To build these guzzlers and provide close access to the many wild animals at both the cabin and ranch locations I needed to consider the size of the tank, the size of the water collector, and the placement of the tank and construction of the collector. Gathering the necessary data to build a reliable data model that would allow me to better understand how it all comes together was quite difficult. I would collect data measured in all sorts of different units and in different increments and formats. I needed to manipulate and convert the data to a standard format that I could then use in my model. The water evaporation portion of the model also proved to be time consuming as I couldn’t understand the difference in the equations or how they fundamentally worked. Lack of sufficient organization also took a bit of a tool as there where many different data sets and models both digital and physical that I needed to keep track of and use intertwiningly. In the end this project was a joint effort between many people who helped by providing the required data, assisting with the construction, and give general direction and professional suggestions.

CONCLUSION

This report is meant to explain the design and building process that was used to build the two guzzlers in the Jemez mountains region. It’s also meant to be a reference or guide for others who are interested in building their own guzzlers.

REFERENCES

1. https://www.rainmakerwildlife.com/
2. https://dengarden.com/swimming-pools/Determine-Evaporation-Rate-for-Swimming-Pool
3. https://www.engineeringtoolbox.com/evaporation-water-surface-d_690.html
4. https://www.wunderground.com/dashboard/pws/KNMJEMEZ5#history
5. https://wrcc.dri.edu/vallescaldera/