Hydraulic Analysis of the Tachoaleche Watershed

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Summary

The outlet for the Tacoaleche watershed is located in the town of Tacoaleche, Zacatecas, Mexico. It is a natural channel with man made raised banks that conveys both sewage and storm water away from the cities of Zacatecas and Guadalupe. Between Guadalupe and Zacatecas lies the reservoir of El Pedernalillo. This reservoir stores water for the dry season for irrigation purposes. The area receives intense precipitation in short duration storms that frequently causes flooding. Various sets of curve numbers were used to represent the soil conditions to model the watershed. Rainfalls representing 2 year and 20 year storms were used with varying soil conditions, dry and wet, as well as varying storage conditions in the reservoir, empty, half full, and full. The resulting flows ranged from 60 cms to 800 cms. Reasons for elevated discharges during precipitation events were examined as well as mitigation strategies.

Introduction

The Tacoaleche watershed encompasses an area greater than 400 km^2. This basin holds most of the town of Tacoaleche and the city of Zacatecas and all of the town of Guadalupe. Population estimates for the area are around 1.3 million on the whole region (Visit Mexico). The figure below (Figure 1) illustrates the area that we were working with. Tacoaleche is at the very northernmost point with Zacatecas and Guadalupe being the yellow area on the western side about 1/4th of the way down the watershed.

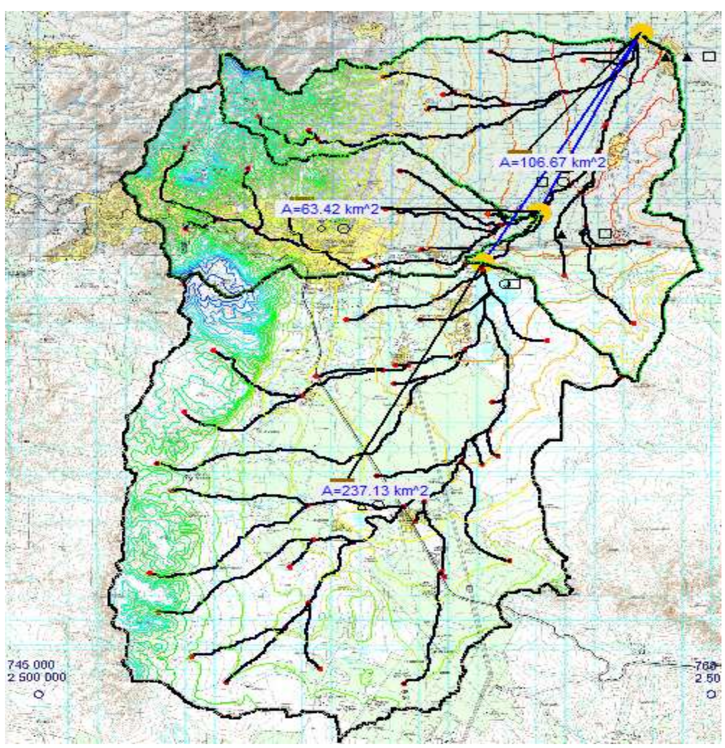

Figure 1. Map of watershed.

The entire watershed lies in an arid climate zone receiving 12” of precipitation on average per year. The majority of the precipitation comes during a few months of the year, June through September. The majority of the precipitation falls during intense storms that last less than three hours. The soil is a desert soil with little organics and topsoil present. It is often cracked and baked relatively hard by the sun. The plant cover is very similar to the desert portions of Utah. The forests are small and comprised primarily of Gamble oak, with the majority of the vegetation being sage brush-like and coarse grasses. There is some agriculture present, though that is limited. The fringes of the watershed lie on a steep, rocky gradient that eases into a flatter topography on the valley floor.

There is a main canal of wastewater flowing out of the city of Zacatecas through Guadalupe. This channel ends in a seasonal reservoir known as El Pedernalillo. It is used for the storage of water for agricultural irrigation purposes in the dry season. There is no low-level outlet or regulation structure, rather when it is full, it spills over and proceeds down the channel through the town of Tacoaleche. This is where the majority of the flooding occurred until recently when the banks of the channel were built up. The canal conveys water with a high solids content and has a low gradient, therefore many of those solids conveyed, drop out and are deposited on the streambed raising the level of the river continually.

Materials and Methods

It was decided that WMS would be used to set up all the parameters of the model and then mapped over to the HEC-HMS program to run the model. There was a lack of good soil and land use data for our area. All of the parameters that we used in our models were estimated by the group as a whole. It was desired to obtain information concerning the effect that the nearby Perdenalillo reservoir would have on the outlet. The large sub-basin was divided into three sub-basins. One included the urban area the other included the area where the reservoir was located and the last one was everything else in the watershed.

The SCS curve number and SCS transform method was selected for the analysis. Estimates for the curve number of each sub-basin were generated by the group as a whole (see Tables 1 & 2). A Hydrology textbook was used to produce the curve number estimates.

Table 1. Dry Conditions of a Type A Soil

Dry Conditions (type A soil)					
	CN	Initial Abstraction (mm)	Impervious (%)	Lag Time (min)	Area (km^2)
Urban Basin	89	6.28	30	220	63.3
Reservior Basin	74	17.84	1	368	237
Rest of Watershed	50	50.8	1.5	546	107

Table 2. Wet Conditions of a Type D Soil

Wet Conditions (type D soil)					
	CN	Initial Abstraction (mm)	Impervious (%)	Lag Time (min)	Area (km^2)
Urban Basin	95	2.97	30	89.4	63.3
Reservior Basin	92	4.42	1	198	237
Rest of Watershed	84	9.67	1.5	215	107

Precipitation

The group from Mexico was able to generate IDF curves for seven rain gage stations in the area. This data was used to produce the amount of rainfall expected in a 2-year storm and also a 20-year storm. The coverage each gage had on the watershed was estimated using theissen polygons. The group from Mexico also described rain storms in that area as short and intense. They estimated the average duration of the typical storm to be three hours long. A hypothetical hyetograph was produced by the group to produce a short intense storm of three hours. The amount of precipitation was calculated using the observed data from the IDF curves and weighting all of the gage stations.

Reservoir Routing

The largest obstacle in this model was routing through a reservoir. The group from Mexico provided a storage-elevation curve for the reservoir of interest. This data was then input into the HMS model to simulate the effect the reservoir has on the watershed under different conditions. No information was available for the weir so estimations were made for the weir coefficient, width, and length.

Results

It was found that there were a few characteristics about our watershed that affected the total runoff. The nature of the area is very flat and planar which it turn causes for much settling of the water that is flowing through the area. The water puddles and therefore cannot reach the outlet before it is evaporated into the atmosphere. The only way we could find high outflows from the watershed was to increase the moisture content of the soil or model a large storm across the watershed. To begin we chose to model a 2 year storm across the whole watershed and produce some basic results of runoff (see Figure 2).

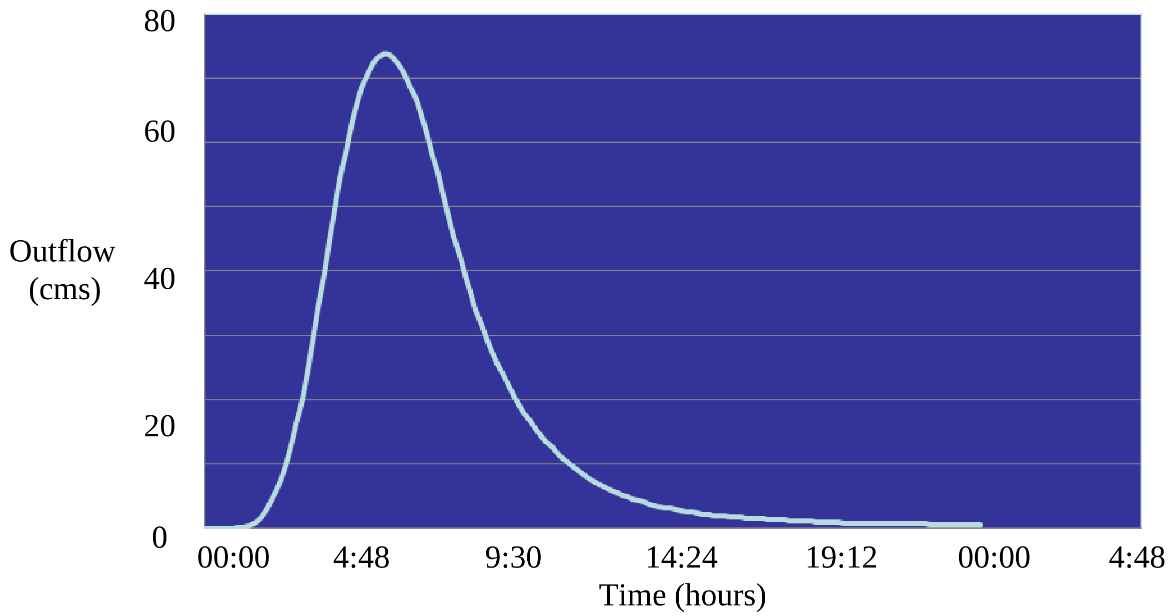

Figure 2. Basic watershed model results for 2 yr. Storm.

The model above showed a large influx of water five hours after the storm had hit and then it was observed as a slow normal runoff. The outlet of the watershed could easily handle the 75 cms and this type of storm would not lead to a surplus in runoff or a problem with flooding in the small village of Tacoaleche. This type of storm was actually quite common for the area and the soil moisture that was used for this model was dry because of the desert conditions that exist.

The results that were cause to worry was the event of a twenty year storm with the lake taken into account. Perdenalillo is the reservoir just south of the city of Guadalupe and had the power to cause for disaster downstream if the lake had any storage from previous rainfall. The lake was first taken into account and reservoir routing was used (see Figure 3).

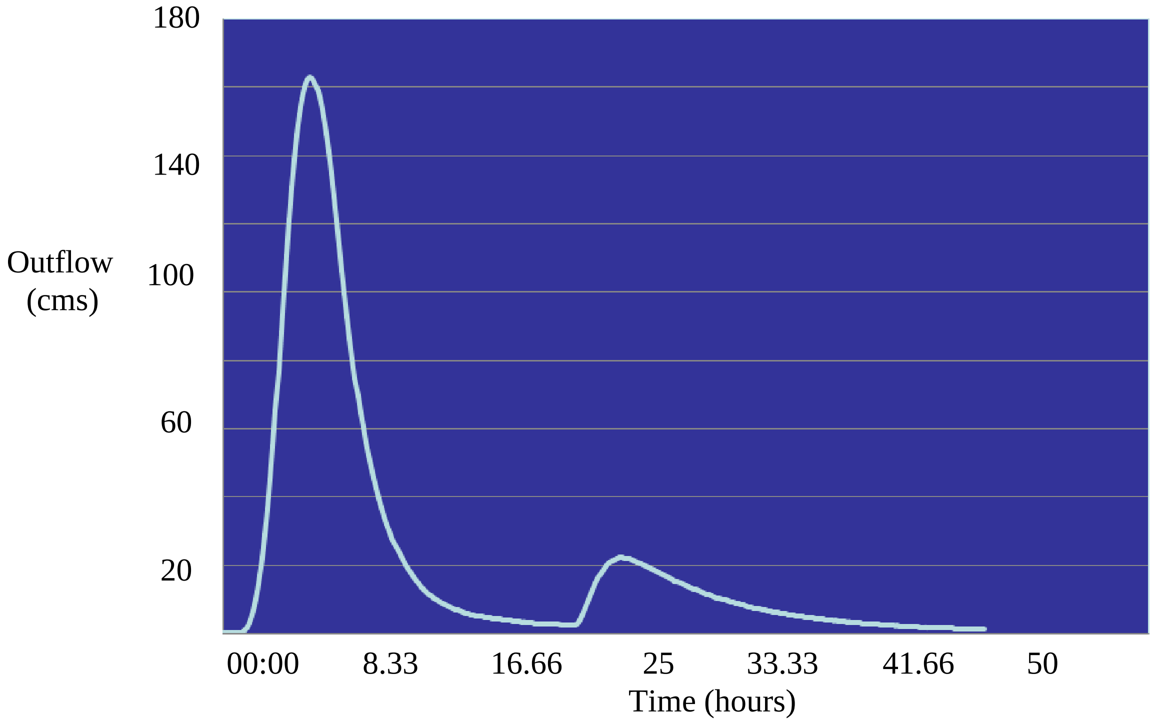

Figure 3. Storm routing through Lake Perdenalillo of a 20 yr. Storm.

The reason the second peak appears is because it takes a day to fill up the reservoir and then the water starts to cascade over the outlet of the reservoir thus causing a second jump. This storms peak was much higher than the two year event as the peak rises to well over 160 cms. This event would definitely have some small affects on runoff and the downstream village of Tacoaleche. There would be some slight flooding but nothing of a huge problem.

The twenty-year storm with the soil saturation set at high would be the storm with the most lasting affects. The runoff would be great and the lake would already be full and not allow for any storage of the rainfall. There would also be great flooding in the small village and much devastation would come to the people of that community. The banks of the river would no be able to handle the amount of water and there would be no initial losses. The percent impervious would be zero due to the saturation and flooding would be the only answer for the water runoff (see Figure 4). As you can see the amount of water flowing through Tacoaleche would be just below 800 cms. This would definitely take a toll on the river and people.

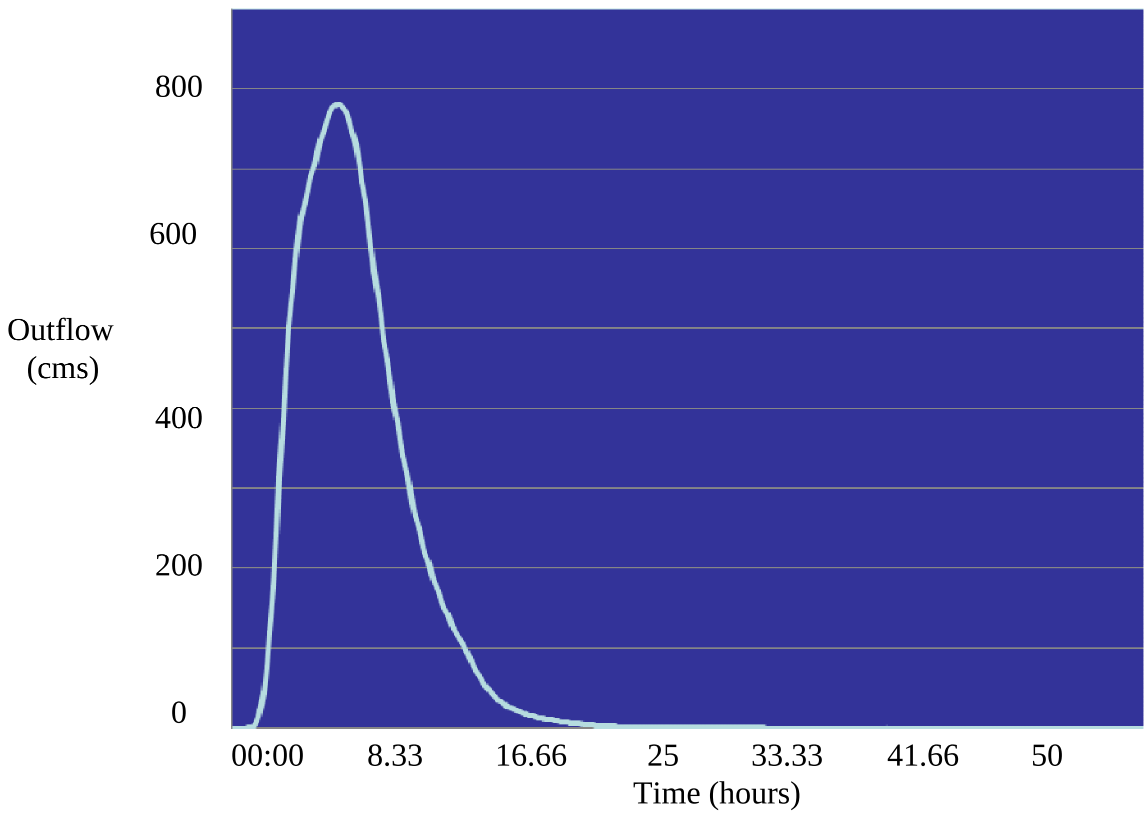

Figure 4. Watershed runoff in a 20-year storm event and 85% ground saturation.

Discussion of Outcomes

As discussed previously many estimations were made during this project. This was attributed to the lack of data on the area and time constraints. The results could be improved if better data was obtained and put into the model. This could be easily done within WMS or HMS. Data is easily modified and new models can be run in a relatively short period of time.

The people of this area should not be concerned with flooding during a two-year event. As shown in our modeling efforts the flows are not reaching dangerous levels during smaller rain storms. However, when a twenty-year rain storm occurs flows reach levels that indicate flooding is imminent.

This project focused on the effect of the reservoir on the watershed. Using varying conditions our group examined and predicted outcomes for different scenarios. This is not the only area that needs examination. It was made known to us by Professor Azul that this area is the fasting growing area in all of Mexico. Another interesting thing to model would be the effects of urbanization. As this area increases in urban area the outflows from the watershed will only increase.

Another option to increase accuracy would be the use of GSSHA. The watershed could be broken up into smaller sub-basins and modeled to obtain results from specific areas. This would increase accuracy due to the use of physics within the model procedures. In order to reduce problems when using GSSHA it is recommended to use smaller basins.

Conclusion

Our project as a whole has been successful. There were a number of obstacles that had to be overcome but as we look back there were some great feats accomplished. Our teamwork and communication improved from our journey down to Zacatecas, our models came together as we sought particular results, and our understanding of the WMS and HMS was improved as we worked together to learn. These are just a few of the things we took away from this class. One of the most important things is that we were able to share a little bit of our knowledge with those in Mexico and help them gain a greater understanding of the types of tools that are there for their use. After spending a whole day with them and talking them through the basic modeling procedures of the software we fell that they were able to benefit.

To proceed from the point where we left them they will need to come up with better modeling parameters and continue to study the land and soil types in their own area. It will be important for them to also gain a better understanding of GSSHA and experiment with using that software to improve their accuracy. If they do chose to use GSSHA it would be a lot more helpful for them to break apart the three sub-basins and analyze each one individually. From a technical viewpoint we feel they have the knowledge and tools but simply need more experience.

References

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