17.13 A DISCUSSION OF THE FLOODING THRESHOLD IN EASTERN NORTH DAKOTA UTILIZING SWAT

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1. INTRODUCTION

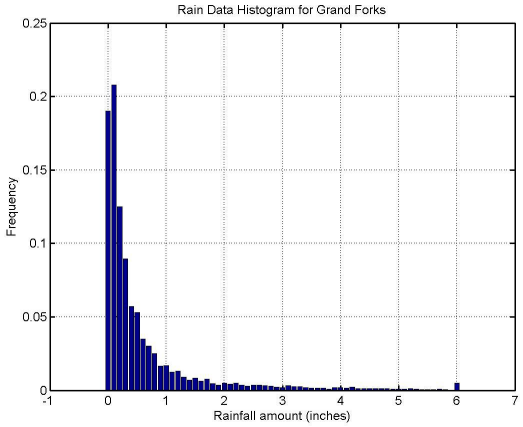
During the summer of 2002 four major storm events occurred in eastern North Dakota and western Minnesota leaving the region under a considerable amount of standing water. The events left their mark destroying numerous agricultural products, localized flash flooding and overland flooding within communities and agricultural fields.

This paper describes the impact of one of these storms and how the use of geographical information systems (GIS) facilitated the investigation process. On July 9-10, 2002 a severe rainstorm event occurred in eastern North Dakota in the vicinity of Buxton, ND. Twelve to fifteen inches of rain fell in a matter of a few hours. Due to the low sloping topography the water ponded in many places only to be evaporated or infiltrated.

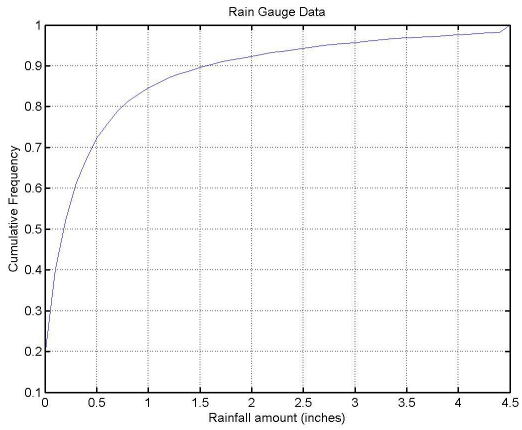
A flooding threshold scenario is constructed by using the Soil and Water Assessment Tool (SWAT), radar output, and recorded climate data within a GIS framework. This scenario provides community planners and decision makers a view on the location of the major ponding areas and the threshold amount of rainfall before the ponding began.

2. REGIONAL STATISTICS

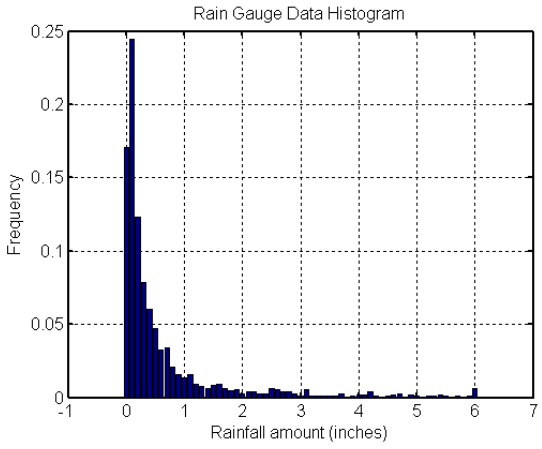
Utilizing rain gauge data from the North Dakota Atmospheric Research Board (NDARB) a statistical analysis on regional rainfall was performed. The collected data is from 1977 up to and including 2002 and the rain gauge network is spread over the entire state of North Dakota.



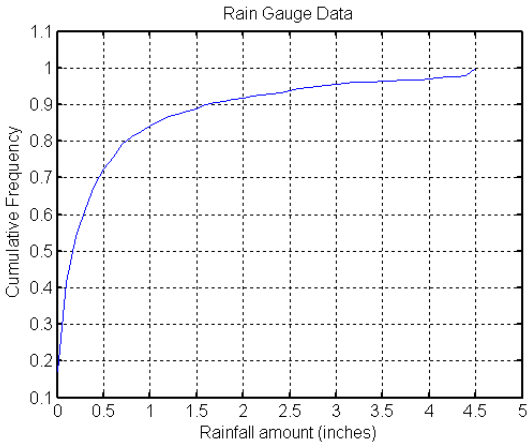
The frequency diagram above shows the rainfall pattern for the region separated into 0.1-inch bins. A near exponential pattern to the rainfall with the most percentage of rainfall events (21%) of 0.0 inches to 0.1 inches is shown. Taking a look at the cumulative frequency diagram below the same data is plotted. The plot shows the mean to be 0.25 inches and approximately 70% of the rain events are of 0.5 inches or less and 90% of the rain events are of 1.5 inches or less.



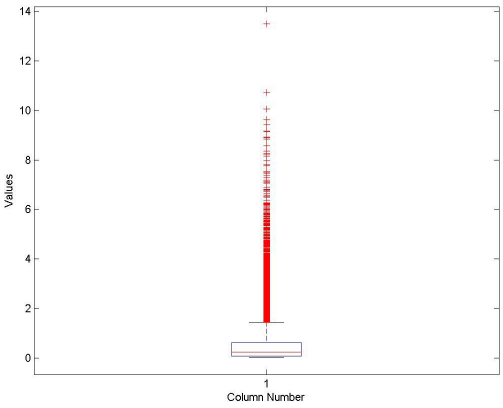
If the rainfall event data from the past 5 years is used to create a frequency histogram a change in the pattern is noticed. There are several spikes in the chart; at the 1.5, 2.5, and 4.0 inch marks.



In the same sense, comparing the cumulative frequency diagrams, from below and above, shows that the tow data sets are similar out to the 90% level. Past the 90% level, the most recent five years have a higher percentage of heavy rainfall events than the overall data set. These extreme events and the possible outcomes are the focus of this study.

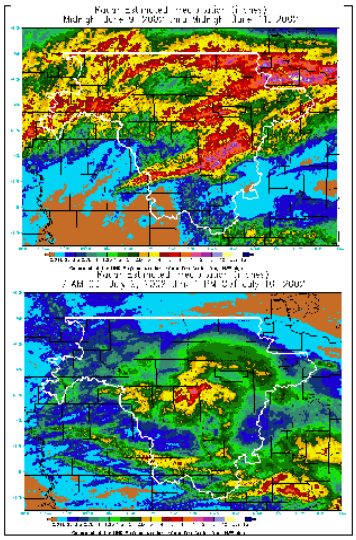


The box plot, below, shows the small window in which the precipitation falls. There are a large number of outliers, this is due to the 1.5 Inter Quartile range mathematical function. The mean of the events is 0.25 inches with the maximum percentile of 1.43 inches. The overall maximum is 13.5 inches as an outlier. Using the data given by the box plot, an event representing each quartile will be run in the GIS model.



3. RAIN EVENTS ON RADAR

The summer of 2002 brought a number of heavy rain events into eastern parts of North Dakota and northwestern parts of Minnesota. In the area of Grand Forks and Traill Counties of North Dakota, three such events occurred with one occurring in each summer month. This project will be highlighting the July 9-10 storm that occurred over Buxton, ND. This particular event was recorded to have precipitated 12-15 inches of rain in a matter of hours. However, the cell that is used in the GIS analysis only produced 8.15 inches in the same time frame. The radar image below shows an event near Warroad and Roseau, MN in June of 2002 on top and the radar output for the July event at Buxton, ND on the bottom.



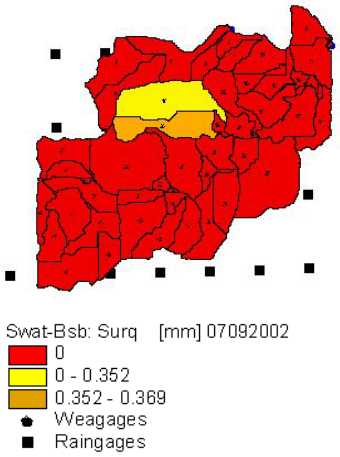
This data was received from the NASA Goddarad Space Center. The radar output is an aggregation of the two-day rain event. Once the precipitation cell was selected the cell was shifted to reside over Thompson, ND. The data was then reproduced into a grid, usable in ArcView. The grid was then made into a point file and the points were used to represent “rain gauges” in the GIS framework.

4. SWAT OUTPUTS

The Soil and Water Assessment Tool (SWAT) was used for the GIS analysis of the precipitation events for Thompson, ND. The focus of the GIS analysis is to find a precipitation event that produces apparent overland flow. Keying in on the event occurring over Buxton, ND, and evaluating the hydrologic response by moving the storm over Thompson, ND. The SWAT outputs were created by using a number of uniform precipitation events over the watershed and a copy of the precipitation event that occurred over Buxton, ND.

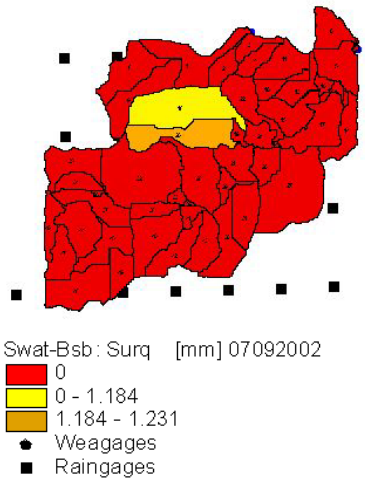
4.1 0.25 inch SWAT output

Using the statistical data of the region, the mean of all the recorded rain events is 0.25 inches. Applying an average rain event to the GIS gives a good idea of normally occurring hydrological tendencies to the watershed. Below is the SWAT output for stream outflow for the selected watershed.



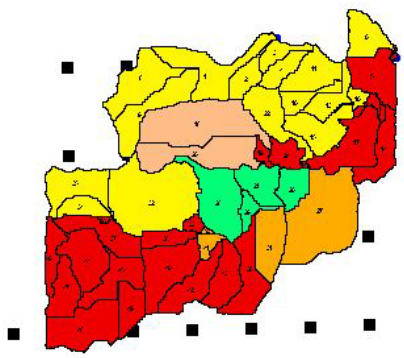
4.2 0.5 inch SWAT output

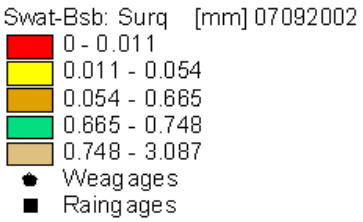
A rain event yielding 0.5 inch of precipitation was then entered into SWAT representing a value within the third quartile range.



4.3 1.0 inch SWAT output

A uniform 1.0 inch precipitation event was created to represent the fourth quartile range of 0.62-1.43 inches.

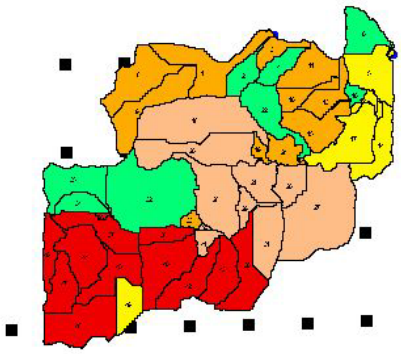


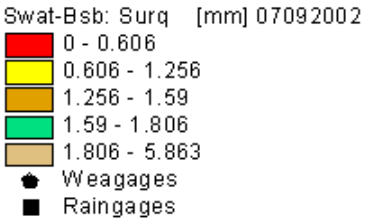


The 1.0 inch precipitation was the first to have runoff that came from non-urban areas. However, the sub-basins with the most runoff are the two urban sectors for which the model produced runoff during the previous two events. During this particular event the majority of the watershed still had minimal runoff that contributed to the overall stream outflow; the areas that did contribute to the outflow had less than one millimeter.

4.4 1.5 inch SWAT Output

A 1.5 inch precipitation event represents an outlier to the overall box plotted statistical analysis. Using an outlier to the total statistical average shows the areas of possible inundation and flow problems.

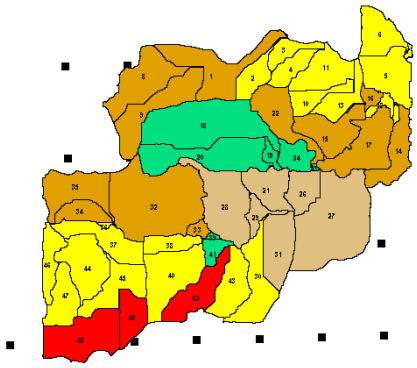


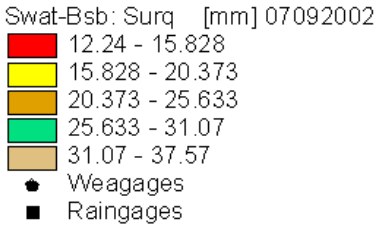


The SWAT output shows areas of large runoff as well as minimal runoff. Again, the sub-basins with the highest amount of runoff are those of urban description or those near the urban areas. However, the sub-basins to the southwest of the urban areas still influence the overall runoff minimally at 0-0.606 millimeters.

4.5 Final SWAT Output of Buxton Storm Event

The final precipitation event that was run within the GIS model was the of the transplanted Buxton precipitation event. This particular event produced 8.15 inches of rain within the selected cell.





The SWAT output for an event of this magnitude shows a large amount of runoff. The urban area is no longer the area with the most runoff, however the urban area produces 26.5-31.07 mm of runoff.

5.0 CONCLUSIONS

In comparing the five precipitation events in the SWAT model a runoff threshold can be construed from the outputs. At the 1.0 inch precipitation mark, or the third percentile, the model shows a significant increase in the runoff. In particular, looking at the two urban sub-basins and the four sub-basins to the southeast of the urban area the runoff is more than double from the half-inch event.

Once the precipitation reaches the 1.5 inch level, the runoff is significant over the majority of the watershed. However, due to the soil and land use practice south of the urban area the runoff is minimal at this point.

6.0 REFERENCES

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