Report for 2004TX158B: Radar-Based Flood Alert System for Austin, Texas

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"Radar Based Flood Alert System for Austin, Texas"

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INTRODUCTION

Overview

Flood Warning Systems have been in use for three decades and have steadily increased the ability to predict peak flows at a point of interest in a watershed while alerting city officials and residents to flooding conditions. Currently, the City of Austin has a localized Flood Early Warning System (FEWS) in place that utilizes a series of approximately 80 rain gages that report rainfall rate and amount and 40 creek and lake gages that monitor water levels and flow rates. While this system provides useful information, much like any gage based system; it has the potential to malfunction during operation giving incorrect data and also cannot provide the complete spatial coverage as that of radar based flood warning systems. For this reason, a real-time flood warning system is being developed for the Onion Creek watershed in Austin, Texas.

The rainfall events of October 1998, November 2001, and July 2002 were historically damaging storms for the City of Austin due to flooding; therefore developing a Flood Alert System for the Onion Creek watershed in South Austin is necessary. Flooding problems are prominent in areas of the watershed where tributaries intersect the main branch of Onion Creek as well as in the downstream, urbanized areas of the watershed.

The system follows the template used in the Flood Alert System (FAS-1) that has been a valuable tool in flood prediction for the Texas Medical Center in Houston, Texas. Developing a similar system for Onion Creek proves to be a challenge. The watershed spans approximately 340 square miles and varies in elevation. The Austin hill country is mostly composed of sedimentary limestone and calcitic rocks, and is underlain by the Edwards Aquifer. The Edwards Aquifer is a karst, therefore complex, aquifer that adds additional dimension to the hydrologic modeling and FAS development for Onion Creek.

The availability of Next Generation Radar (NEXRAD), hydrologic modeling tools, Geographic Information Systems (GIS), and internet capabilities has made the development of advanced, real-time flood warning systems possible. Operation of the Flood Alert System for Austin (FAS-Austin) begins with the radar data obtained from the National Weather Service's NEXRAD, KEWX, in San Marcos, Texas. This radar data is produced in terms of radar reflectivity data which then is directly converted into rainfall estimates. These rainfall estimates are transformed into flow values that are used in flood predictions and flood warnings.

The rainfall is input directly into HEC-1, a flood hydrograph package developed by the Hydrologic Engineering Center. HEC-1 converts rainfall directly into runoff in a manner that allows for fast computations using hydrologic parameters such as subbasin characteristics, loss rates, and river routing that have been computed using GIS or have been gathered from a HEC-HMS model created by the United States Army Corps of Engineers and the City of Austin for Onion Creek. Quick results are available every five to six minutes, which corresponds to the time it takes the radar to make one complete volume scan of the atmosphere. The results, therefore, give flow values in real-time. Large historical rainfall events and hypothetical storms have been calibrated for Onion Creek and its tributaries to ensure the model's prediction accuracy. In addition to FAS-Austin, a pattern recognition program called PreVieux is being used to help predict flooding. PreVieux is a product of Vieux and Associates that uses radar data to project a storm one hour into the future which provides a more precise warning for heavy rainfall to a specific area of the watershed.

Once fully operational, this state-of-the-art Flood Alert System at Onion Creek will provide an increased lead time and accurate predicted flows for the City of Austin. Lead time, is the amount of time available from the point where a prediction is made using modeling technologies to the time of a peak flow predicted. Increasing the lead time allows for more flood precautionary measures to be implemented. The increased lead time and accurate flow levels will give city officials and emergency personnel a chance to perform road closures and administer high water warnings. The accuracy of the Flood Alert System will also help prevent the loss of life in the event of a flood and raises awareness of the elevated dangers associated with severe flooding.

Motivation for Research

Since 1993, nearly 45 billion dollars in damage has occurred and at least 599 people have lost their lives due to flooding disasters (not including hurricanes) in the United States. The National Oceanic and Atmospheric Administration (NOAA) estimates that while only seven percent of U.S. land is designated as flood plains that nearly fifty percent of the communities in the United States are affected by flooding. The number of those affected by flooding continues to rise each year by a percent or two. Table 1.1 is data taken from NOAA and shows a brief list of damaging floods in recent history throughout the United States. The location of the flooding, the dates of the storm events, the amount of monetary damage, and the number of deaths in each case is listed.

Table 1.1 Recent Flood Related Damages and Deaths in the United States

Date	Location/Flood Problem	Damage	Deaths
Summer 1993	Midwest Flooding	$21 billion	48
October 1994	Texas Torrential Rain	$1 billion	19
1995	Northern California Flooding	$3.6	unknown
May 1995	Texas, Oklahoma, Louisiana, Mississippi Rain, Hail, Tornadoes	$5-$6 billion	32
January 1996	Northeast, Mid-Atlantic, Appalachians Blizzard Snow Melt	$3 billion	187
Winter/Spring 1998	Southeast El Nino rainfall	$1 billion +	132
June 2001	Gulf Coast/Texas Tropical Storm Allison	$5.1 billion	22

The occurrences of damaging floods are not confined to specific regions but are capable of inundating any piece of land that receives ample rainfall. Since controlling the rainfall intensity, duration, and location is not a feasible option to protecting structures and lives from the danger flooding imposes, creating a system that is capable of warning those in harms way is a practical and viable alternative.

George Oswald of The City of Austin comments on the use of the current Flood Early Warning System (FEWS) during the November 2001 Storm as well as the improvements expected with the addition of gage-adjusted radar and FAS-Austin.

> "Generally the system was operating very well during the event; a very high percentage of the rain gages and stream gages remained operational under very demanding conditions. Our manually developed warnings and suggested action plans were very accurate. We used IDF curves and historical rainfall/response records to make our calls that night. It was an all out effort of three engineers manually interpreting data and then polling the group for consensus action recommendations. The success in that storm depended on having three individuals with significant knowledge of hydrologic principles, past floods and flood hazard

> areas. Obviously, radar based rainfall estimations and predictive models have the potential to improve prediction accuracy while reducing the skills set required to issue flood warnings and recommended public safety actions."

The City of Austin has seen devastating floods recently as well and could therefore benefit from a real-time, radar-based flood warning system for the local creeks. Figure 1.1 and 1.2 show two recent flood events that caused major damage to the city and are courtesy of the City of Austin's website. Figure 1.1 shows the flooding associated with the November 2001 rainfall which caused damage throughout Austin and the Onion Creek Watershed. Figure 1.2 shows one home (in Williamson Creek) damaged in the October 1998 storm that caused 20 counties throughout the state of Texas to be declared disaster areas. The October 1998 event occurred when a continuous wave of moisture moved inland from the Pacific Ocean off the coast of Mexico. Almost one billion dollars in damage was reported, 31 people lost their lives, and approximately 7,000 people were evacuated from their homes.

Figure 1.1 November 2001 - Flood waters reached extreme levels causing damage to vehicles and structures.

Figure 1.2 October 1998 – Flood waters in caused extensive damage in this Williamson Creek home.

Figure 1.3 was provided by the City of Austin and is a map of Onion Creek. It shows the location of Onion Creek in relation to downtown Austin, the counties encompassed by the creek, major highways in the area, and the eight major tributaries that feed into Onion Creek. Other things to note on this map include the areas encircled with red. These indicate the flood-prone areas in Onion Creek. Special attention should be paid to Williamson because it is one of the most urbanized areas in Onion Creek and experiences more potential for loss of property and loss of life during a flood event than any other location in the watershed. Onion Creek, in general, is in need of a radar based flood alert system that will aid the city officials, emergency personnel, and local citizens in flood prediction with the goal to reduce the amount of property that sustains damage and prevent the loss of life.

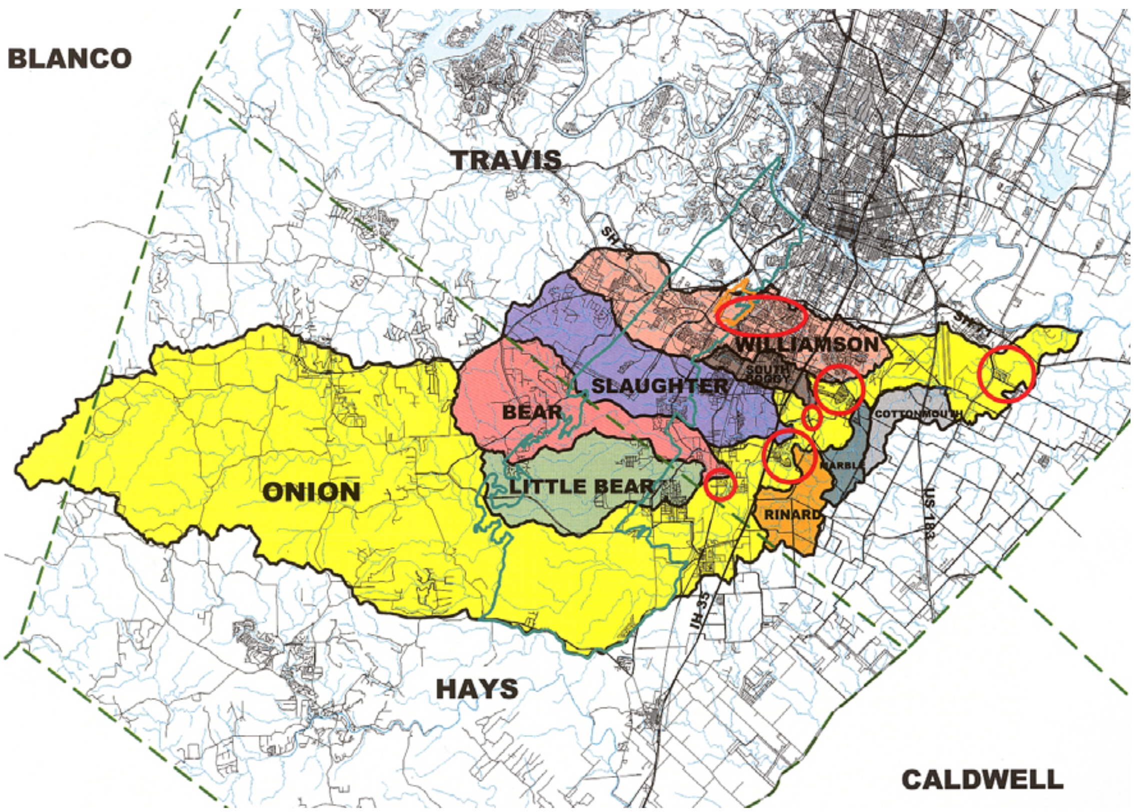

Figure 1.3 – Location of Onion Creek and its tributaries in relation to Austin, Texas, areas encircled with red indicate flood prone areas of the watershed.

The channel of Onion Creek at different locations in the watershed can be seen in Figures 1.4 and 1.5. Figure 1.4 is Onion Creek as it is seen in the upper end of the watershed. Figure 1.5 shows Onion Creek as it flows through one of Texas' state parks.

Figure 1.4 Onion Creek Channel near Driftwood, Texas

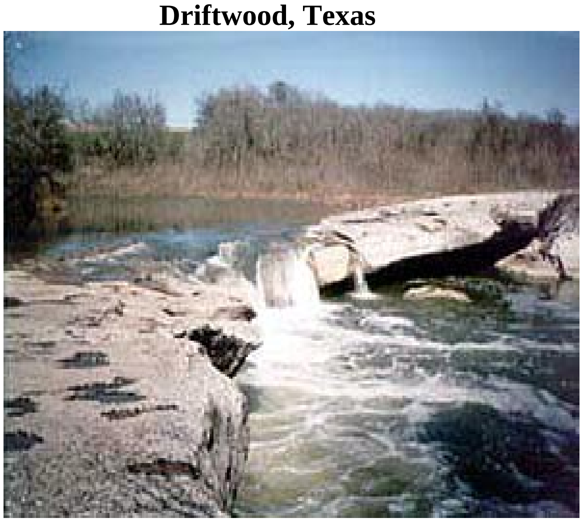

Figure 1.5 Onion Creek Channel in McKinney Falls State Park

Research Objectives

1. Use Geographical Information Systems and HEC Geo-HMS to delineate subareas and gather hydrologic parameters for Onion Creek to be used in a Real-Time Flood Alert system for the City of Austin, Texas.
2. Develop a HEC-1 model for Onion Creek within a GIS framework and calibrate the model to observed data for several storm events using radar rainfall and hypothetical events.
3. Examine recharge characteristics of the Edwards Aquifer as it relates to the accurate prediction of hydrologic response in the upper portion of the Onion Creek Watershed.
4. Use the calibrated HEC-1 model along with Next Generation Radar (NEXRAD) data to develop a real-time model that predicts the flow at various points of interest in the watershed.
5. Provide guidance and up to date information regarding real-time flooding issues for city officials and emergency personnel.

CONCLUSIONS AND FUTURE RESEARCH

Conclusions

ArcView GIS along with various extensions was used to delineate the Onion Creek watershed and to gather values needed to calculate parameters that are used to hydrologically describe the watershed. The USACE HEC-HMS Model that was created by the USACE in conjunction with the City of Austin was applied to the subareas delineated in ArcView GIS. Hydrologic parameters from the HMS model were reviewed and used to the extent possible. Parameters describing each of the 61 subareas in Onion Creek and the Onion Creek channel including the basin area, loss method, transform method, and routing method, along with gage-adjusted radar rainfall data were used to create the Onion Creek HEC-1 Model.

In addition to the model calibration, recharge characteristics of the Edwards Aquifer were examined and tested in the model. The model was created as the basis for a Flood Alert System servicing Onion Creek in Austin, Texas. Three historical storm events, including the June 1997, November 2001, and the June 2004 storms, were input into the model for calibration efforts and design storm parameters were applied to the model in various instances to better understand the hydrologic response of the watershed and to provide guidance to Austin officials. Conclusions derived from this model creation and storm calibration are listed in detail.

- The Onion Creek HEC-1 Model performed with much more accuracy than the USACE HEC-HMS Model for the November 2001 storm. The success in the HEC-1 model is attributed to more accurate hydrologic parameters and to the subareas chosen for the model.

- It was originally thought by the City of Austin that the November 2001 storm was less than a 100-year event. After modeling uniform rainfall it is evident that the non-uniform November 2001 event was greater in magnitude than a 100-year event producing a peak flow of 93,200 cfs. The November 2001 storm is one of the largest events ever recorded on Onion Creek. With the model created in this study the November 2001 storm was more accurately defined.
- The radar data from Vieux and Associates, Inc (used in the HEC-1 model) produced outflow values that matched the measured data far more accurately than the NEXRAIN radar data (used in the HEC-HMS model) as seen in Figure 6.3. NEXRAIN data is processed differently than the data from VAI such that it produced a skewed rainfall product.
- The recharge zone for the Edwards Aquifer is present across approximately 75 square miles of the 340 square mile basin, although it directly affects half of the watershed. The recharge zone is a place where water enters the underground aquifer. The amount of recharge is solely dependent on the amount of rainfall the area receives. For Onion Creek, recharge becomes a more prominent issue as the intensity and duration of a storm increase. For instance, in the large rainfall event of November 2001 recharge accounted for approximately half of the volume of water in the Onion Creek channel above the Driftwood gage. However, in the smaller June 1997 and June 2004 events the model results matched the measured outflow more accurately when recharge wasn’t included.
- Based on the previous conclusion regarding recharge, the Onion Creek HEC-1 Model that was used for the smaller June 1997 and June 2004 events should be

the primary model used in the Flood Alert System for Onion Creek. This is primarily due to the frequency of events that are more similar to the June events modeled. In addition, the Onion Creek HEC-1 Model that includes recharge should be run simultaneously during rainfall events for the uncommon but more devastating larger storms where recharge is a factor.

- Another recharge conclusion revolves around the issue of the stream flow in the channel prior to a storm event. If the antecedent flow is very low there is a better chance that as the next storm moves over the watershed the percentage of water lost to recharge will be high. Compare this situation to one where the flow in the channel is fairly high just before a storm. As this storm moves though, the saturated channel bed does not permit much infiltration to the aquifer. Thus, the recharge is less for events where flow in the channel is higher prior to the storm.
- Design storm data was put into the Onion Creek HEC-1 Model. The output from these various model runs shows that the location in the watershed where precipitation occurs affects the peak and the length of time for that peak to occur. Rainfall in the lower end of the watershed has the most adverse affects on the basin, and rainfall in the upper end affects the basin the least. This proves that it is important to know not only the intensity of the precipitation, but also the location where the rain is likely to fall.
- The use of radar rainfall data in the model calibration provided accurate results. The improvements in the quality of the radar data over time are obvious when comparing the results seen in the outflow hydrographs for the June 1997 event and the June 2004 event. In 1997, radar data was widely used but still lacked

accuracy. Today, there have been numerous technological advances such as the improved understanding of the Z-R relationship that enhance the quality and accuracy of the radar data that is available for input into the Onion Creek HEC-1 Model that weren’t available in 1997.

Future Research

In addition to the work done in this study, there is still much more to do in relation to the project. These ideas to further the research in this area include the following list.

- Continued calibration to various rainfall events would be useful to get the Onion Creek HEC-1 Model as prepared for real-time use as possible. The results from another large event similar in magnitude would be useful if the radar data exists for such a storm.
- Program the Onion Creek HEC-1 Model to run in simulation mode for various storms to compare the real-time capabilities of the model to the existing Flood Early Warning System's response and the USGS Stream Gage data. After the real-time simulation is complete, a continual feed of radar data can be directly dropped into the calibrated model for model results in real-time and displayed on a website to make the flow data and the alert levels available to the public, emergency personnel, and city officials.
- The low water crossings that are in the process of being installed at approximately ten to 15 locations in Austin, Texas should be tied into FAS-Austin to create a more complete flood warning system.
- In addition to the actual installation of FAS-Austin other research related options include the application of Flood Alert System's to other flood prone areas in Texas and elsewhere.
- The issue of slope in the Onion Creek watershed is an important factor that makes this watershed unique. While slope was analyzed in this study in a GIS

framework it is an topic worthy of future study. Taking a closer look at slope calculations and issues would be helpful in further understanding the hydrologic response of the basin.

- To increase the accuracy of the model used, LiDAR data could be used in place of the 30 meter DEM to delineate the watershed. LiDAR maps an area on a much smaller scale on the order of ten feet between data points with 15cm of vertical accuracy (Whitko, 2004). LiDAR can be sampled every six inches, but in many cases data this detailed overloads computer systems. Detailed data of this magnitude would be useful for more accurate slope calculations in Onion Creek where slope is a concern.
- Recharge to the Edwards Aquifer is a complex and variable component of this study that poses many questions that need to be examined more closely. Different recharge modeling techniques, a more in depth study relating to the karst aquifer, or anything else that would further the knowledge of this issue would be useful.