March 2007

Large Alberta Storms

Introduction

Most of the largest runoff events in Alberta have been in response to large storms. Storm properties, such as location, magnitude, and geographic and temporal distribution can affect the runoff response. Therefore, the nature of the largest recorded storms in Alberta is of interest in examining the context of the largest runoff events.

In order to characterize the largest historic storms, a comprehensive list of storms must be developed. Depth area analysis of the storm data can then be used to evaluate the magnitude and geographic distribution of these storms. GIS tools can be used to asses the variance in location of these storms across the province. Examination of hourly data for select large storms can provide insight into the temporal distribution of these large events.

Available Data

Environment Canada (EC) has collected rainfall data in Canada since about 1870. Although there are about 1700 gauges in the database, not all gauges have been in operation at any given time. Earlier storms were picked up by about 150 gauges, whereas more recent storms have been recorded at about 650 gauges (See Figure 1).

Most of these gauges report daily rainfall data, with hourly data available at about 28 gauge locations (sites with published IDF curves). The daily data is sufficient to identify storms and characterize their location, magnitude and geographic distribution. The hourly data is useful for evaluating the temporal distribution of select storms.

The daily rainfall values for all gauges in Alberta, plus gauges within 2 degrees of the Alberta border, have been extracted from the EC data-set and added to an Access database for use in analysis. Equivalent data for Montana was also obtained and added to the database. Additional data has been published by Alberta Environment since about 1970, with up to 70 additional gauges reporting data. Most of these gauges have been used in flood forecasting activities, and are located in the eastern slopes of the Rockies. Hourly data is available for most of these gauges.

Storm Identification

Many of the large storms that have caused historic flooding can be readily identified based on the resulting runoff response. Review of the available temporal data for these storms suggests that the duration of these storms is typically in the range of 15 to 60 hours. Therefore, it was decided to define the magnitude of a storm at a given gauge as the largest sum of three consecutive daily rainfall values covering the date of the storm. A sensitivity analysis showed that addition of a fourth value usually added little to the sum. The readily identified storms were found to typically report a rainfall magnitude of 150 – 200mm near the eye of the storm, and also report several gauges in excess of 100mm. The largest reported rainfall amounts rarely exceeded 200mm.

Based on these observations, the entire database was queried in chronological order for events with multiple gauges reporting three day sums exceeding 100mm. A list was developed of all storm dates that met this criterion. Text flies were then prepared for each storm date including the geographic coordinates of each gauge in operation and the associated storm value.

Approximately 145 large historic storms have been identified, with the first being in June 1908 in the southwest corner of Alberta. Of these storms, 25 occurred prior to 1950. The relatively small number of storms in the first half of the century is due to the low gauge density during that time period. Most of the gauges available before 1950 were located in the southern half of the province. The low gauge density is also highlighted by the lack of identification of the storm that caused the known large runoff event of June 1915 across much of central and south-western Alberta. The increased gauge density in recent years enables better definition of the storm magnitude and distribution.

Depth Area Analysis

In order to assess the magnitude of these storms, a depth area analysis was undertaken. An Excel VBA tool was developed to load in the data for each of the identified storms and prepare an interpolated grid covering the entire province plus adjacent areas. The gauge location data was converted to a transverse mercator projection and the grid spacing set at 2km, resulting in a grid of about 530 x 830 points. A sensitivity analysis showed that a finer grid did not result in a significant difference in results, even at the lower range of areas.

Once this grid was developed, all values were entered into an array and sorted in descending order. For each specified area, the point in the array denoting this area was identified, and the average of all values exceeding this value was computed. This resulted in an array of mean rainfall values for each of the specified areas. The specified areas ranged from $10km^2$ to $500,000km^2$.

Plotting of select depth area curves showed significant variance over the lower range of drainage areas, but similarity over the higher range. This is likely due to the gauge density either hitting or missing the eye of the storm, and the resulting impact on the interpolated grid. Based on this observation, an area of $1000km^2$ was selected to represent the relative magnitude of each storm. Figure 2 shows the depth area curves for the seven largest storms. The mean of the depth area curves for the top 10, 20, and 50 storms is also shown.

This figure shows that with the exception of the July 31, 1987 storm, the depth-area relationship of the top 10 to 20 storms is very similar. For smaller areas (< $100km^2$), there is significant variance between the largest storms, but this is likely due to the gauge network not always picking up the eye of the storm. For an area of $1000km^2$, the mean rainfall for the highest storms is typically about 200mm +/- 25mm. Storms in this range have been responsible for most of the recent largest flooding events recorded in the province. The similarity between the storms increases with area covered.

The July 31, 1987 storm consisted of multiple distinct eyes located several hundred kilometres apart, giving the appearance of 2 distinct storms. One eye was located over the Simonette River basin near Grande Prairie, and the other was located over the Buffalo Head Hills. Significant runoff responses were noticed at both of these sites. This storm had several recorded rainfall values exceeding 200mm, with the largest approaching 300mm. The storm centre traveled north from the Gulf of Mexico, paralleling the Rocky Mountains 4. A tornado formed as the storm passed by Edmonton, causing significant destruction. It then veered to the west before settling over the Simonette basin and releasing a large amount of rain for two consecutive days before moving off to the east.

Storm Location

Over an area as large as the province of Alberta, certain location trends for storms would be expected. An impact due to the Rockies would be expected, due to orographic lifting. Also, theoretical water carrying capacity would be expected to diminish with latitude due to cooler temperatures approaching the Arctic Circle. However, analysis of the largest storms appears to show that the largest events can occur just about anywhere in the province.

To examine the location effect on storm magnitude, the largest storm values for each gauge were extracted from the database. This data was then analysed with a GIS tool. All gauges reporting storm values exceeding 150mm were drawn separately on the resulting map (see Figure 3). It is clear that most areas of the province have recorded storm values in this range. Analysis of the large storms using a GIS tool also shows that most areas of the province have been covered by at least one of these large events.

Temporal Rainfall Distribution

Daily rainfall data provides limited information on the temporal distribution of storms. However, some general inferences can be made. Observing that 2 or 3 consecutive daily rainfall values make up the total storm rainfall for most gauges, it is apparent that storm duration is typically in the 20 to 60 hour range.

Other sources of rainfall data that do include temporal distribution information include IDF curve data sheets, storm mass curves published in some PMF studies, and hourly rainfall data collected from real-time gauges by Alberta Environment. Data from these sources confirm storm durations are typically in the 20 to 60 hour range. The actual distribution of rainfall within a storm is highly variable (see Figure 5), both for different gauges during the same storm, and for the same gauge under different storms. For these large storms, the peak hourly rainfall rates are typically in the 10 to 15 mm/hour range, with a few exceeding 20mm/hour. This contrasts with the peak hourly rates for short duration storms used in stormwater modelling, where hourly volumes can reach up to 50mm.

Conclusion

Analysis of large Alberta storms shows that there is a typical storm that causes widespread flooding. These storms typically have mean rainfall values in the range of 200mm over a 1000km^2 area, and have durations in the 20 to 60 hour range. Storms in this range have occurred over most areas of the province.

This analysis has also identified most of the largest storms that have occurred in the last 100 years. GIS data-sets have been prepared for each of these storms. This information can be used to facilitate assessment of likely runoff response, confirm timing of observed historical highwater data, and provide context on the magnitude of historic events.

Although the available data is sufficient to characterize the nature of these large storms, the gauging network is not of sufficient density to consistently pick up the most intense portions of all storms. This results in significant scatter in rainfall amounts over smaller areas. The gauging network also requires considerable interpolation to quantify inputs to specific areas. Significant variance in the temporal distribution of rainfall during actual storms has also been observed. These factors all present limitations to calibration of hydrologic models.

Figure 1 – Rain Gauge Count

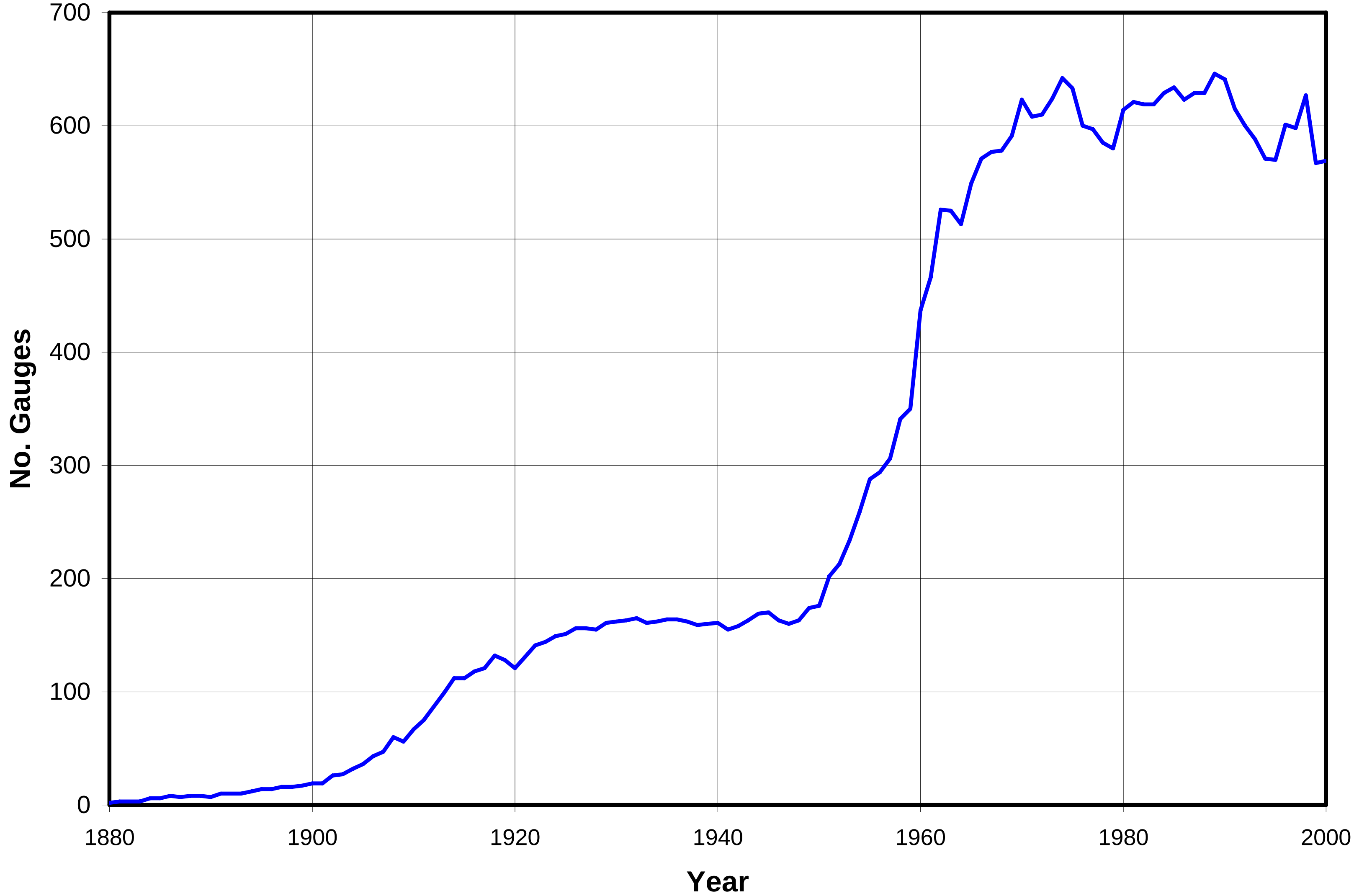


Figure 2 – June 5, 1995 Storm over Pincher Ck Basin

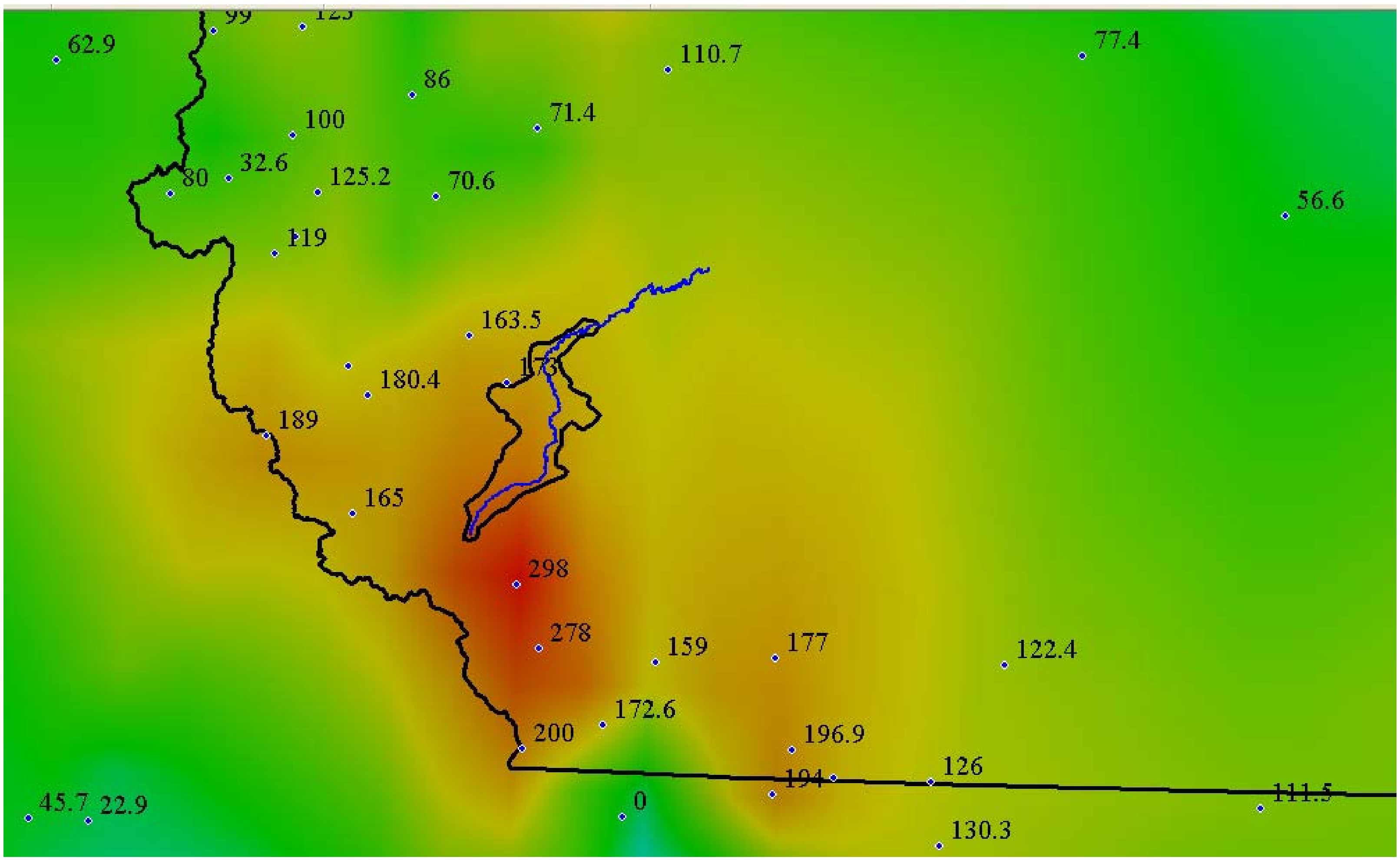


Figure 3 – Depth Area Plot

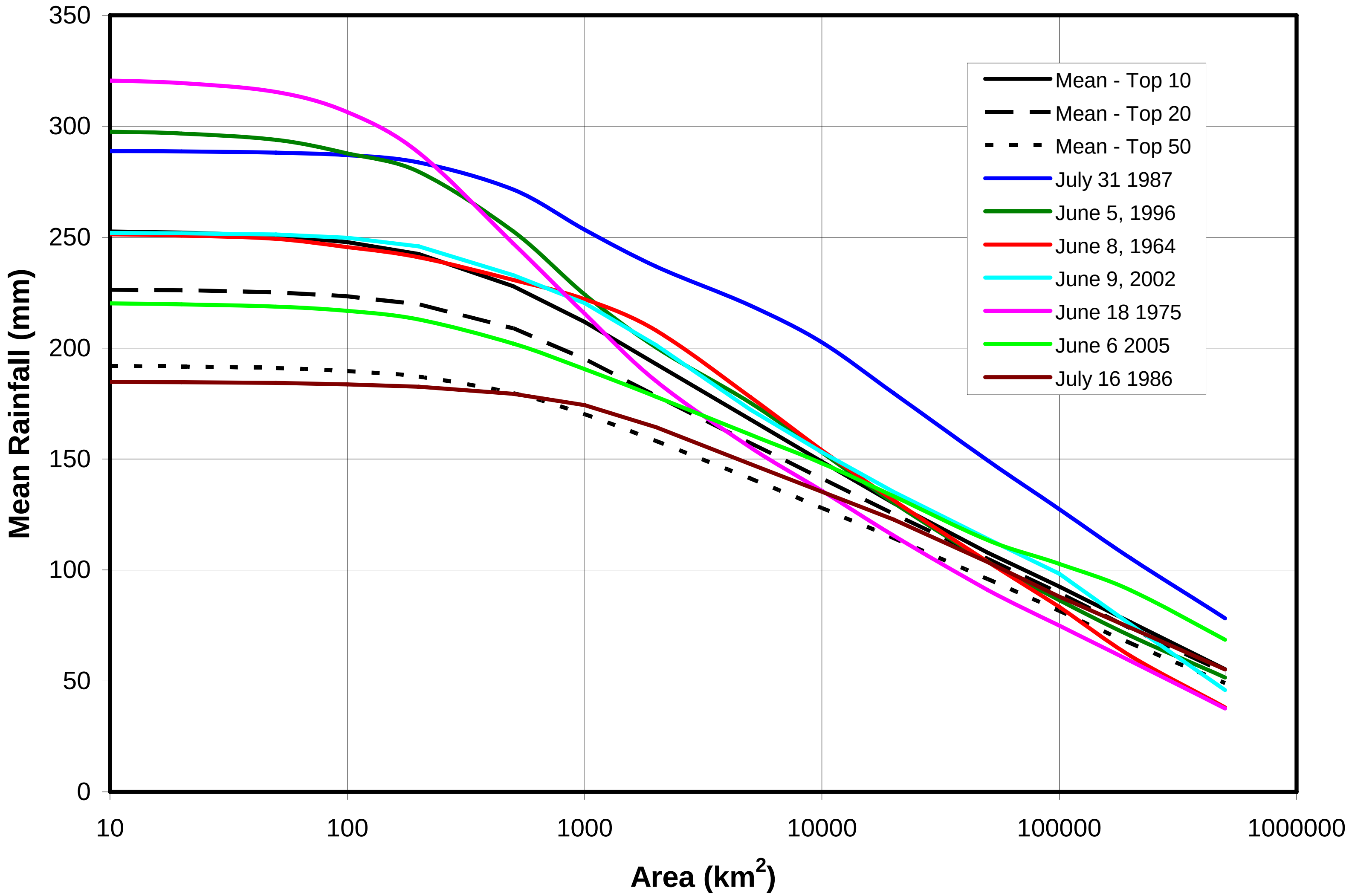


Figure 4 – Map of July 31, 1987 Storm

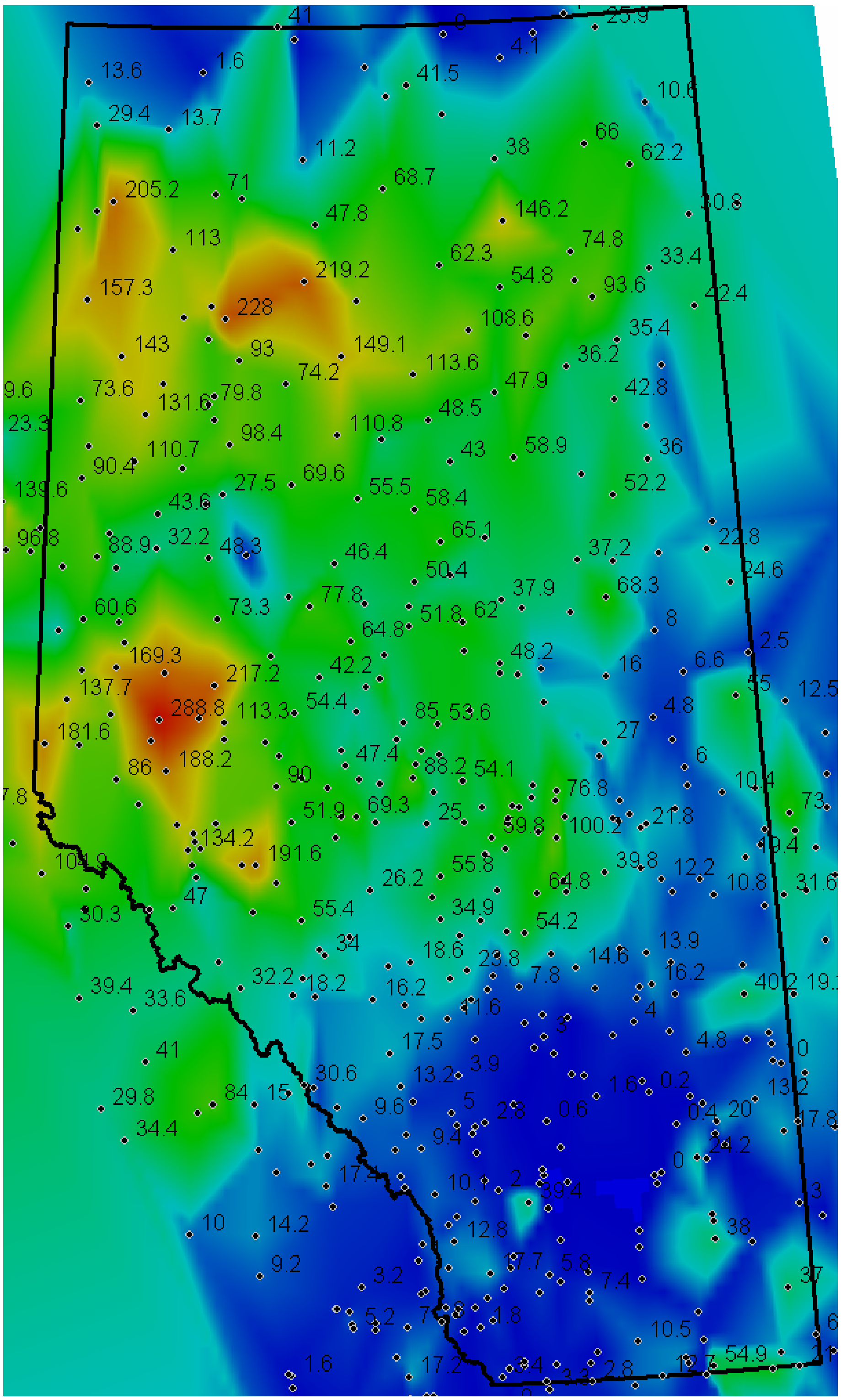


Figure 5 – Storm Location Map

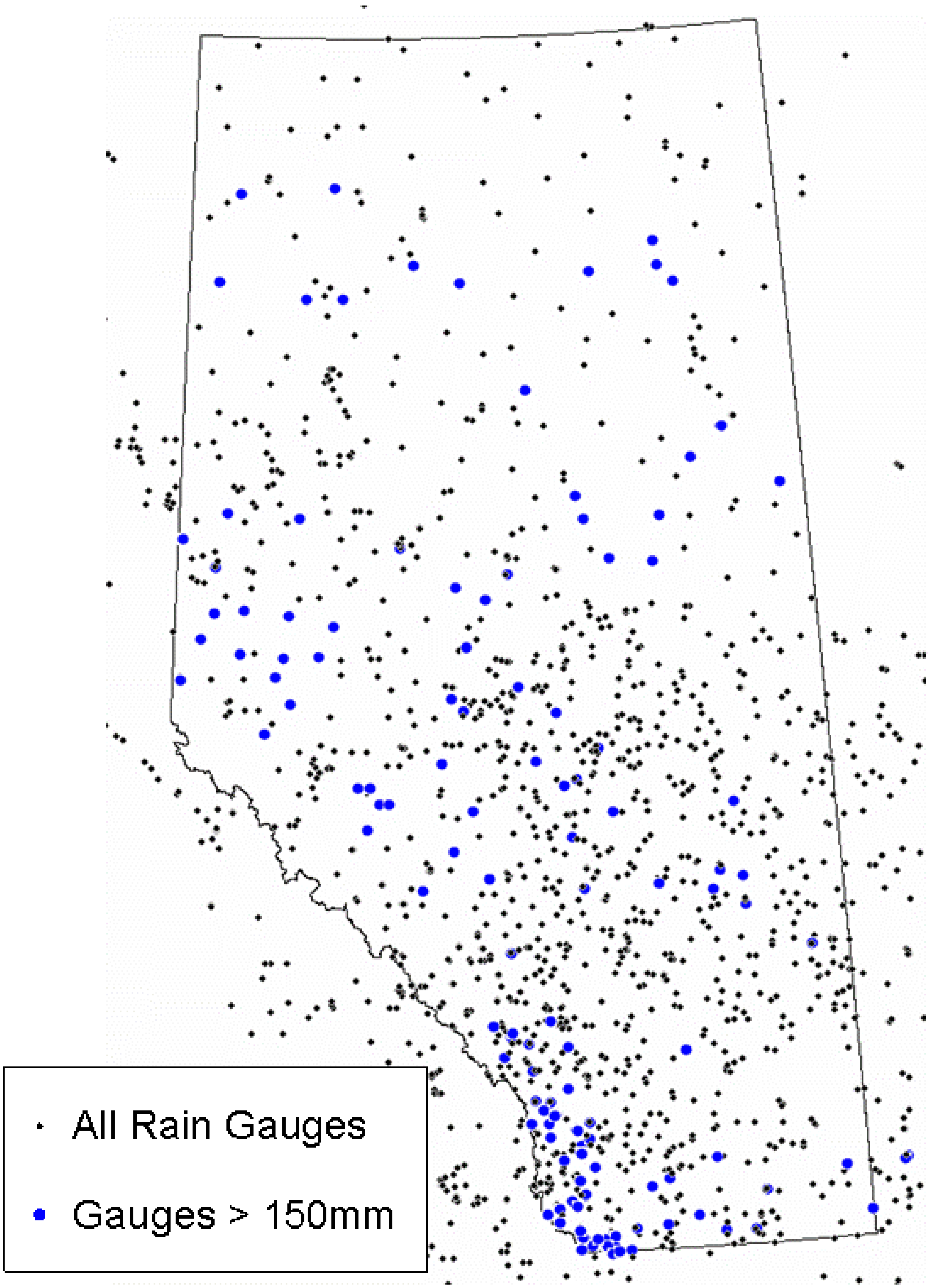
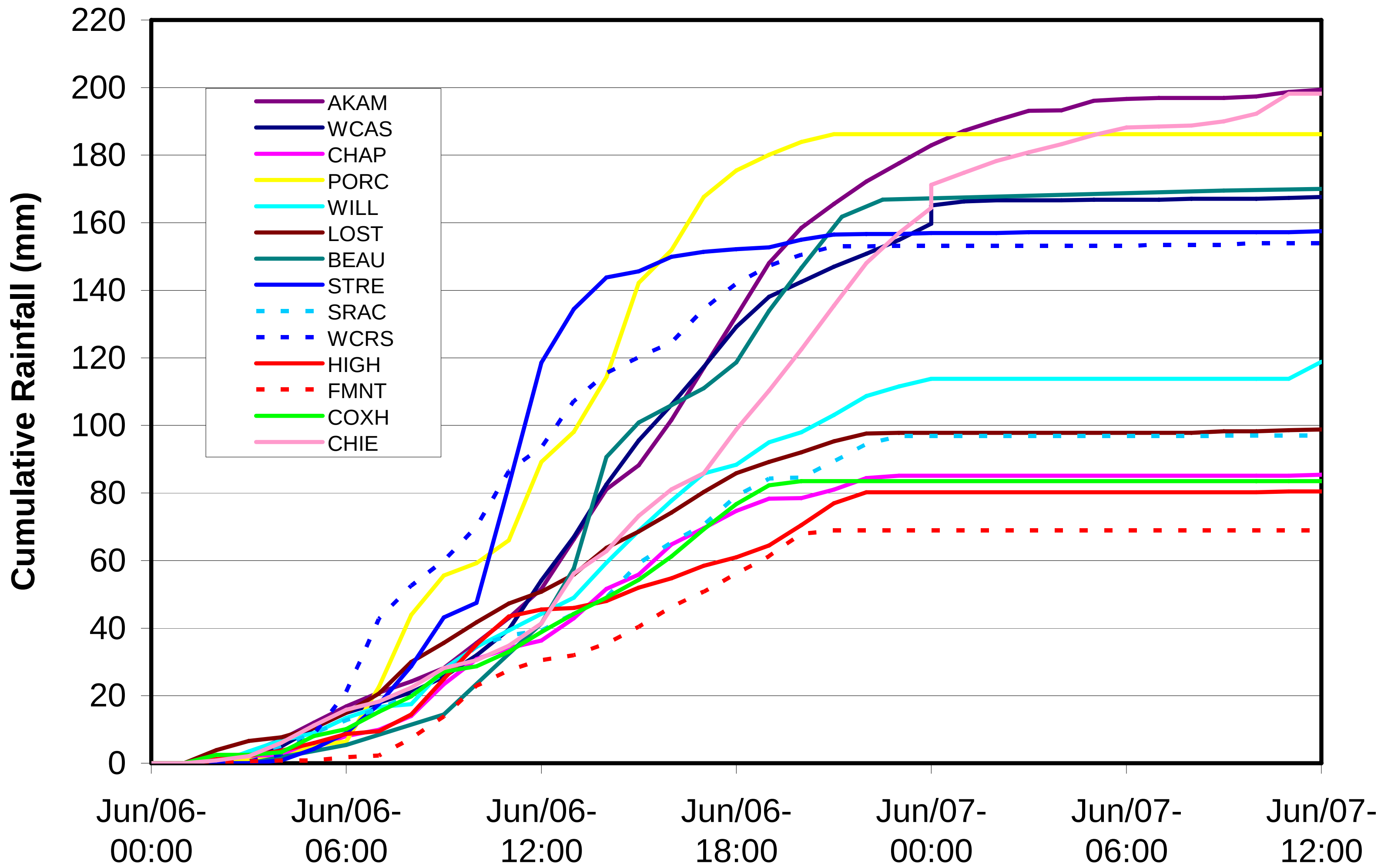


Figure 6 – Temporal Distribution – June 5, 1995 Storm



References

1. Paruk, B. 1988. Storm of July 31, 1987. Journal of Hydrologic Engineering, ASCE, pp 227-231.