Rainfall Estimates and Hydrologic Response for Storm of July 29-30, 2010, in Eastern South Dakota

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Introduction

Heavy rainfall occurred throughout a large part of southeastern South Dakota and extended into southwestern Minnesota and northwestern Iowa on the night of July 29 through the early morning of July 30, 2010, as shown in Figure 1. The rainfall totals were estimated from the National Weather Service WSR-88D radar installations in Sioux Falls and Aberdeen, South Dakota, with totals approaching or exceeding 4 inches in large parts of the affected area.

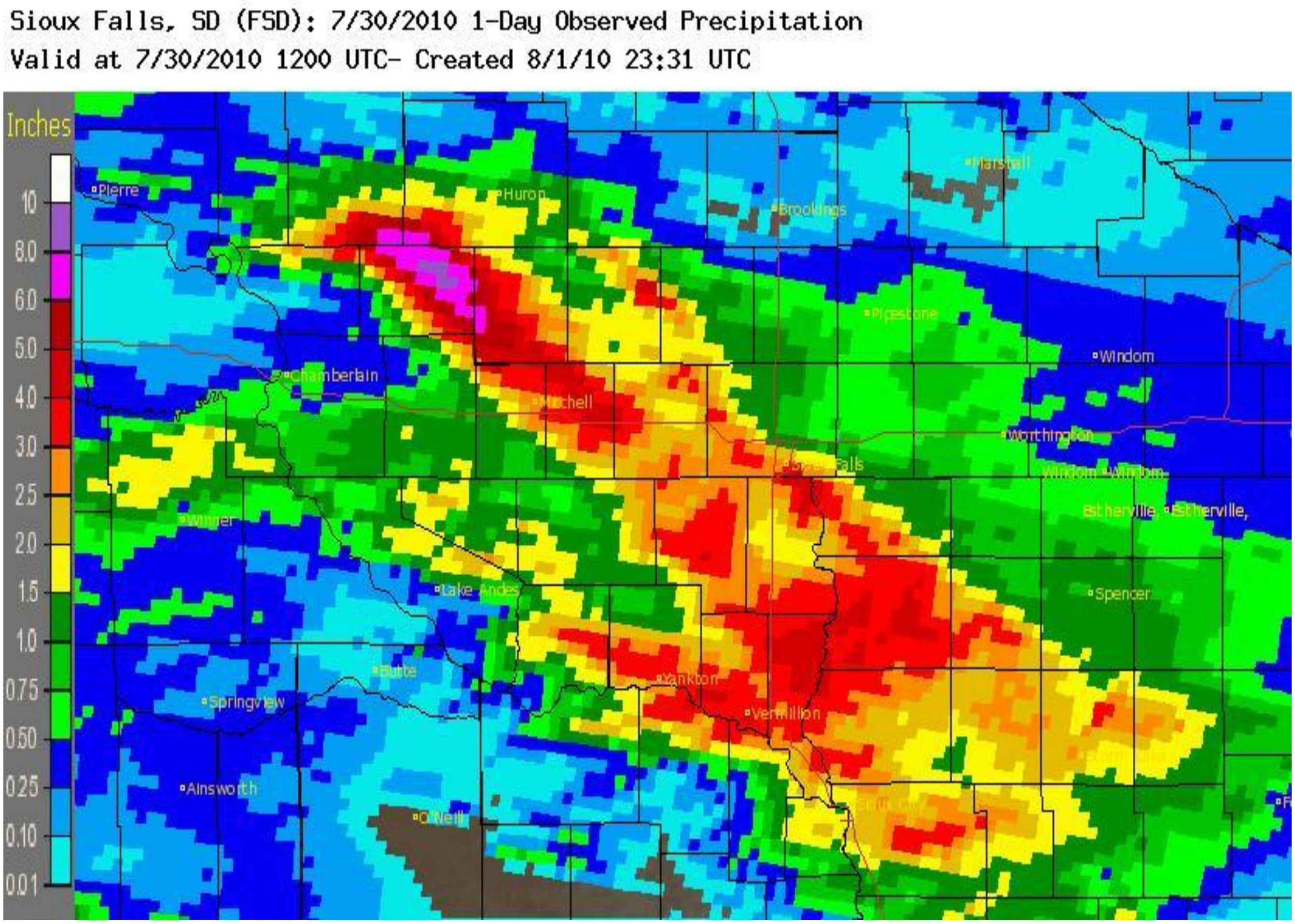

Figure 1. National Weather Service WSR-88D radar estimated rainfall totals on July 29-30, 2010 for parts of Iowa, Minnesota, and South Dakota.

Rainfall Estimates

The largest rainfall totals were in east-central South Dakota and occurred in extreme southeastern Hand County and extreme southwestern Beadle County, extending southeastward through much of Jerauld County and into Sanborn County. The radar precipitation algorithms did a very good job of showing the location of the maximum rainfall, as well as the very tight gradient between the heavier and lighter rainfall areas. However, the radar estimated maximum storm-total values were too low, particularly in southeastern Hand County and northern Jerauld County. This underestimation of the maximum rainfall totals was likely because of a combination of beam attenuation caused by shooting through the area of very heavy rains to the southeast of the maximum area (toward the radar location), and overshooting by the radar beams caused by this being approximately 100 – 120 miles away from the radar and at the edge of where the precipitation algorithms will calculate estimated rainfall. At that range, the radar was sampling the storms at an elevation of 10000 – 12000 feet above the ground.

Figure 2 shows the Sioux Falls, South Dakota National Weather Service (FSD) WSR-88D radar estimated rainfall totals for this event, overlaid with observed rainfall totals (table 1). The rainfall totals for this storm were accumulated from a storm duration of about 6 hours, as determined from the WSR-88D radar observations and from reports provided by the numerous observation points (table 1). Rainfall totals within this area largely exceeded the 6-hour storm total estimated by Hershfield (1961) of about 4 inches for a 100-year recurrence interval for east-central South Dakota. Similarly, rainfall totals in some areas largely exceeded the estimated 24-hour storm total of about 5.5 inches for a 100-year recurrence interval for this area (Hershfield, 1961). Because of the excessive rainfall totals for this area, the National Weather Service (NWS) and U.S. Geological Survey cooperated in documenting rainfall totals and the resulting hydrologic response in the vicinity of the heaviest rainfall.

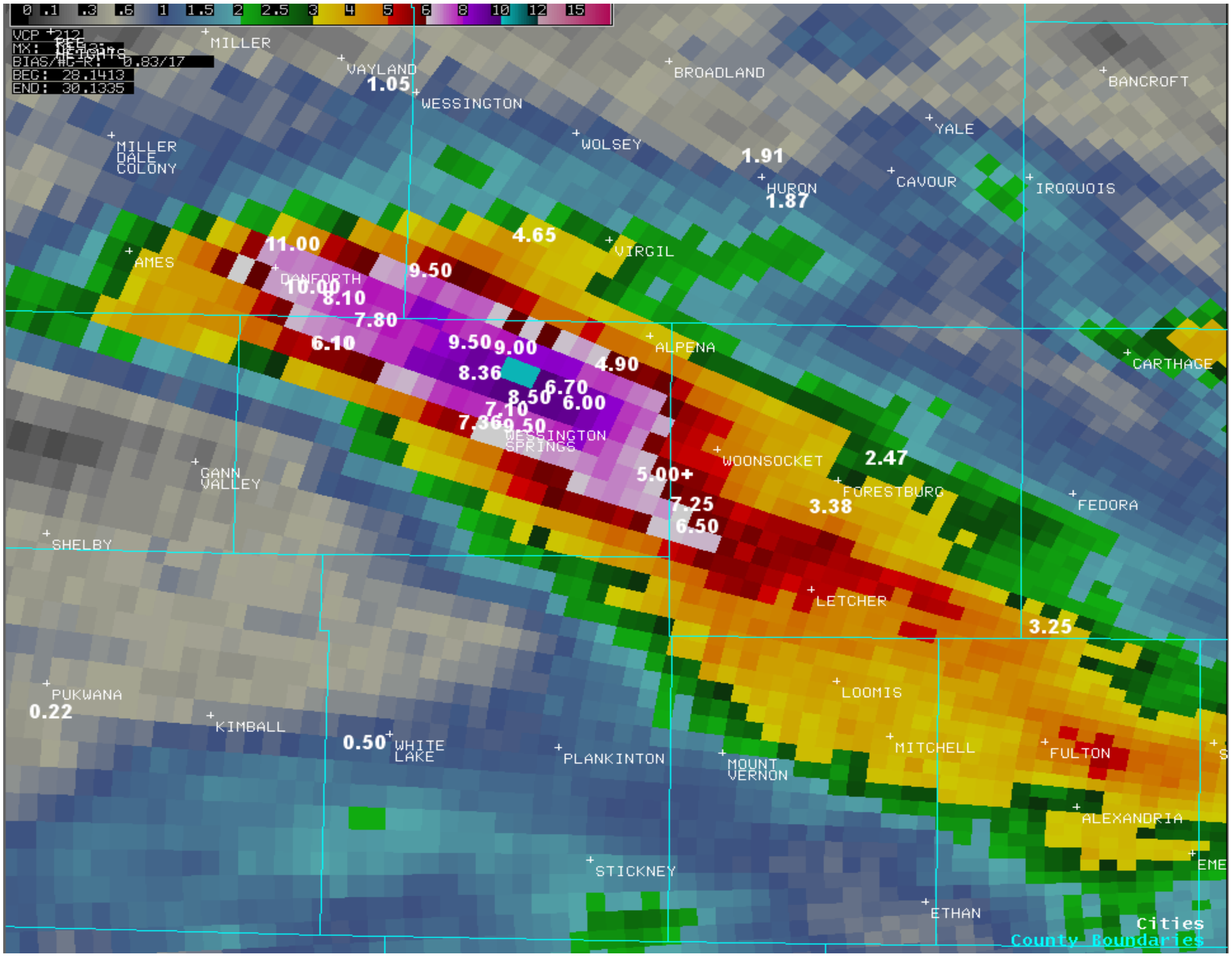

Figure 2. National Weather Service FSD WSR-88D radar estimated rainfall totals and observed rainfall totals for areas with especially heavy rainfall on July 29-30, 2010.

	Rainfall Amount	Latitude	Longitude
Jerauld County			
	4.90*	44 08 23	98 23 41
	9.50	44 09 00	98 40 12
	7.36	44 04 47	98 33 59
	7.10	44 05 06	98 34 16
	9.00*	44 09 33	98 33 52
	9.50*	44 10 10	98 36 44
	8.36*	44 07 06	98 35 32
	9.50*	44 04 50	98 33 59
	7.80*	44 11 41	98 43 49
	6.10*	44 09 55	98 46 30
	6.00*	44 05 50	98 26 43
	6.70*	44 06 36	98 27 35
	8.50*	44 05 51	98 30 45
	5.00+*	44 01 26	98 22 28
Hand County			
	11.00*	44 15 18	98 48 25
	6.98	44 14 28	98 46 12
	1.05	44 27 56	98 45 42
	10.00*	44 13 26	98 47 29
	8.10*	44 13 12	98 46 43

	Rainfall Amount	Latitude	Longitude
Beadle County			
	9.50*	44 13 55	98 40 50
	1.91	44 23 53	98 13 23
	1.87	44 21 49	98 11 56
	4.65*	44 17 04	98 34 23
Sanborn County			
	7.25*	43 59 41	98 19 28
	3.38	43 58 26	98 04 14
	2.47	44 02 32	98 04 12
	6.50*	43 58 56	98 18 54
Aurora County			
	0.50	43 43 53	98 42 42
Miner County			
	3.25	43 51 45	97 47 27
Brule County			
	0.22	43 51 45	99 10 45

Table 1. Observed rainfall totals for this event, collected from official and unofficial NWS observers, automated rain gauges, volunteer CoCoRaHS observers, and a survey of area residents. Rainfall amounts marked with an asterisk indicate those from the residential survey.

Antecedent Conditions

Numerous heavy rainfall events occurred across much of southeastern South Dakota in the early summer of 2010. Figure 3 shows the percent of normal rainfall that occurred in South Dakota in June 2010. The James, Vermillion, and Big Sioux River Basins in the southeastern part of the state received 200 percent to locally more than 400 percent of normal rainfall in June.

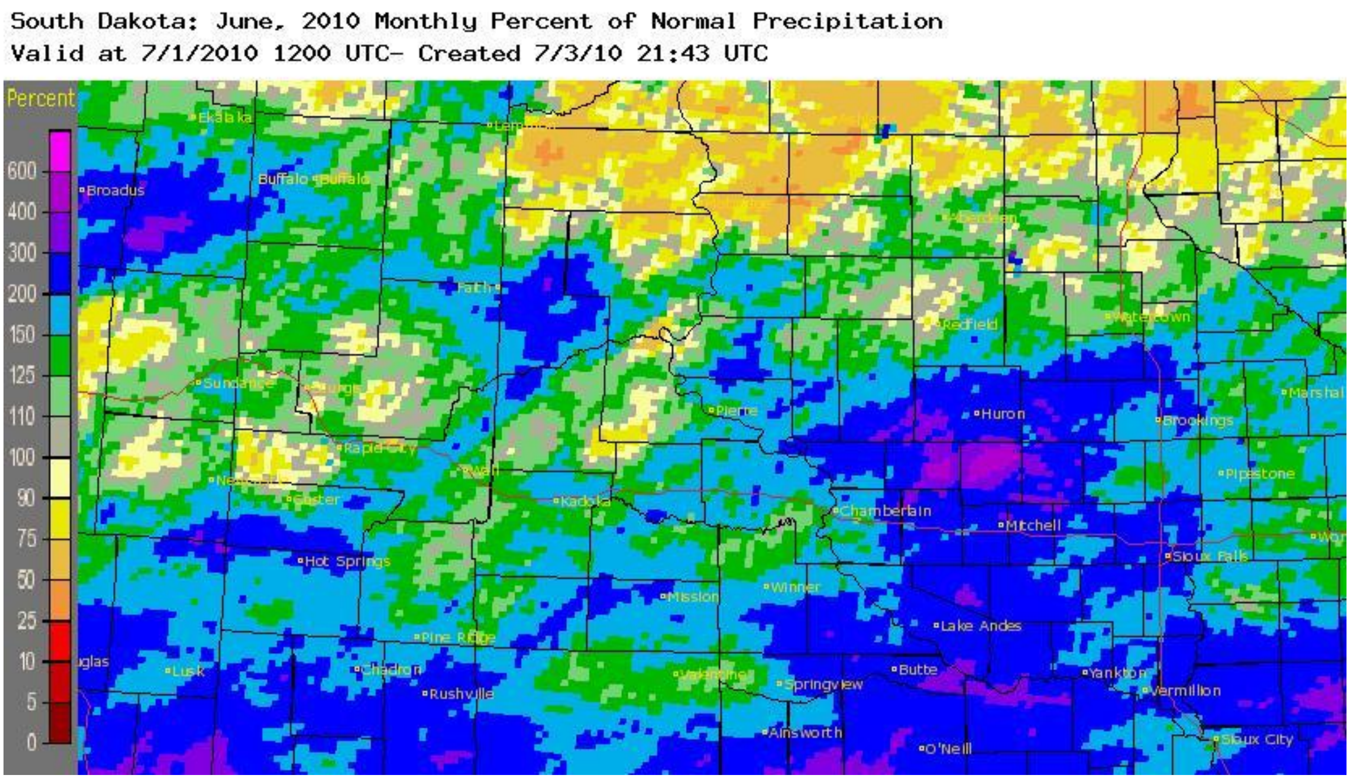

Figure 3. Percent of normal rainfall in South Dakota in June 2010.

Another heavy rainfall event had occurred about one week prior to the July 29-30 event in southeastern South Dakota. On July 21-22, widespread rainfall of 1 to 3 inches fell in the area, with heavier amounts of 3 to 6 inches along the Missouri River from Pickstown to Sioux City, and around the Sioux Falls area. Figure 4 shows the FSD WSR-88D rainfall estimates from that event.

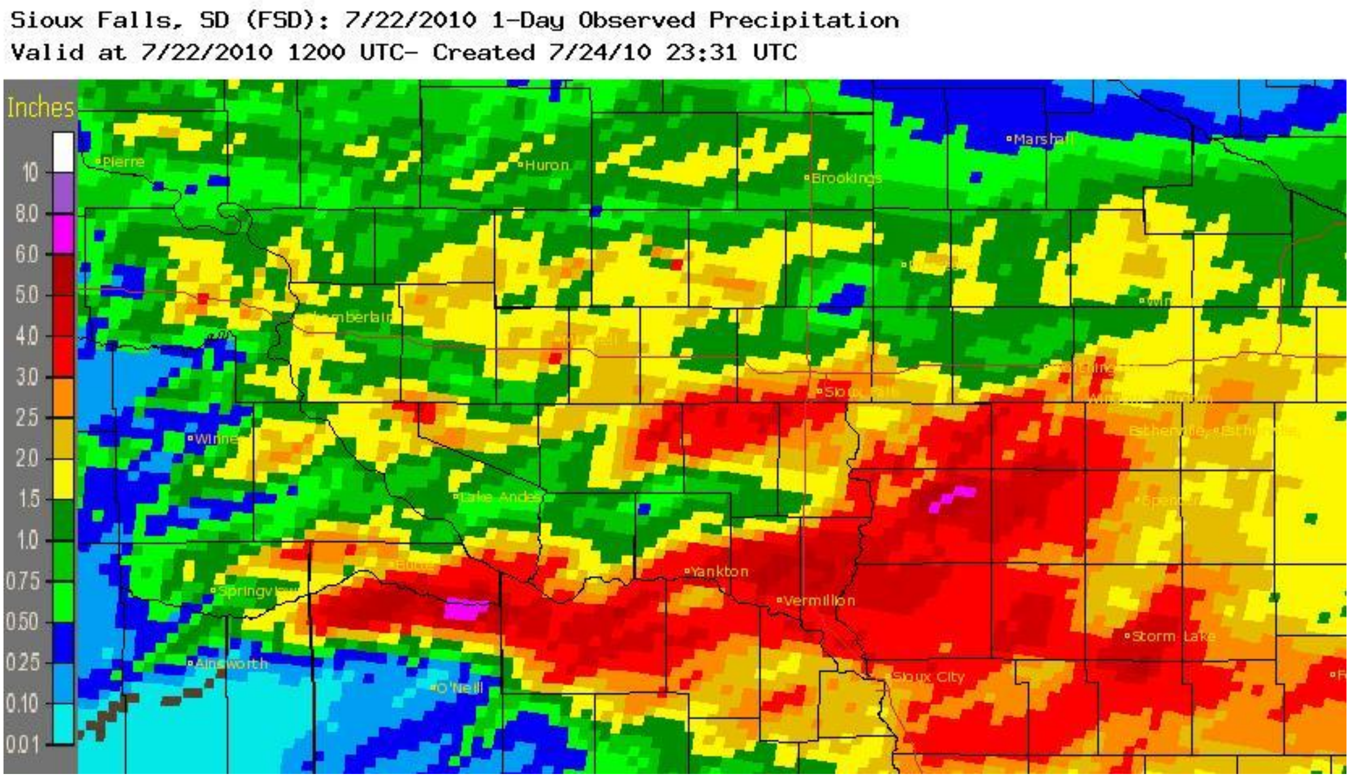

Figure 4. NWS FSD WSR-88D rainfall estimates for July 21-22, 2010.

Including the July 29-30 event, the percent of normal rainfall in July totaled 150 to 400 percent of normal across most of southeastern South Dakota (see Figure 5). When looking at records for the meteorological summer (June – August) from several NWS observing stations, just the June and July, 2010 rains established new rainfall records for the season, and values from many other stations ranked in the top five wettest summers, and this was not including future additional rains that fell in August 2010.

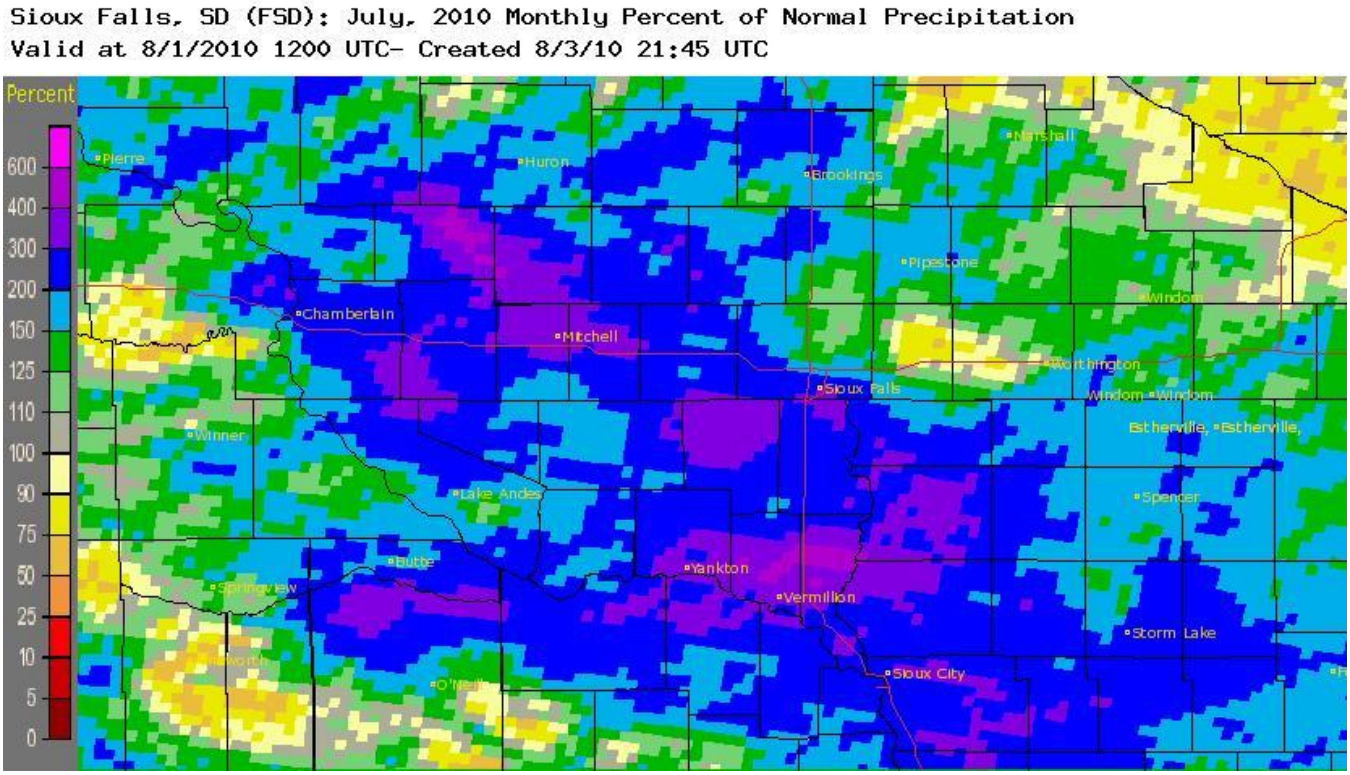

Figure 5. Percent of normal rainfall in southeastern South Dakota for July 2010.

After two months of much above normal rainfall, the soils were extremely wet. Figure 6 shows the NOAA Climate Prediction Center calculated soil moisture anomalies. All of eastern South Dakota was more than 40 mm (1.6 inches) above normal, and the southeastern one-quarter of the state had anomalies of 100 to 140 mm (3.9 to 5.5 inches) above normal.

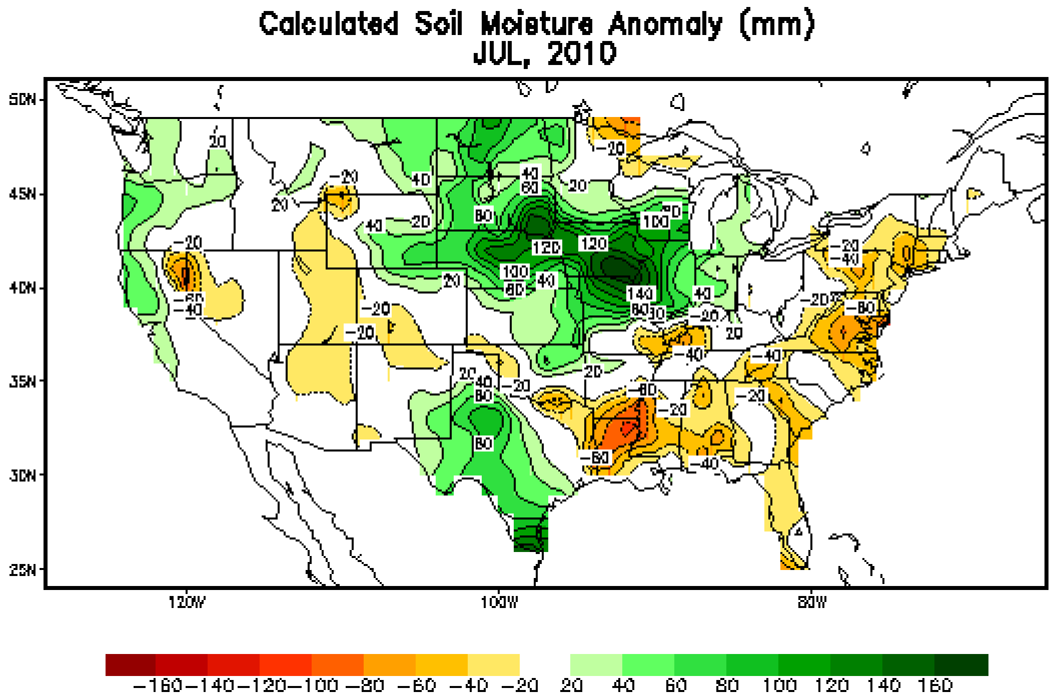

Figure 6. NOAA Climate Prediction Center calculated soil moisture anomalies for the United States.

Hydrologic Response

Some of the heaviest rainfall during the July 29-30, 2010, event occurred in an area from Wessington Springs to Rose Hill Dam (Figure 7), along the relatively steep eastern flanks of the Wessington Hills, which are about 300 to 500 feet higher than the surrounding flat lands of the James River Basin to the east. This area is within the headwaters of the Sand Creek and Firesteel Creek drainage basins, which are tributaries to the James River. The most substantial runoff was generated in areas of steepest topography such as within the drainage area for Rose Hill Dam, which is located along the northeastern flanks of the hills and which failed on the night of July 29.

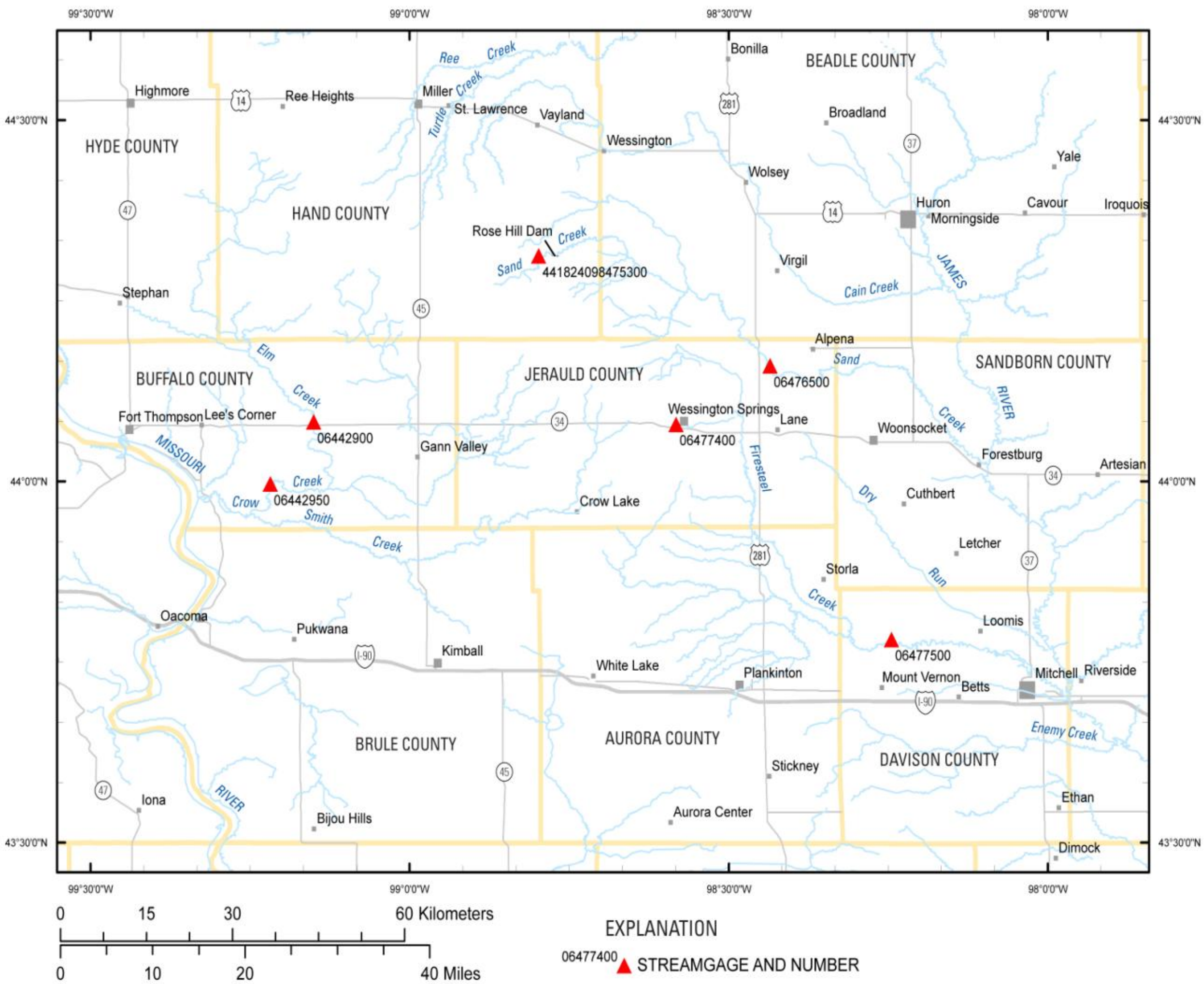

Figure 7. Locations of U.S. Geological Survey streamgages in the vicinity of the July 29-30, 2010 storm.

Determinations of peak flow were made by the U.S. Geological Survey (2011) for various locations in the storm vicinity, as shown in Table 2 and Figure 7. The largest peak flow determined was 12,500 cubic feet per second (ft^3/s) along Sand Creek upstream from Rose Hill Dam (streamgage 441824098475300). This flow determination was made because of the unusually large magnitude of the flow event, and there are no other available flow records for this site.

Streamgage Number	Streamgage Name	Period of Record (Water Years)	Drainage Area (square miles)	Peak Flow for July 29-31, 2010 (cubic feet per second)
441824098475300	Sand Creek above Rose Hill Dam	2010	32.5	12,500
06476500	Sand Creek near Alpena	1950-97, 2010	260	7,900
06477400	Firesteel Creek tributary near Wessington Springs	1968-79, 2010	0.21	100
06477500	Firesteel Creek near Mt. Vernon	1956-2010	587	7,280
06442900	Elm Creek near Gann Valley	1988-99	377	650 (E)
06442950	Crow Creek near Gann Valley	1972-84	807	300 (E)

Table 2. Selected information regarding peak flows for USGS streamgages in the vicinity of the July 29-30, 2010 storm. Values denoted with an "E" are not annual peak-flow values, and were estimated by relating high-water marks to rating curves for discontinued streamgages.

A smaller peak flow of 7,900 ft^3/s was determined for discontinued streamgage 06476500, Sand Creek near Alpena (Table 2), which is located about 20 miles southeast (downstream) from Rose Hill Dam (Figure 7). Although heavy rainfall (Figure 2) occurred throughout much of the intervening reach between streamgages 441824098475300 and 06476500, the flow at the downstream streamgage was substantially smaller, presumably because of attenuation (diminishment of flow as the flood crest moved downstream). The annual peak-flow record for streamgage 06476500 (which dates back to 1950) is shown in Figure 8, and the 2010 peak exceeded the next largest peak (2,240 ft^3/s in 1960) by a factor of about three and one-half.

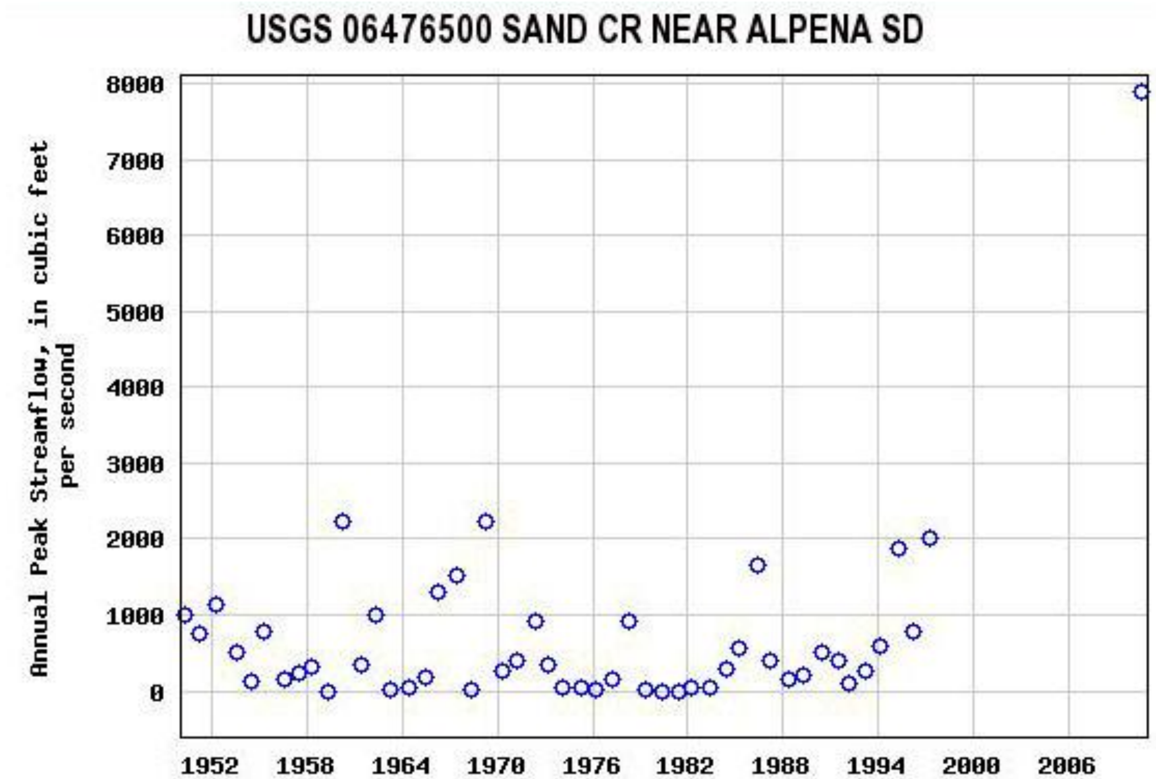

Figure 8. Annual peak-flow records for U.S. Geological Survey streamgage 06476500.

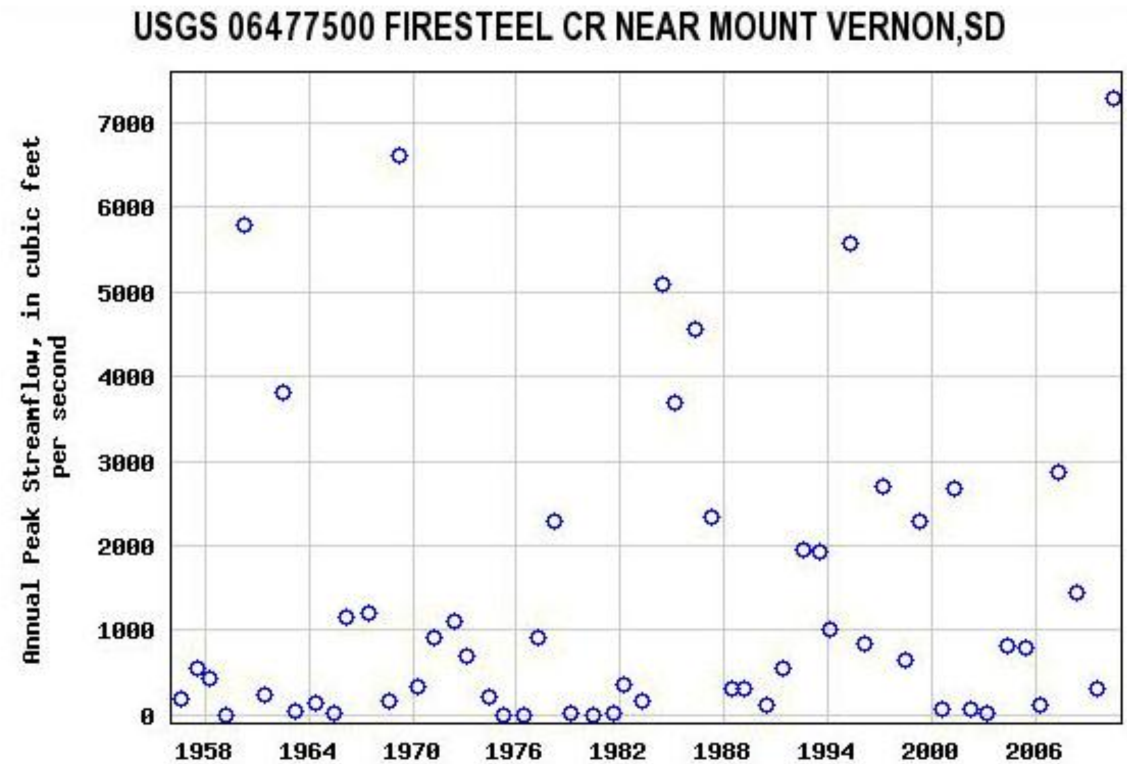

Figure 9. Annual peak-flow records for U.S. Geological Survey streamgage 06477500.

Another relatively large peak flow of 7,280 ft^3/s was recorded at streamgage 06477500, Firesteel Creek near Mount Vernon (Table 2). This streamgage is about 25 miles southeast of Wessington Springs (Figure 7), which is located along the eastern flank of the Wessington Hills. This peak flow occurred on July 31, about 2 days after the storm. Determinations of peak flows were not made for any locations farther upstream along the main stem of Firesteel Creek; however, larger flows probably occurred upstream, with flows presumably attenuating in a downstream direction. The annual peak-flow record for streamgage 06477500 (which dates back to 1956) is shown in Figure 9, and the 2010 peak is about 10 percent larger than the next largest peak flow (6,610 ft^3/s in 1969).

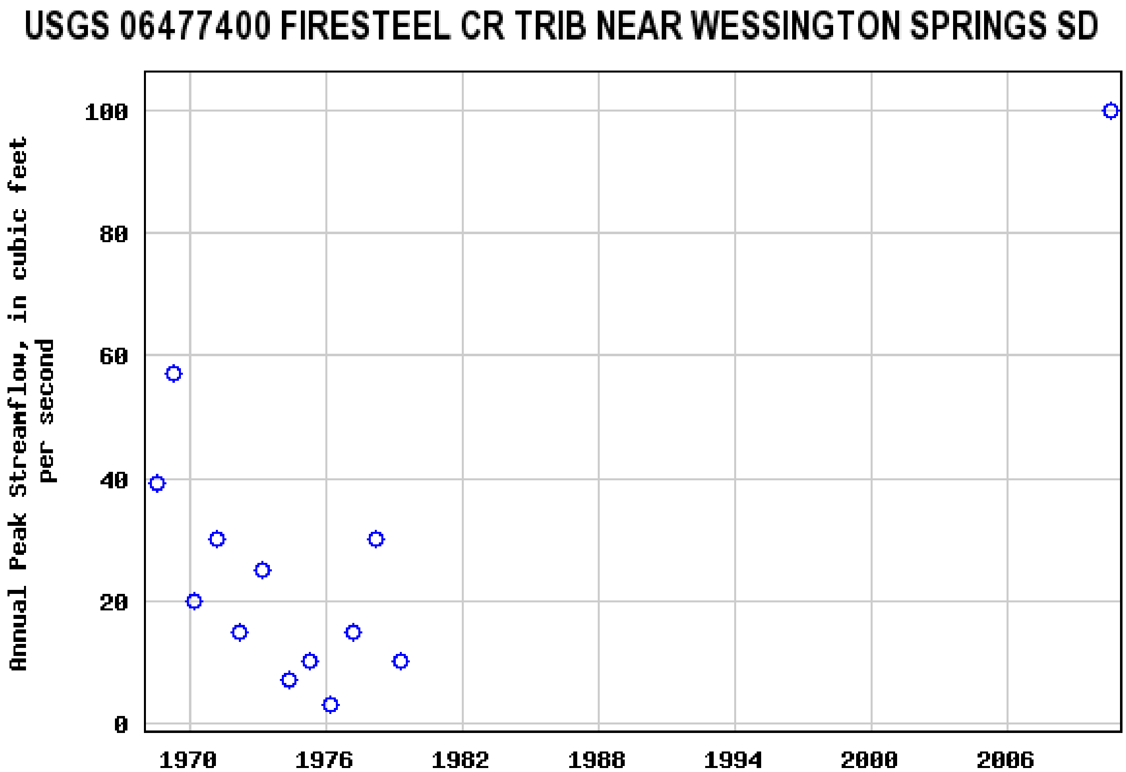

Figure 10. Annual peak-flow records for U.S. Geological Survey streamgage 06477400.

A peak-flow of 100 ft^3/s was recorded at streamgage 06477400, Firesteel Creek tributary near Wessington Springs, which is located about 1 mile west of Wessington Springs and has a drainage area of only 0.21 square miles. This is the largest peak flow recorded (by a factor of about two) at this streamgage (Figure 10), for which only 12 years of previous record are available (Table 2). This flow rate is equivalent to an "equilibrium" runoff rate of 0.74 inches per hour over the watershed area. This runoff rate is similar to the smaller end of the range of observed rainfall (6.00 to 9.50 inches over 6 hours) in the vicinity of Wessington Springs (Figure 2).

Flows resulting from the storm were estimated for two other discontinued USGS streamgages (table 2, 06442900 and 06442950) located generally southwest of the storm center; however, flows at both streamgages were relatively small and neither was considered to be the largest flow of the water year. Evidence of larger flows was observed in the headwaters of these stream reaches much closer to the storm center; however, peak flows apparently attenuated substantially while being routed downstream.

References

Hershfield, D. M., 1961: Rainfall Frequency Atlas of the United States. *Weather Bureau Technical Paper No. 40*, 115 p.

U.S. Geological Survey, 2011: National Water Information System (NWISWeb)—Peak streamflow for South Dakota. U.S. Geological Survey database, accessed January 27, 2011 at, *http://nwis.waterdata.usgs.gov/sd/nwis/peak*.