FLOOD DAMAGE IN SOUTH DAKOTA

Eugene L. Rowen, South Dakota Department of Highways; and
Larry J. Harrison, Federal Highway Administration, Denver

•SOUTH DAKOTA experienced its most devastating flood in history on June 9 and 10, 1972. The official report shows 238 dead from the flood and five people still missing. These people were swept away by the raging water. The Black Hills are very rough and steep, and the water came rushing down the steep slopes swallowing houses, cars, bridges, trucks, and everything in its path.

This flood covered portions of four counties, Lawrence, Meade, Pennington, and Custer. The rain began at 5:00 p.m. on June 9 and continued until 2:00 a.m. on June 10 when it slowed to a drizzle that continued all day. Official reports on point rainfall accumulation show up to 14 in. covering about a 40-mile long by 15-mile wide area in the eastern Black Hills area.

Damage survey estimates for local and federal-aid roads as well as for the Black Hills National Forest roads and bridges were in excess of $22 million. This included an estimated $13 million for damage to bridges alone. Two bridges were lost on the Interstate System, and emergency repairs were necessary on four others before traffic could be routed over them. Eighteen other bridges were completely destroyed on the state highway system. A total of 106 bridges were damaged or destroyed within the flood-ravaged area. Personal property losses totaled over $200 million. Most of this damage was along Rapid Creek, which flows through the center of Rapid City.

We are now reconstructing and repairing the bridges and roads in the area. Two weeks after the flood all state highways were open to traffic. Maintenance personnel and equipment were moved in from all over the state to restore the roads for emergency traffic as soon as possible. Seven emergency contracts were let to reconstruct damaged road sections for emergency traffic.

The flood peaks, given in Table 1, experienced at specific locations on six of the larger streams within the 40-mile long coverage of the June 9-10 event present a vivid picture of the magnitude of the storm from both peak flow and geographical standpoints. (All streams flow easterly out of the Black Hills.)

These peak discharges are from a U.S. Geological Survey study of the entire flood area and are subject to minor revision before a future report on the flood is issued.

When viewed from this representative sampling of extremely high flood peaks experienced throughout the flood area and because many residents of Rapid City on "sleepy" Rapid Creek had homes nestled along the banks of the low water channel and on the floodplain, it becomes clearer why so many lives were lost.

In the firm belief that we all can benefit from a review of some hydraulic design practices that were detrimental to maintaining the structural integrity of highway facilities during the passage of floodwaters, the major types of damage are briefly discussed, and recommended design considerations are presented that, if incorporated into current design practice, will lessen similar damage in the future.

Flood evidence indicates that bridges supported on spread footing foundations were much more subject to failure than those supported on steel or timber piling. Undoubtedly a combination of local scour at bridge piers, in many cases aggravated by large amounts of debris caught on the upstream face, and overall streambed scour under the bridge played major roles in the failure of structures. The tremendous forces exerted by floodwaters on the massive accumulations of debris trapped by the superstructure of bridges also contributed to the failures, as did other factors. In the instances where we had failure, these footings were founded on densely packed and cemented streambed gravels. This formation is very difficult to penetrate with piling

Table 1. Flood peaks in South Dakota for the 1972 floods.

Location	Flood Peak (cfs)	Discharge per Square Mile (cfs)	Previous Peak (cfs)
Deadman Gulch at Sturgis	4,700	800	Not available
Bear Butte Creek at Sturgis	19,500	370	12,000
Box Elder Creek north of Rapid City	51,600	440	1,180
Rapid Creek above Canyon Lake Dam	31,200	600	2,600
Rapid Creek below Canyon Lake Dam	50,000	550	3,300
Spring Creek at SD-16	21,800	210	772
Battle Creek near Hermosa	44,100	400	Unknown

and is capable of withstanding substantial spread footing loads. Spread footings founded on this formation below scour depth would be quite adequate. However, scour depths far exceeded predicted values. For these reasons, the state is seriously considering the exclusive use of pile foundations for all future designs except when spread footings are founded on scour-resistant material.

In line with our discussion of bridge foundations, we recommend that consideration be given to the use of a discharge in excess of the design quantity for foundation scour design. This would produce excess ponding depth upstream of the structure, or water would flow over the embankment, but any attendent damage would be rapidly and economically repaired. This is not so, however, should foundation support be removed by scour and the structure itself fail. We would be interested to know of any agency that does consider this aspect and would like to know the design practice used.

Typical local pier scour damage was evident in many bridges in downward displacement of the upstream portion of a bridge foundation. An unusual instance involved twin structures with the downstream bridge distressed in this manner. Debris plugged the upstream bridge with the resulting overflow impinging on the streambed just upstream of the downstream structure.

Damage to roadway embankments was widespread in that roads typically parallel streams within the floodplains. In many instances entire roadway prisms were removed. Based on the positive experience of rock and wire slope protection in areas of known high flows, the state is considering more common use of riprap where needed for design discharges with recognition that protection is afforded for the rare flood events as well.

We are all aware of existing highway-to-stream crossings that would have necessitated the expenditure of substantially less maintenance and/or flood repair money had the adverse hydraulic characteristics of the stream crossing been evaluated initially and had highway alignment been revised accordingly. The state is making a concerted effort to take this into account in current designs.

Observations of damaged stream crossings also stress the vital need for proper orientation of drainage structures parallel to natural channel alignment rather than perpendicular to roadway alignment as noted. Repair of scour on the outside as well as deposition on the inside of the resulting bend in such installations may very well require expenditure of far greater funding over the life of the project than would be occasioned with proper hydraulic design.