MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 20-419 (project 537) | September 2020

Quantifying Mountain Basin Runoff Mechanisms for Better Hydrologic Design

the ISSUE

Many current hydrologic guidelines assume that runoff from design storms is produced by an infiltration-excess mechanism where rainfall intensity exceeds the infiltration capacity of the soil. However, mountain basins often have shallow soils. In such cases, saturation-excess runoff might occur when the entire soil becomes saturated. Saturation-excess occurs when rain falls on a location that is completely saturated from a low-permeability layer up to the soil surface. Neglecting saturation-excess runoff might lead to inaccurate hydrologic analyses. These analyses are used for dam safety evaluations and for bridge and culvert designs

the RESEARCH

This project examined the hydrologic response of five Front Range basins for flood events in 1976, 1997, and 2013. A numerical model was constructed in the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) for each basin. Within HEC-HMS the soil moisture accounting method was used, which can simulate infiltration-excess runoff, saturation-excess runoff, and subsurface stormflow. The models were calibrated by comparing them with the observed streamflow response for each basin and event. The models were then examined to determine the active streamflow generation mechanisms. Specifically, the soil layer was examined to see whether it approached saturation during runoff production, which would indicate saturation-excess runoff. The model parameter values were also varied to consider whether the observed streamflow responses could be produced by the other runoff production mechanism. The model results were compared to the behavior of in-situ soil moisture observations where available. Such observations are valuable because infiltration-excess runoff is expected to produce saturation first at the top of the soil layer, while saturation-excess runoff

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Project Title

Quantifying Mountain Basin Runoff Mechanisms for Better Hydrologic Design of Bridges and Culverts

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the **RESEARCH** cont.

is expected to produce saturation first at the bottom of the soil layer. Finally, similar analyses were performed by simulating various probable maximum precipitation and annual exceedance probability design storms.

the **FINDINGS**

The results suggest that infiltration-excess was the runoff mechanism for the 1976 flood in the North Fork of the Big Thompson River. In contrast, saturation-excess was the runoff mechanism for the 2013 flood in studied basins where runoff occurred. Infiltration-excess runoff likely occurred for the 1976 event because the storm had a short duration but an intense rainfall rate. In contrast, saturation-excess runoff likely occurred in 2013 because the storm was less intense but much longer. For the 2013 storm, available soil moisture observations also suggest that saturation occurred first at the bottom of the soil profile and progressed upwards, suggesting saturation-excess runoff. Furthermore, infiltration-excess runoff could not reproduce a double-peaked hydrograph that was observed for South Boulder Creek. Shorter duration but more intense design storms tend to produce infiltration-excess runoff, while less intense but longer design storms tend to produce saturation-excess runoff.

the **IMPACT**

The study identified a key limitation in some current hydrologic guidelines. It also suggested an avenue by which this limitation can be overcome. Thus, the study is expected to produce more accurate estimates of runoff and streamflow from design storms and improved hydrologic analysis and design for dams, culverts and bridges.

For more information on this project, download the entire report at https://www.ugpti.org/resources/reports/details.php?id=994

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.

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