Impact of the June 2005 storm groundwater levels in the Bow River Basin, Alberta

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Abstract

The Bow River Basin of southern Alberta captures a diverse landscape encompassing ice-capped mountains, forested foothills and dry prairie grassland. Most of the basin's population of 1.1 million resides in or around the City of Calgary. The Bow River and all of its major tributaries, with the exception of Nose Creek, originate in the Rocky Mountains. In contrast, stream systems are mostly lacking on the prairie. Most of the precipitation that falls in the Bow River Basin falls in the Rocky Mountains, leaving the foothills and prairie in the rain shadow. The rain shadow effect can reverse in summer when southern continental air masses press against the eastern slopes of the Rockies. These events occasionally drop substantial quantities of water and were the cause of a major flood event in 2005.

The Bow River Basin is the only river basin in Alberta having Provincial groundwater observation wells situated in the province's three main physiographic regions: Rocky Mountains, the foothills and the prairies. The aquifers monitored include glacial and preglacial sands and gravels and Cretaceous/Tertiary sandstone. Four groundwater observation wells were installed across the basin by the Province in the late 1980s and eight wells were added in the Rocky Mountains region after 2000. Groundwater hydrographs for six wells, three in the Rocky Mountains and three in the foothills-prairie region, were examined in relation to monthly precipitation.

Groundwater hydrographs in the Bow River Basin exhibited seasonal and long term responses to variations in precipitation. Seasonal responses were more pronounced in the Rocky Mountains, masking year to year trends. In the foothills and prairie year-to-year responses were more pronounced and seasonal effects were subdued. All wells exhibited multi-year upward or downward trends in water levels, which corresponded to wet or dry time periods. Long-term water levels were relatively stable in most wells, however one well in the driest part of the basin showed a continuous long-term decline.

In the Rockies the precipitation supply is dependable. Aquifer storage appears to be near-capacity and as a consequence aquifers are likely to reject potential recharge as surface runoff, feeding the Bow River. In the foothills-prairie region, moisture deficits are common. Surface runoff and contributions to the Bow River system are minimal. Normal precipitation can be captured entirely by soil moisture, which acts as an impediment to groundwater recharge, particularly in the drier east. Annual moisture deficits can be cumulative, increasing resistance to moisture inputs. For significant recharge to occur, individual or cumulative snowmelt or precipitation events must be of sufficient magnitude to overcome moisture deficits in the unsaturated zone. Events resulting in a breakthrough of saturated conduits through the vadose zone are capable of providing substantial pulses of recharge to the water table. These are capable of reversing years of water level declines in a single event.

In June 2005, four storms hit southern Alberta, lasting a total of 16 days. The entire Bow River Basin was affected with anywhere from 50% to 100% of average annual precipitation falling that month. Heaviest precipitation occurred along the front ranges of the Rockies. Runoff originating along the front ranges caused major flooding downstream, while runoff on the prairies was not significant. In the Rocky Mountains the hydrograph responses to the storm were dramatic and immediate, mostly in response to the pressure load of the additional water. Water levels mostly receded the same season and long term gains in water levels were relatively minor. In contrast, in the foothills and prairie water level peaks were delayed between 2 to 13 months following the storm, but the rise was substantial and sustained. Each of the wells achieved new highs as a result of the storm. In the Duchess well, at the most eastern driest point in the basin, the storm erased seventeen years of continuous water level decline.

The storm of June 2005 is best known for the flooding caused by runoff generated in the Rocky Mountains. In this region, the aquifers were incapable of accepting the amount of water dropped on the landscape. Groundwater levels spiked from the pressure load, but longer term gains were relatively small. In contrast, the drier landscape east of the Rockies, runoff was minor, but recharge and long-term gains in groundwater storage were substantial. The load of infiltrating water was sufficient to overcome being trapped by capillary pressures created by soil moisture deficits. As a consequence significant quantities of water were captured by the groundwater zone.

The hydrographs illustrate that where water tables were high, such as in the Rocky Mountains, runoff was generated, leading to flooding. In areas east of the Rockies, where water tables were relatively low, the ground accepted moisture, minimizing runoff. Moreover, the hydrographs illustrate the importance of infrequent large-scale storm events on the long-term sustainability of aquifer levels in the eastern Bow River Basin and semi-arid landscapes in general.