Earthquake Impacts on hydrology: a case study from the Canterbury, New Zealand earthquakes of 2010 and 2011

Davie, Dr Tim*, Smith, Dr Jeff; Scott, David; Ezzy, Dr Tim, Cox, Dr Simon***, Rutter, Dr Helen******

Abstract

On 4 September 2010 an earthquake of magnitude 7.1 on the Richter scale occurred on the Canterbury Plains in the South Island of New Zealand. The Canterbury Plains are an area of extensive groundwater and spring fed surface water systems. Since the September earthquake there have been several thousand aftershocks (Fig. 1), the largest being a 6.3 magnitude quake which occurred close to the centre of Christchurch on 22February 2011. This second quake caused extensive damage to the city of Christchurch including the deaths of 189 people. Both of these quakes had marked hydrological impacts.

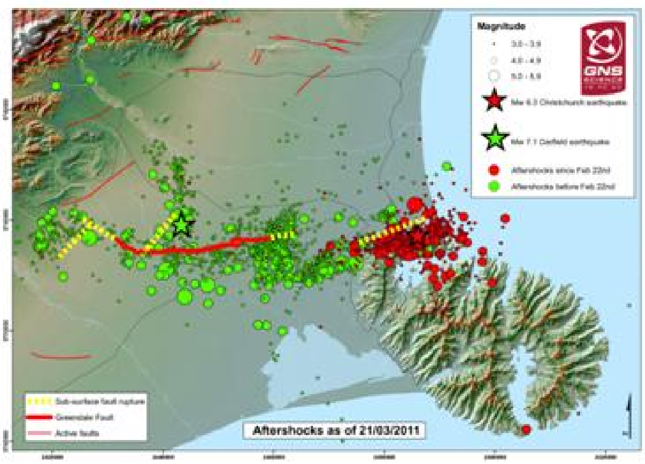

Figure 1: Canterbury earthquake and aftershocks. The Canterbury Plains make up the flat area between the Southern Alps to the west and Banks Peninsula to the East. The city of Christchurch is immediately north of the eastern cluster of aftershocks.

Water is a vital natural resource for Canterburywith groundwater being extracted for potable supply and both ground and surface water being used extensively for agricultural and horticultural irrigation.The groundwater is of very high quality so that the city of Christchurch (population approx. 400,000) supplies untreated artesian water to the majority of households and businesses.

Both earthquakes caused immediate hydrological effects, the most dramatic of which was the liquefaction of sediments and the release of shallow groundwater containing a fine grey

* Manager Surface Water Resources & Ecosystems, Environment Canterbury, Christchurch, New Zealand
** Senior Scientists, Environment Canterbury, Christchurch, New Zealand
*** Structural Geologist, GNS Science, Dunedin, New Zealand
**** Senior Hydrogeologist, Aqualinc Research Ltd, Christchurch, New Zealand

silt-sand material. The liquefaction that occurred fitted within the empirical relationship between distance from epicentre and magnitude of quake described by Montgomery et al. (2003).). It appears that liquefaction resulted in development of discontinuities in confining layers. In some cases these appear to have been maintained by artesian pressure and continuing flow, and the springs are continuing to flow even now.

In spring-fed streams there was an increase in flow that lasted for several days and in some cases flows remained high for several months afterwards although this could be linked to a very wet winter prior to the September earthquake. Analysis of the slope of baseflow recession for a spring-fed stream before and after the Septemberearthquake shows no change, indicating no substantial change in the aquifer structure that feeds this stream.A complicating factor for consideration of river flows was that in some places the liquefaction of shallow sediments led to lateral spreading ofriver banks. The lateral spread lessened the channel cross section so water levels rose although the flow might not have risen accordingly.

Groundwater level peaks moved both up and down, depending on the location of wells. Groundwater level changes for the two earthquakes were strongly related to the proximity to the epicentre. The February 2011 earthquake resulted in significantly larger groundwater level changes in eastern Christchurch than occurred in September 2010. In a well of similar distance from both epicentres the two events resulted in a similar sized increase in water level but the slightly slower rate of increase and the markedly slower recession recorded in the February event suggests that the well may have been partially blocked by sediment flowing into the well at depth. The effects of the February earthquake were more localised and in the area to the west of Christchurch it was the earlier earthquake that had greater impact. Many of the recorded responses have been compromised, or complicated, by damage or clogging and further inspections will need to be carried out to allow a more definitive interpretation. Nevertheless, it is reasonable to provisionally conclude that there is no clear evidence of significant change in aquifer pressures or properties.

The different response of groundwater to earthquakes across the Canterbury Plains is the subject of a new research project about to start that uses the information to improve groundwater characterisation for the region.

Montgomery D.R., Greenberg H.M., Smith D.T. (2003) Stream flow response to the Nisqually earthquake. *Earth & Planetary Science Letters* 209 19-28