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Induced Seismicity Due to Wastewater Injection Near Peace River, Alberta

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Summary

A cluster of 8 small earthquakes commenced in 1998 near the Town of Peace River, Alberta. The level of seismicity has recently increased, with six events since June 2014 through October 2015. Understanding the potential cause of this cluster is important to improve hazard assessment. This study explores a possible link between these earthquakes and wastewater injection. On the basis of spatial and temporal correlation with injected volumes, it is interpreted that all eight earthquakes were triggered by disposal in one well. The earthquakes appear to have propagated further away from the well over time, with the furthest earthquake located about 27km from the inferred injection point.

Introduction

The Peace River cluster includes eight earthquakes near the Town of Peace River. Earthquakes in this area are of particular concern because of the potential for triggered landslides on unstable creeping slopes of the Peace River valley (Morgan et al., 2012). The earthquakes in this cluster are small, ranging from moment magnitudes of 2.4-3.5. The earthquakes may be linked to wastewater injection wells, due to the proximity of these earthquakes to large-volume disposal wells. In the US, wastewater injection has been linked to earthquakes as large as magnitude 5.7 (Keranen, 2014).. The potential for damaging earthquakes induced by wastewater injection and the vulnerability to mass movements near Peace River provide strong motivation to investigate this potential hazard.

The main focus of this study is to explore the likelihood that pore pressure increase due to wastewater injection is the primary trigger for these earthquakes, and to lay the groundwork for future hazard analysis studies on the Peace River cluster. The approach being employed in this study includes a spatial and temporal analysis of the earthquakes and injection rates.

Method

In order to examine possible linkages between wastewater injection wells and seismicity, all the waste water injection wells in the area must be reviewed to see if any connections can be made. There are approximately 30 wastewater injection wells close enough, within about 10km, to the earthquakes to represent potential sources of triggering fluids. The first step to narrowing down this list is to look at injection rates. Past research has suggested that wells injecting wastewater at over 25,000 cubic meters per month are more likely to induce seismicity (Ellsworth, 2013). Application of this criterion narrowed the list of wells down to only 2 wells that are injecting over 25,000 m^3/mo. and within 10 kilometers from the earliest earthquake in 1998. Upon further examination of these wells, it appears that the earthquakes approximately match a radial propagation pattern from one of the wells (Figure 1). The earthquakes farthest away from the well, about 27 kilometers, are well within the range of what is expected for propagation of fluid pressure over the time period the well is injecting (Keranen, 2014).

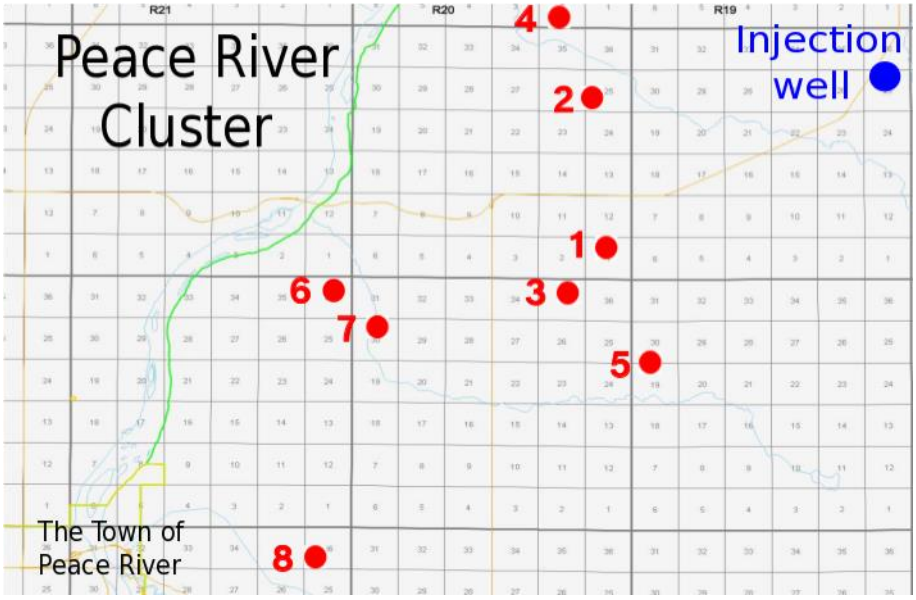

Figure 1: The well thought to be causing the earthquakes is in the top right. The earthquakes are numbered in the order that they occurred. The actual dates of the events are as follows: **October 23, 1998 (M2.6); February 19, 2009 (M3.2); June 14, 2014 (M3.1); July 7, 2014 (M3.5); November 11, 2014 (M3.1); April 26, 2015 (M2.4);** 2 on **May 26, 2015, 2:15AM (M2.9) and 3:42PM (M3.0)** respectively. Background of image obtained from Accumap.

The final well began injecting wastewater in May 1997 at about 17,000 m^3/mo., but quickly rose to about 130,000 m^3/mo. by October 1997. Over the next year, high injection rates continued, averaging about 75,000 m^3/mo. Subsequently, in October 1998 the first earthquake of the Peace River Cluster occurred. Injection rates then decreased, averaging close to 25,000 m^3/mo. over the next decade with no seismicity during this time. In July 2008, however, injection rates began increasing again, averaging about 75,000 m^3/mo. up until another earthquake occurred in February 2009. The relationship between injection rates and the earthquake occurences is shown in the figure below.

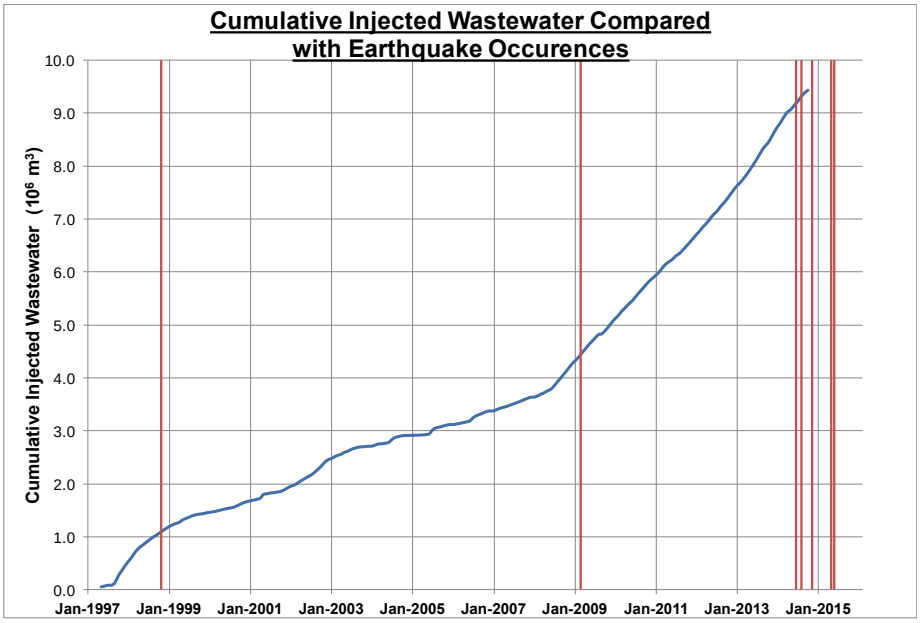

Figure 2: Graph of cumulative volume of wastewater injected by a single well that may be triggering the earthquakes. Also includes red vertical lines representing the occurrence of an earthquake.

Conclusions

The Peace River Cluster commenced in 1998 and contains 8 small earthquakes with magnitudes from 2.4-3.5. This cluster is located in an area where vulnerability exists due to landslides in the steep river valley slopes. After analyzing wells near the Peace River Cluster it appears probable that the earthquakes are linked to an increase in pore pressure from wastewater injection, due to relationships between locations of the wells and earthquakes; as well as relationships between injection rates and rate changes to the timing and location of the earthquakes.

Further research planned for this cluster includes a matched-filtering process to attempt to locate more events. A moment-tensor analysis and relocation of each event could help better characterize the fault system. Other potential research on this cluster could include a pore pressure diffusion model along with a full analysis of faults that could potentially be triggered. All of this information could also be used to do a hazard assesment to determine Peace River's vulnerability to landslides triggered from earthquakes.

Acknowledgements

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References

K. M. Keranen, Sharp Increase in central Oklahoma since 2008 induced by massive wastewater injection., *Science* 345, p. 448-451, 2014.

Morgan et al., Geological Setting for Large Landslides at the Town of Peace River, Alberta., Energy Resources Conservation Board, Alberta Geological Survey, 2012.

W. L. Ellsworth, Injection-Induced Earthquakes, *Science* 341, p. 1225942 (1 – 6), 2013.