

Earthquake Damage Analysis: Christchurch, New Zealand

by Ripley Swan, A study of the causes of damage in the 2010/2011 Christchurch earthquakes.

Introduction

At 4:35 am on Saturday September 4, 2010 a magnitude 7.1 earthquake struck 37 kilometers west of Christchurch, New Zealand. It produced the strongest shaking ever recorded in the country and was widely felt across the South Island and southern parts of the North Island. The quake caused significant damage in Christchurch and the surrounding area but few serious injuries and no loss of life. Five and a half months later, at 12:51 pm on Tuesday February 22, 2011, Christchurch was rocked by another earthquake. With a magnitude of 6.3 and its epicenter just 10 kilometers southeast of Christchurch's city center, it killed 185 people, injured several thousand, and caused enormous amounts of damage. It was the second-deadliest natural disaster ever recorded in New Zealand and by far the costliest, with the two quakes causing an estimated to be \$40 billion as of April 2013.

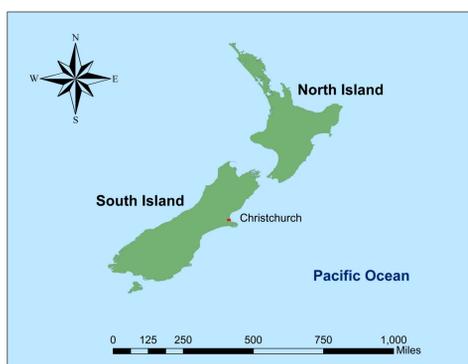


Figure 1: Christchurch is located on the east coast of New Zealand's South Island.

Background

At the root of the vast majority of damage caused by the earthquakes was a phenomenon called liquefaction. When load is exerted on loose sandy or silty soil that is saturated with water, the soil particles try to densify and close the voids between them. But, the void (or pore) space is filled with water, so the load is shifted from the soil to the water. This is called increased pore pressure. In normal loading situations, such as building construction, this extra pore pressure has time to slowly dissipate, and the soil will settle over time. However, in rapid loading/unloading situations, like earthquakes, there isn't time for the pore pressure to dissipate, so all of the loading is taken on by the water, lowering the soil's strength and making it act like a liquid, hence the term liquefaction.

Liquefaction leads to soil flowing horizontally, which is known as lateral spreading. Visible cracks can also appear in the ground, as shown in Figure 2. This can cause buildings, roads and buried utilities to shift and fail. With decreased strength, liquefied soil can also shift vertically, causing buildings to tip or settle unevenly. Older, less reinforced buildings are, therefore, highly susceptible to cracking and collapse when the soil on which they are built experiences lateral spreading or vertical ground motion. Most of the deaths and injuries in the Christchurch earthquakes resulted from building collapses. The city required, and still requires, extensive reparations and demolitions to become fully functional again.



Figure 2: Lateral spreading in the parking lot of a tavern in Kaiapoi just north of Christchurch. Concrete blocks in the wall of the tavern separated as a result of lateral spreading and uneven settlement.

Methodology

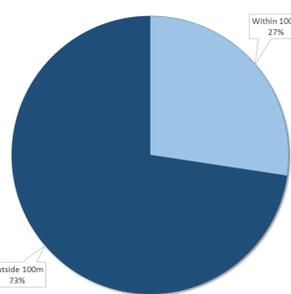
Two datasets were studied to represent the overall damage caused by the earthquakes: **liquefaction / lateral spreading** and **ground cracking**. Both datasets included the severity of the damage for further investigation. The two possible damage causes considered in this project were **soil type** and **proximity to rivers**.

For the soil types investigation, a geologic map of Greater Christchurch (see Figure 11) was created with relevant attributes. Spatial joins were run to attach a soil type to each liquefaction polygon and each ground cracking polygon. These new datasets were then analyzed to find the frequency and severity of damage in each soil type (see Figures 9 & 10).

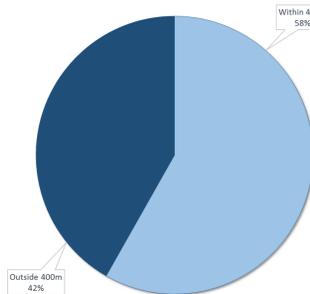
Results & Discussion

Rivers and Liquefaction / Lateral Spreading

Liquefaction and Lateral Spreading vs. Distance to Rivers (100m)



Liquefaction and Lateral Spreading vs. Distance to Rivers (400m)



Figures 3 & 4: Percentages of all liquefaction and lateral spreading within 100m and 400m of rivers.

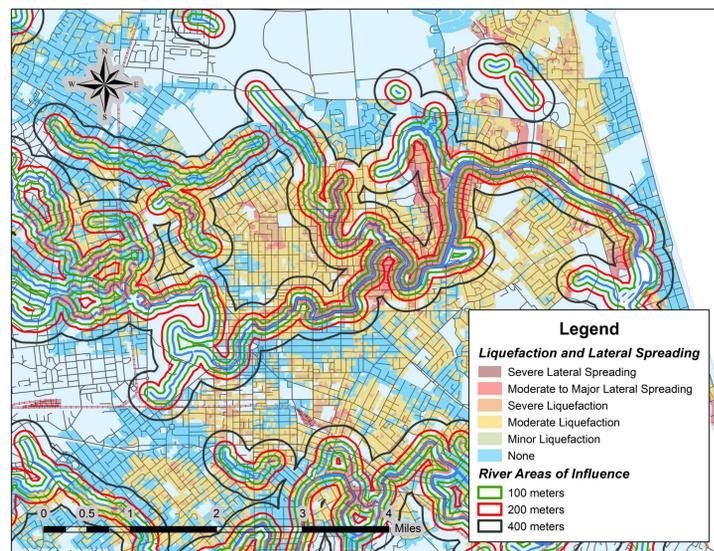
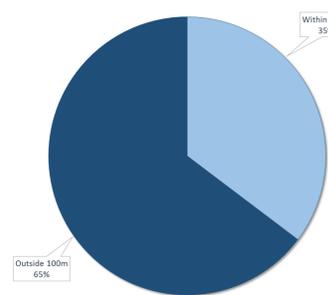


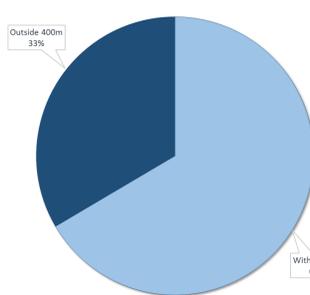
Figure 5: Liquefaction / lateral spreading locations and severities with various areas of influence of rivers.

Rivers and Ground Cracking

Ground Cracking vs. Distance to Rivers (100m)



Ground Cracking vs. Distance to Rivers (400m)



Figures 6 & 7: Percentages of all ground cracking within 100m and 400m of rivers.

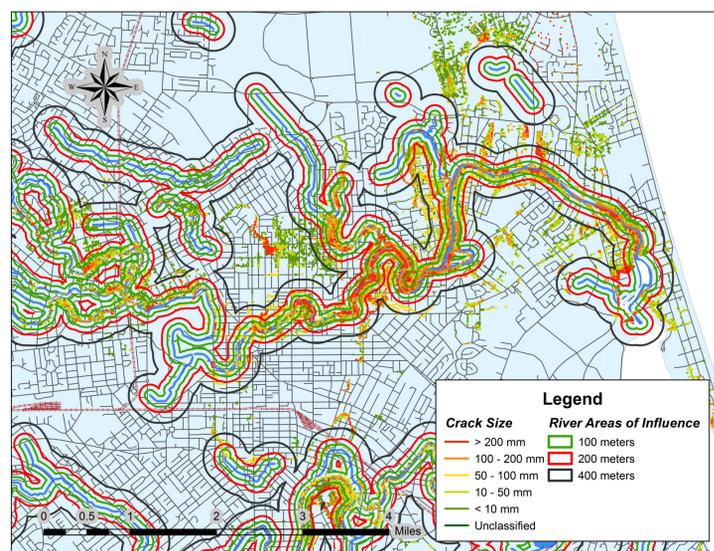


Figure 8: Ground cracking locations and severities with various areas of influence of rivers.

A similar approach was taken for the proximity to rivers investigation. Buffers of 100, 200 and 400 meters were applied to the rivers datasets. Spatial queries were then run to find the amount and the severity of liquefaction/lateral spreading and ground cracking within each distance to rivers (see Figures 3-8).

Damage was classified as 'severe' or 'not severe'. Because lateral spreading is an extreme result of liquefaction, any polygon representing lateral spreading was classified as severe. For the ground cracking, severe was defined as any observed cracks greater than 100 millimeters.

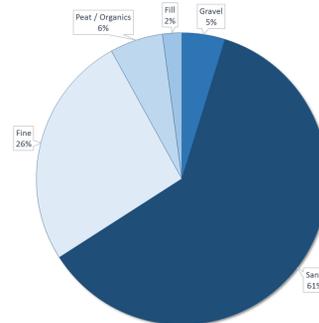
Figures 5 and 8 give visuals of where ground cracking and liquefaction / lateral spreading occurred in relation to rivers. At first glance, the damage seems very much concentrated around rivers, but the numbers must be considered to get the full picture. Figure 3 displays the percentage of all liquefaction and lateral spreading that occurred within 100 meters of a river. Figure 6 shows the same for ground cracking. With less than 50 percent of all damage occurring within the 100 meter buffer in both cases, very close proximity to rivers doesn't seem to be a strong cause of damage. However, stepping back to 400 meters in Figures 4 and 7, there seems to be much more of a correlation, especially in the case of ground cracking. This makes sense because ground cracking often occurs in sloped areas, and land naturally tends funnel down towards rivers.

It is more difficult to visualize which soil type the majority of ground damage occurred in, so Figures 9 and 10 are helpful in evaluating this relationship. Both ground cracking and liquefaction are heavily concentrated in sand. This confirms what is known about the necessary conditions (i.e. sandy soil) for liquefaction. The data in Figure 9 reinforces this even more. Ground cracking is really an extreme result of liquefaction, and almost 2/3 of all ground cracking occurred in sand.

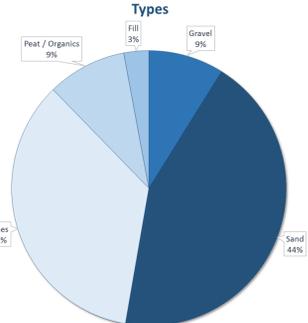
This analysis shows that both proximity to rivers and soil type play a strong role in the susceptibility of land to earthquake damage. There is much more room for study in this field to help ensure that catastrophes such as this can be predicted and avoided in the future.

Soil Types

Ground Cracking vs. Soil Types



Liquefaction and Lateral Spreading vs. Soil Types



Figures 9 & 10: Percentages of all ground cracking and liquefaction / lateral spreading within various soil types.

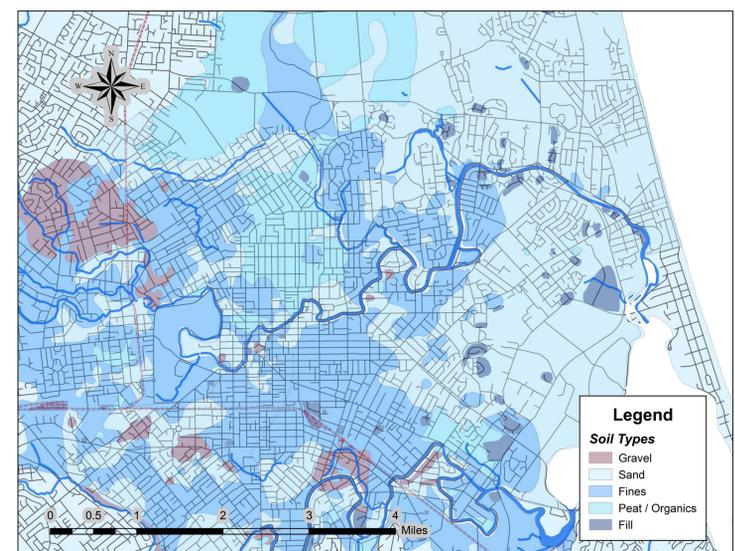


Figure 11: Geologic map of soil types present in Greater Christchurch.

References

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|--|---|
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