

# AQUALINC



## Potential Earthquake Impacts on Groundwater Quality

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GROUNDWATER

IRRIGATION

RESOURCE CONSENTS

FARM ENVIRONMENT PLANS

EFFLUENT MANAGEMENT

WATER MANAGEMENT

1 October 2018

# Outline

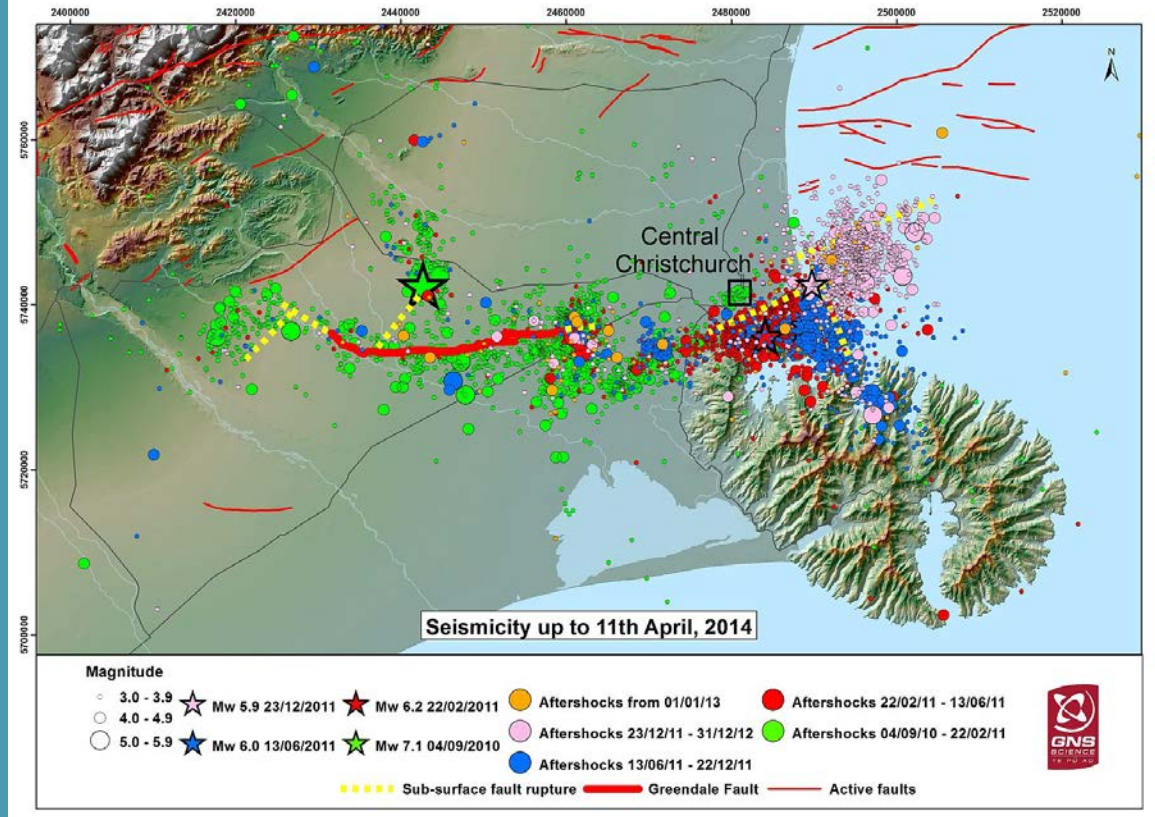


- Background to the areas and earthquakes
- Evidence for increased hydraulic connection between layers
- Evidence for increased transport between aquifers
  - Coliforms
  - Nitrate
  - Chemistry
  - Turbidity
  - Temperature
- Variability in observations
- Discussion and conclusions

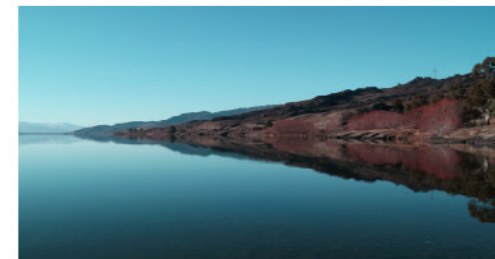
# Background to the earthquakes



- Darfield/Christchurch
  - September 2010/February 2011
  - Initial Mw7.1 along Greendale Fault
  - Observed:
    - Turbid groundwater
    - Increases in GWL
    - Coliform detections
    - Some changes in chemistry

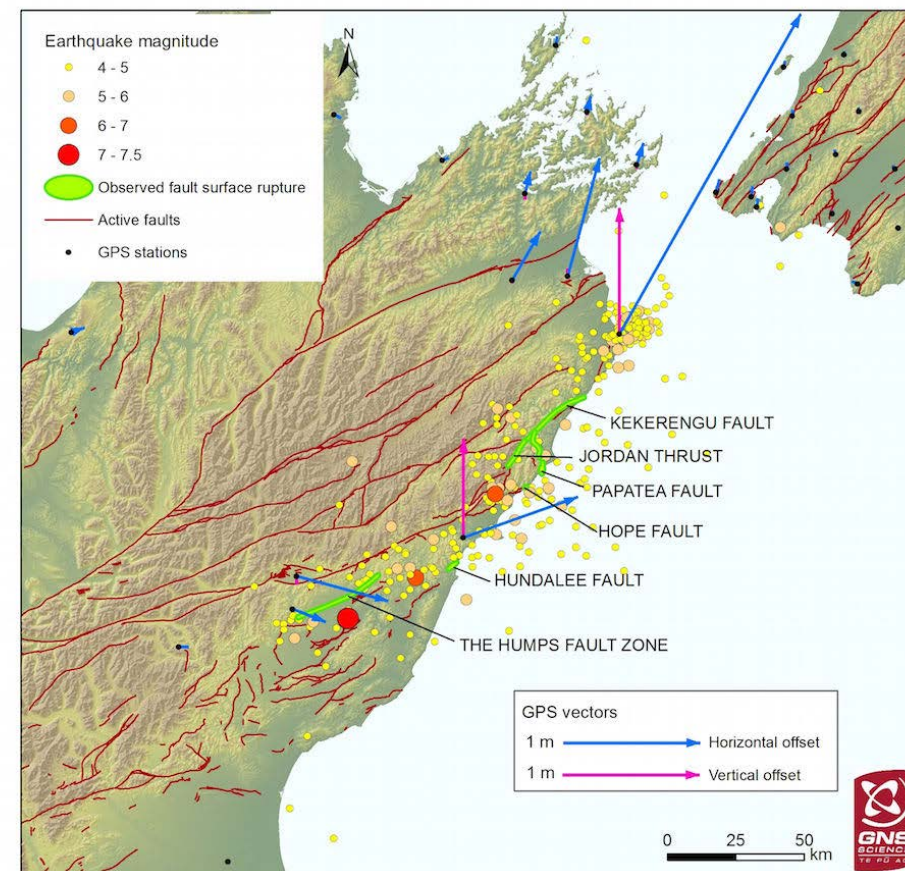


# Background to the earthquakes



- Kaikōura

- 7.8 Mw November 2016
- Complex rupture along 21 faults
- Energy propagated north – 180km zone
- Observed (across NZ):
  - Turbid groundwater
  - Changes in GWL
  - Coliform detections



# Variability of responses observed

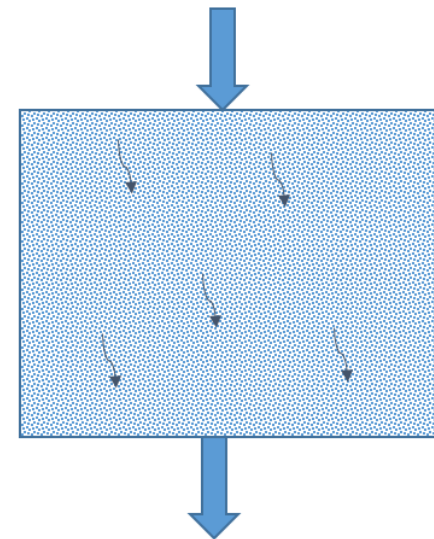


- Responses observed are variable
- Some are sustained, some temporary
- Changes in chemistry highly variable between bores
- Likely often driven by local conditions
  
- Highlight some of the responses that can occur following seismic events

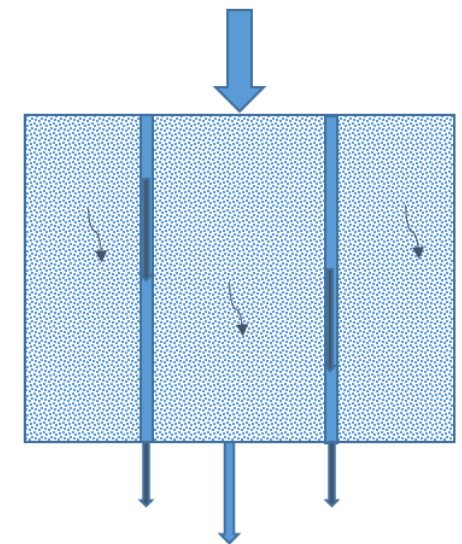
# Evidence for increased hydraulic connection between layers



- Hydraulic response may suggest increased connection
- Does this mean transport?



Piston flow – rapid hydraulic response, slow transport

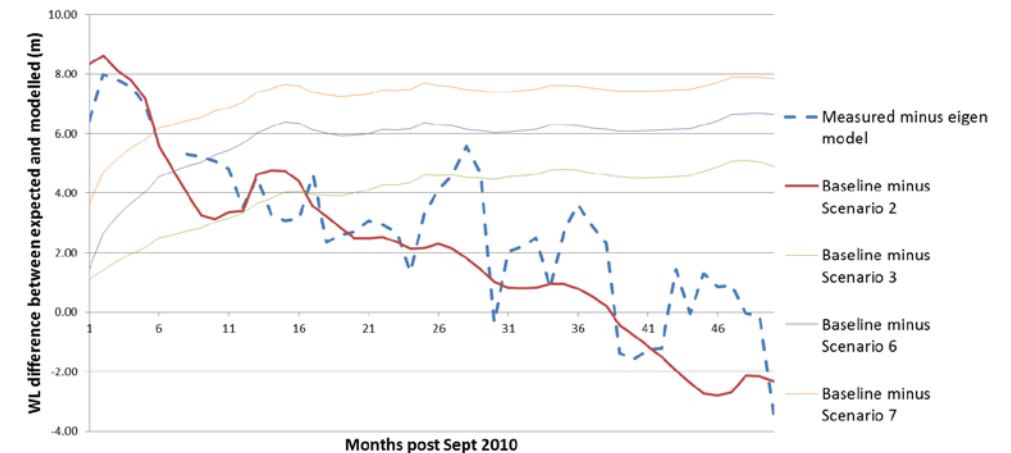
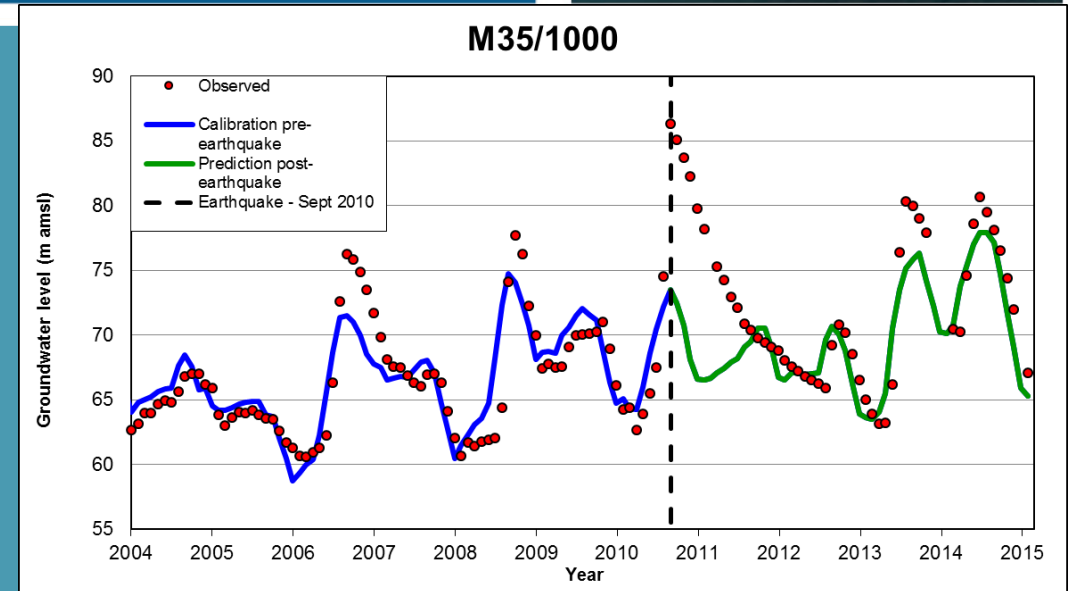


Bypass flow – rapid hydraulic response, rapid transport

# Modelling



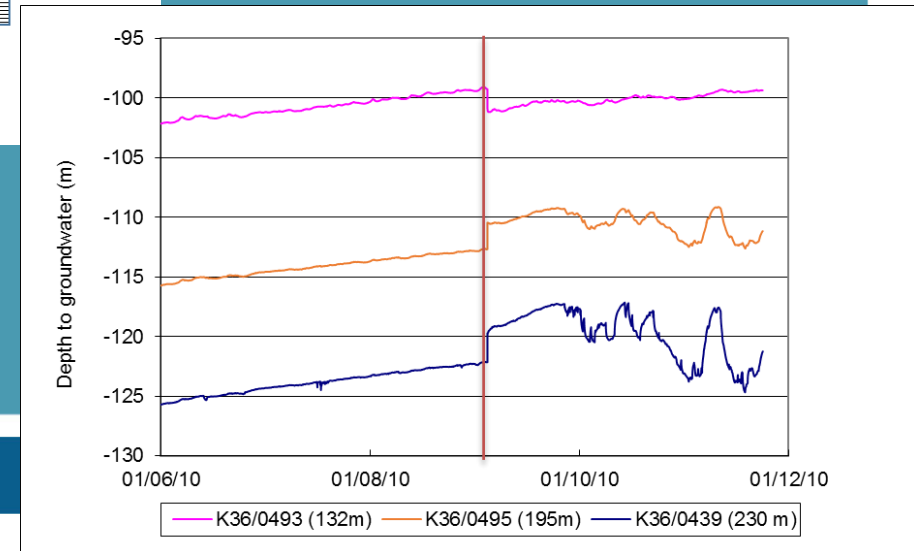
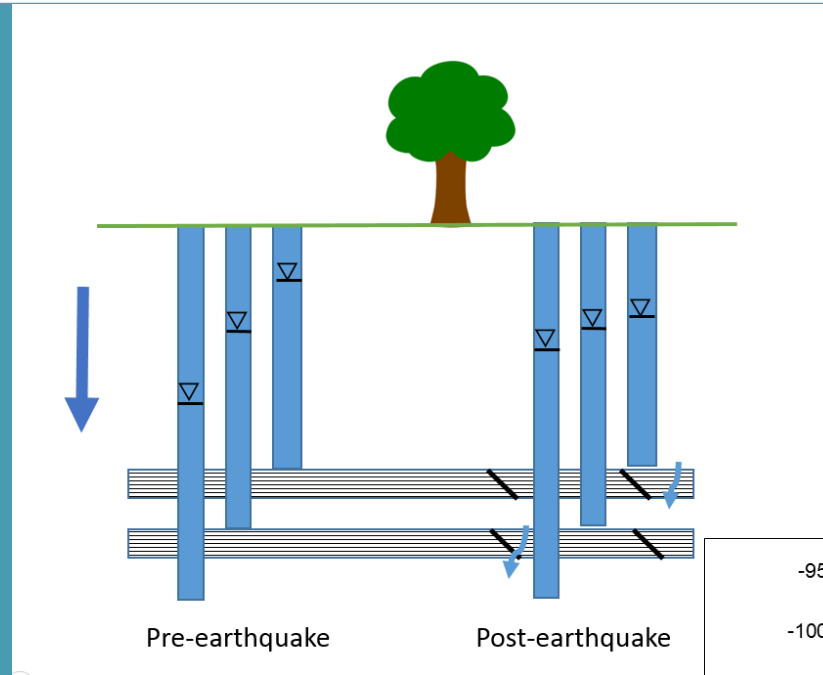
- Increased groundwater levels following the September 2010 EQ
  - Not related to climate or abstraction
  - At eastern end of fault, peak followed by 18 months recession
  - Modelling suggested most likely caused by increase in vertical leakage



# Changes in relative levels between piezometers



- Multi-level piezometers
  - Water level monitoring at same location
  - Different depths
- Groundwater levels converged post-earthquake

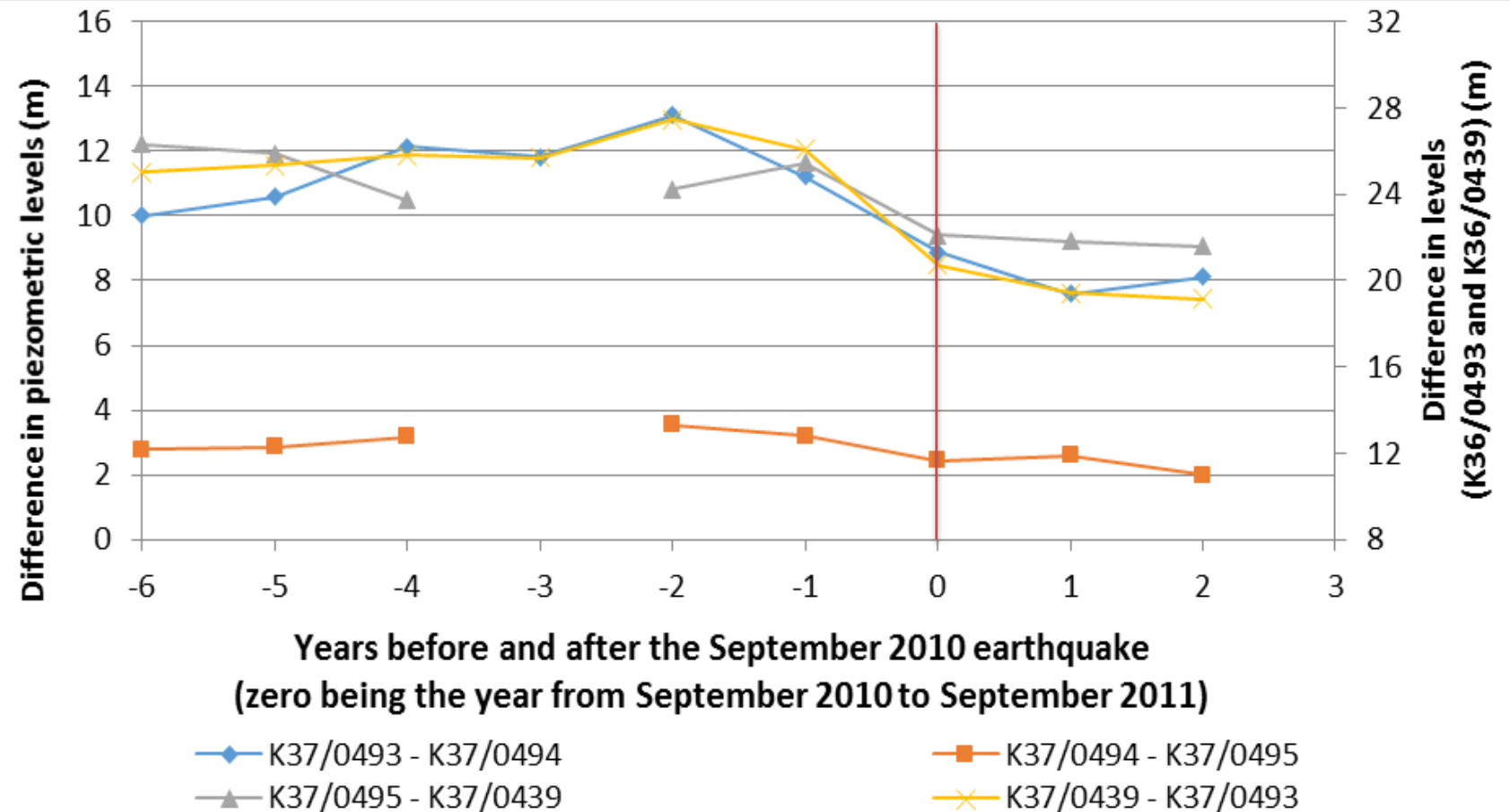




# Continued increased connection



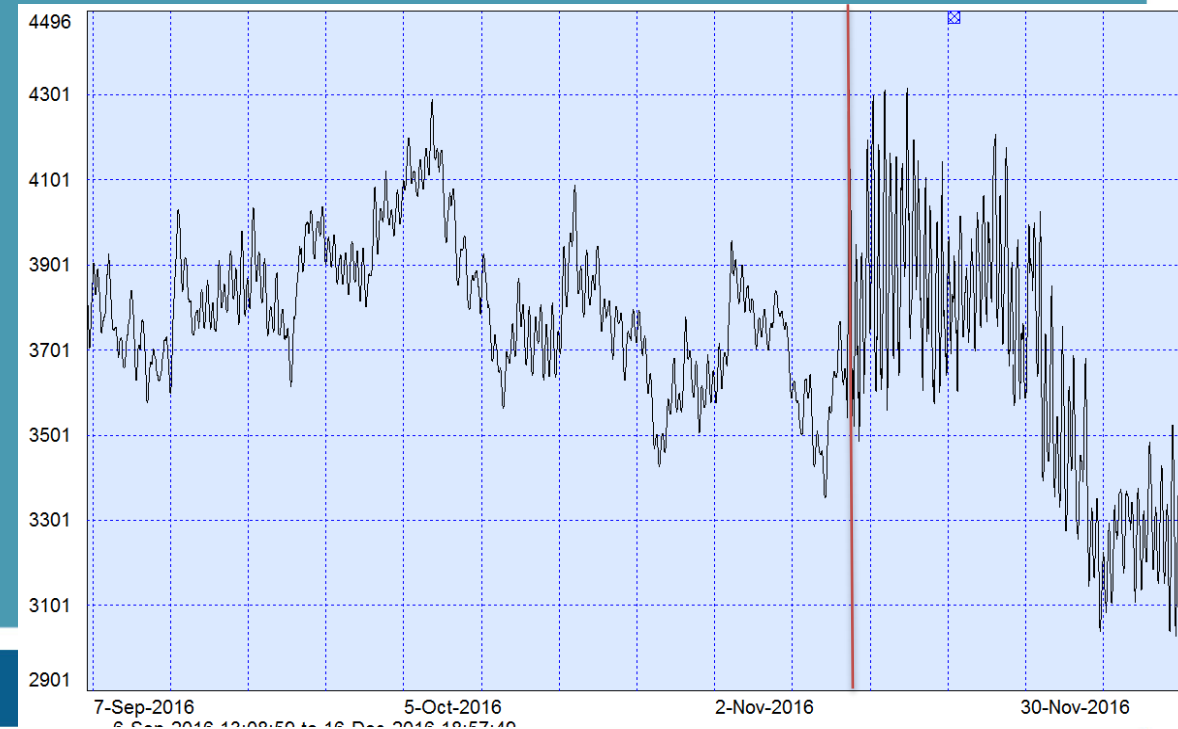
- Evidence that the increased connection is sustained



# Changing tidal responses



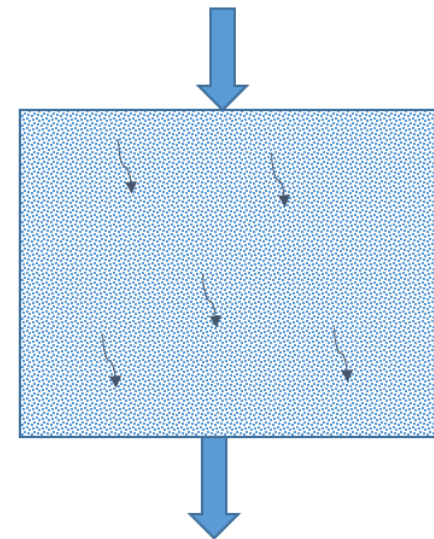
- In Lower Hutt, artesian Waiwhetu Gravels overlain by Taita Alluvium
- Strong tidal signal in Waiwhetu Gravels
- More muted in Taita Alluvium
- Post-Kaikoura EQ, response in Taita Alluvium changed
- Closer hydraulic connection between aquifers?



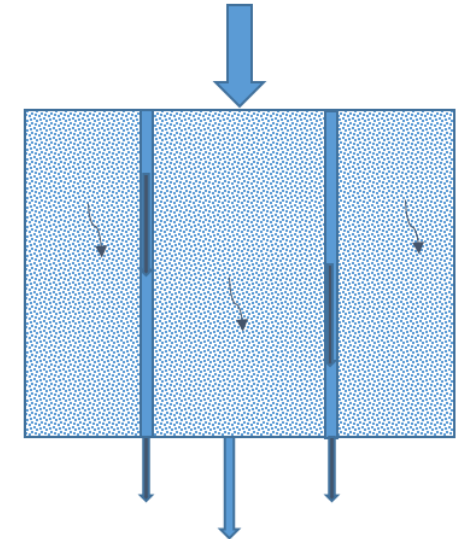
# Evidence for transport through new pathways



- Established that hydraulic responses can occur
- Looking for evidence of contaminant pathways developing
- Possible pathways
  - Discontinuities in aquitard or low permeability layers
  - Discontinuities developed by movement of bore casing – broken seal?
  - Broken casing/infrastructure
- Various indicators of transport



Piston flow – rapid hydraulic response, slow transport

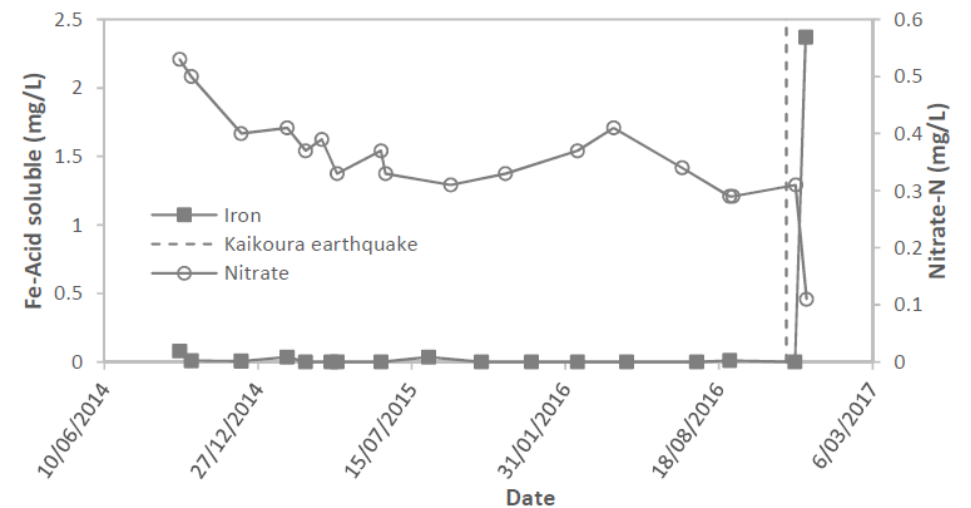


Bypass flow – rapid hydraulic response, rapid transport

# Changes in water chemistry



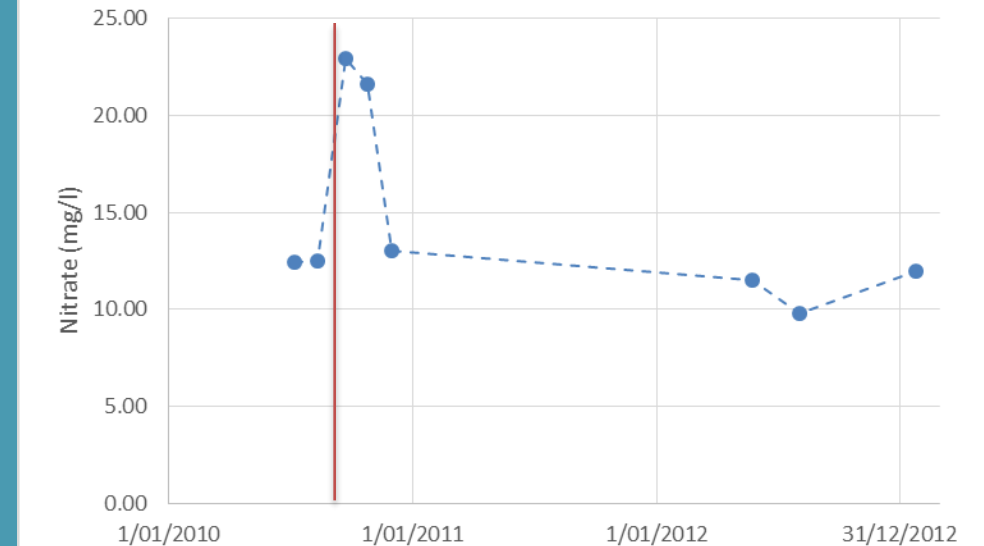
- Minor changes in chemistry recorded
  - Fe, Mn, Ca, Mg, Na, NO<sub>3</sub>
- No pattern spatially, with depth, or (generally) in terms of determinands affected
- Generally returned to normal ranges within a year in Canterbury
- Potential causes:
  - Erosion of clast coatings
  - Movement of water from the surface or near-surface
  - Fe from coatings on bore casing



# Changes in nitrate concentrations



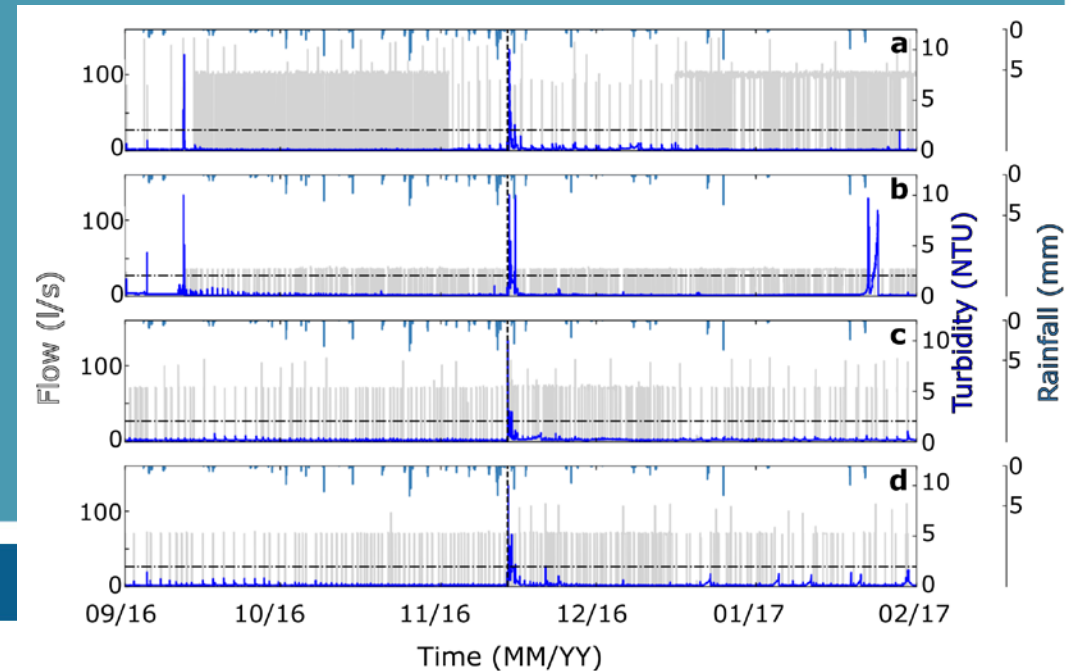
- Occurred in some bores
- Sampling of shallow bores across mid-Canterbury Plains in 2010
  - Coincided with Canterbury EQ
- Increased  $\text{NO}_3$  in intermediate-depth bore (48m) (L36/2304) following the September 2010 Darfield EQ
- Spike then return to background levels within months
- Also E.coli detections associated with peak in nitrates



# Changes in turbidity



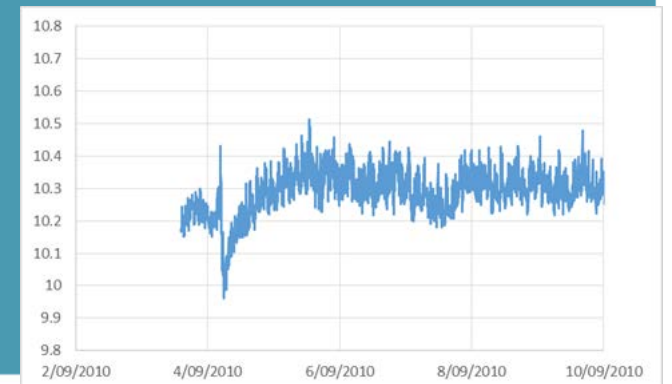
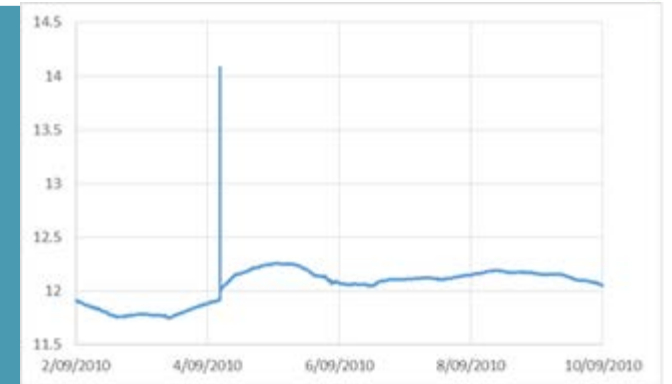
- Widespread consequence following seismic activity
  - Four Marlborough wells monitored on a continuous basis
  - Marked increase in turbidity
  - More rapid decline in post-EQ measurements
  - Possible re-sorting of the sediments
- High turbidity in Wellington bores accompanied by high total coliforms
  - Possible ingress of surface water
  - Possible inflow through cracks in well casing



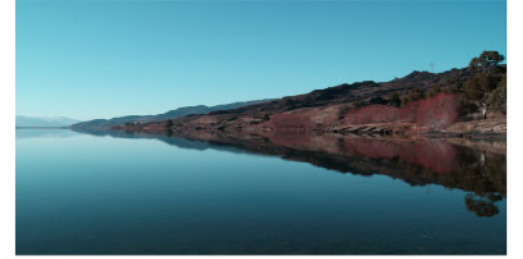
# Changes in temperature



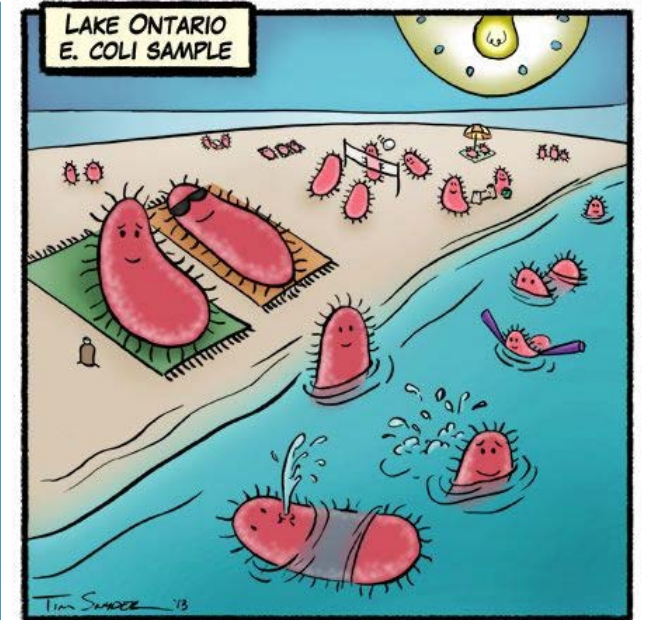
- Temperature changes recorded in Canterbury
- Up to 2 – 3°C
- Ranges of responses
  - Spikes, offsets, gradual changes
- Possible evidence for water sourced from the surface or changed flow paths



# Changes in coliform detections



- E. coli indicator organism
  - Used to detect possible faecal contamination
- Total coliforms
  - May or may not indicate faecal contamination
  - Also associated with plant/soil material, biofilms
- Evidence that soil or surface bacteria have entered groundwater





# Changes in coliform detections

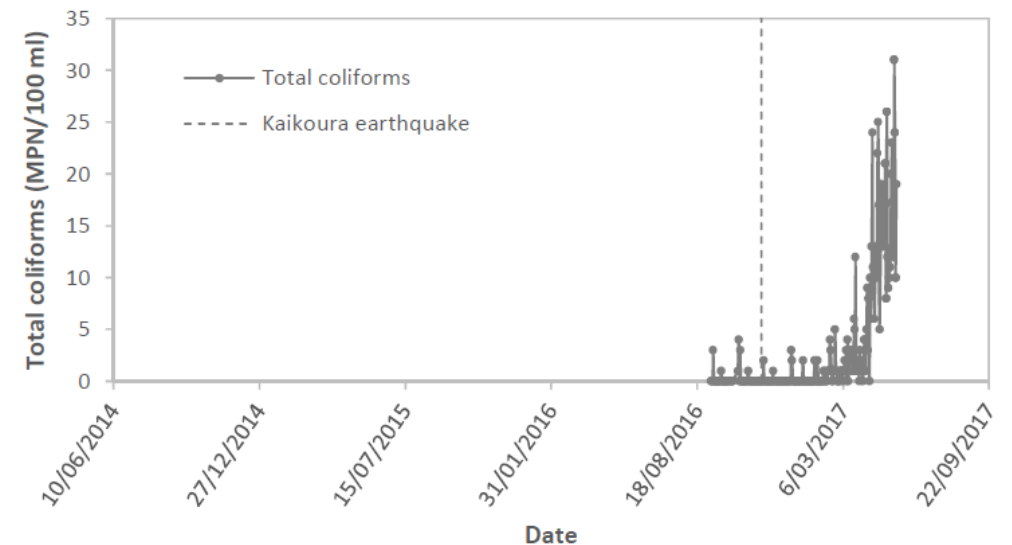


- Testing after February 2011 Christchurch EQ
  - 2503 samples
  - 21 +ve for E. coli
  - 192 +ve for total coliforms
- Most positive detections occurred in first four weeks after 2011 February EQ
- Source inconclusive
  - Damaged pipes or well casing?
  - Less likely contamination of the aquifer

# Changes in coliform detections



- Waterloo Wellfield
  - Testing after November 2016 Kaikōura EQ
  - Marked increases in total coliforms at the Waterloo wellfield
- In some cases high total coliforms associated with high turbidity
- In September 2017 (10 months post-EQ), still increasing
- Suggested due to either
  - Damage to infrastructure
  - Water moving through discrete pathways from the surface



# Discussion



- Evidence for increased connection between aquifers as result of earthquakes
  - Changes in water chemistry, microbes, temperature, turbidity, groundwater levels
- From groundwater level data, no evidence of the ‘healing’ of fractures suggested by Wang et al (2015)
- Chemistry/temperature data suggest effects are short-lived
- E Coli/total coliforms may be different
  - Short-lived effects in Canterbury
  - Longer terms consequences in Lower Hutt

# Discussion



- Causes
  - Enhanced pathways between surface and aquifer
  - Enhanced pathways between aquifers
  - Damage to infrastructure allowing enhanced pathways to develop
    - Damage to casing
    - Damage to bentonite seal
  - Damage to infrastructure, such as sewers
- Concerns
  - Human health
    - Microbiological
    - Nitrates
    - Potential for other surface contaminants to migrate

# Conclusions



- Enhanced leakage between aquifers, or between surface and aquifers, may occur following seismic events
- Generally impacts do not appear to be major
  - Do not occur consistently
- However, the potential for contaminant transport cannot be ignored
  - Potential for contamination should always be evaluated following major seismic events

Thank you



Questions?

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