# Earthquake Impacts in the Christchurch CBD

**Prof Jarg Pettinga & Dr Tom Wilson**

Dept. Of Geological Sciences

Thanks to Dr Matthew Hughes (UC), Professor Misko Cubrinovski (UC), Ian McCahon (Geotech Consultants) for additional material

# Overview of the Presentation

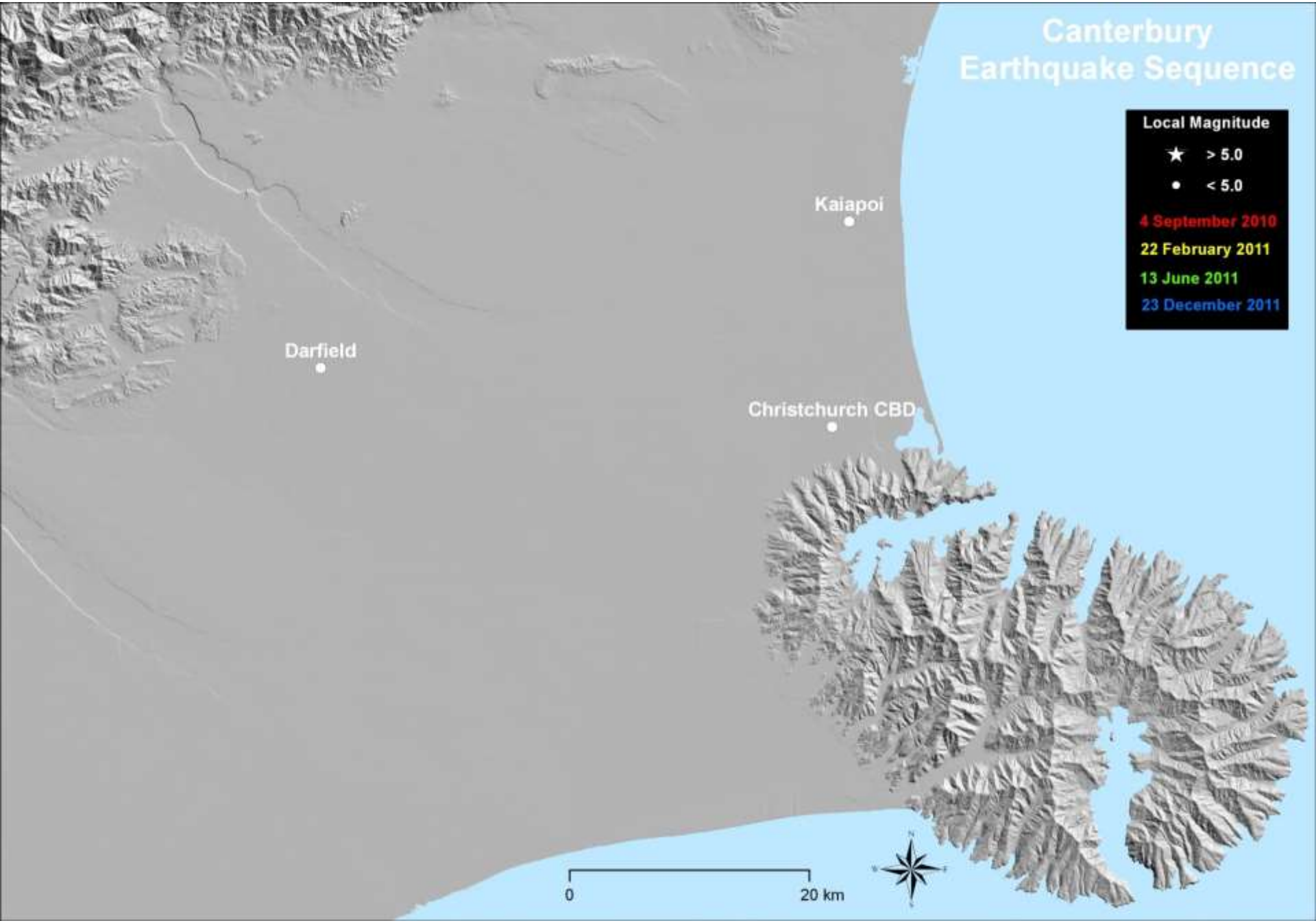
Jarg:

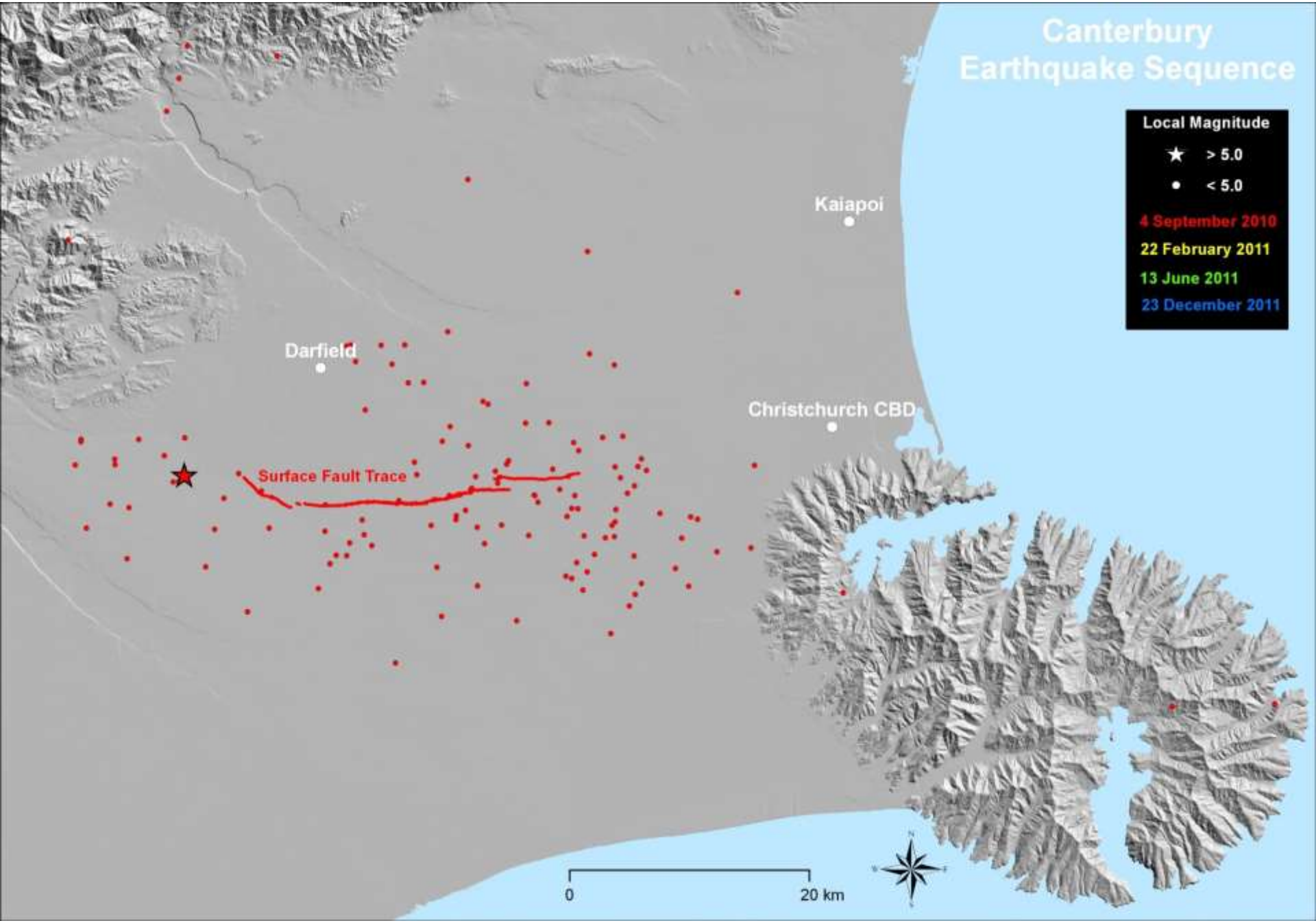
- The seismic context & liquefaction

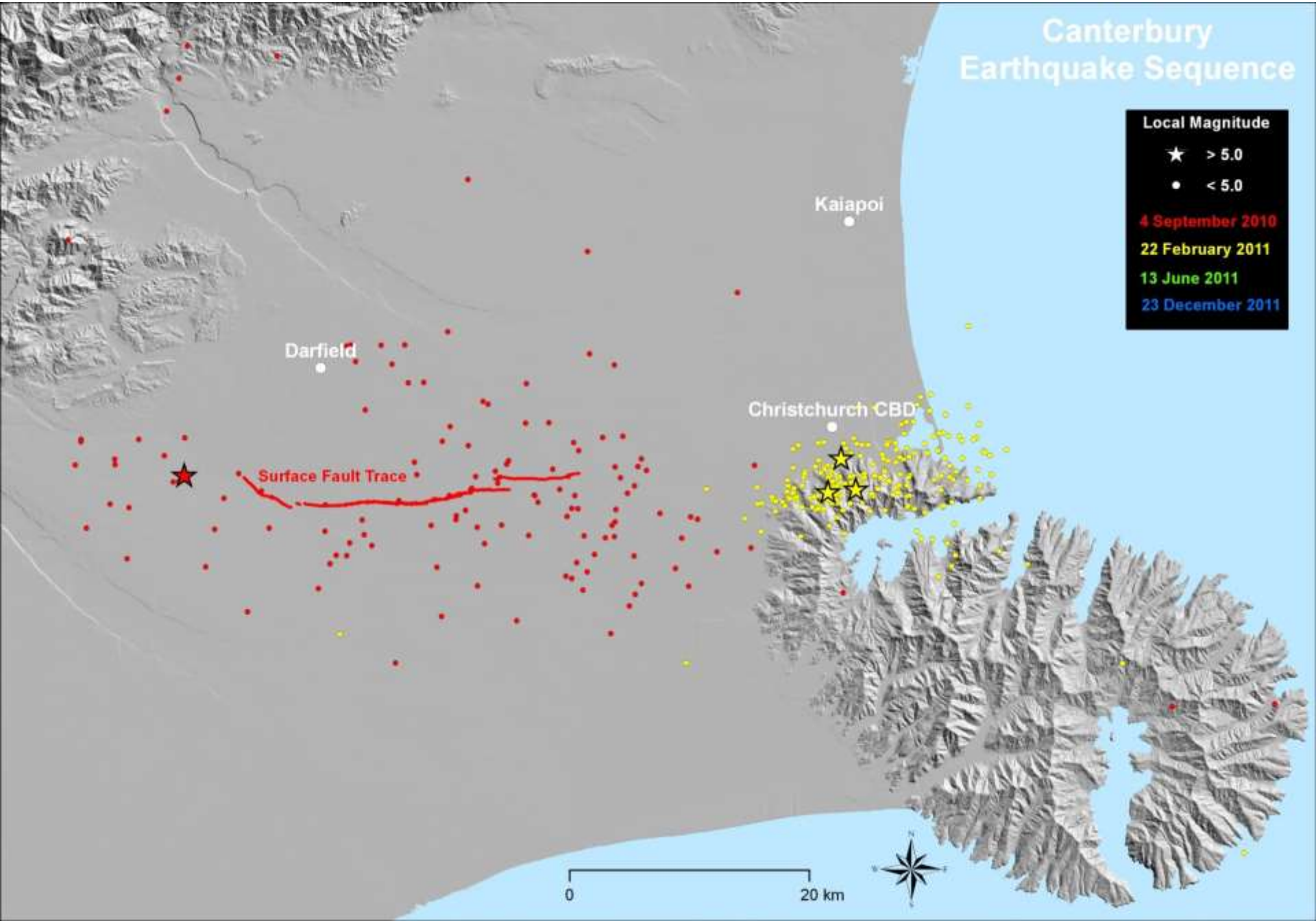
Tom:

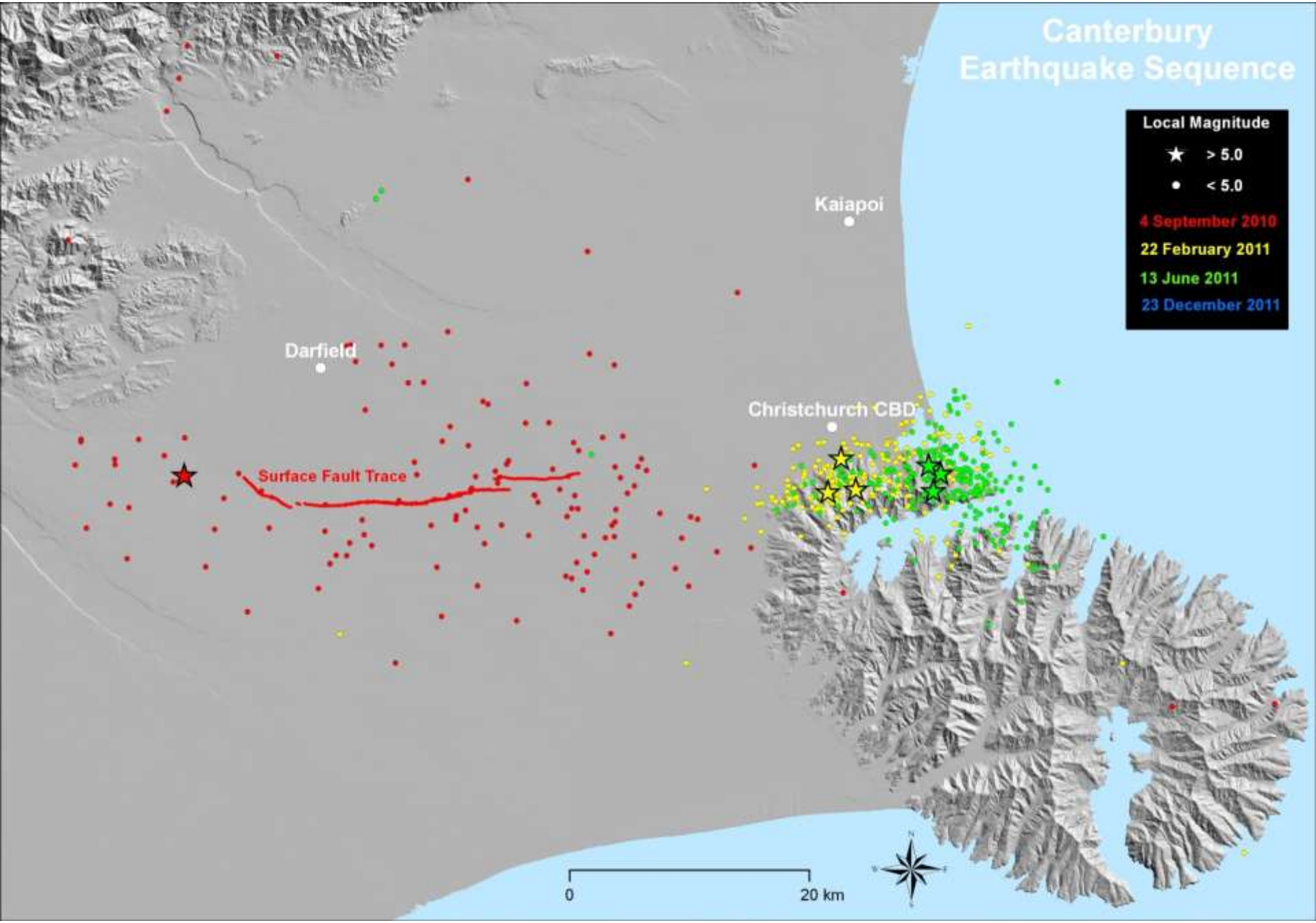
- Potable Water Supply
- Waste Water Network

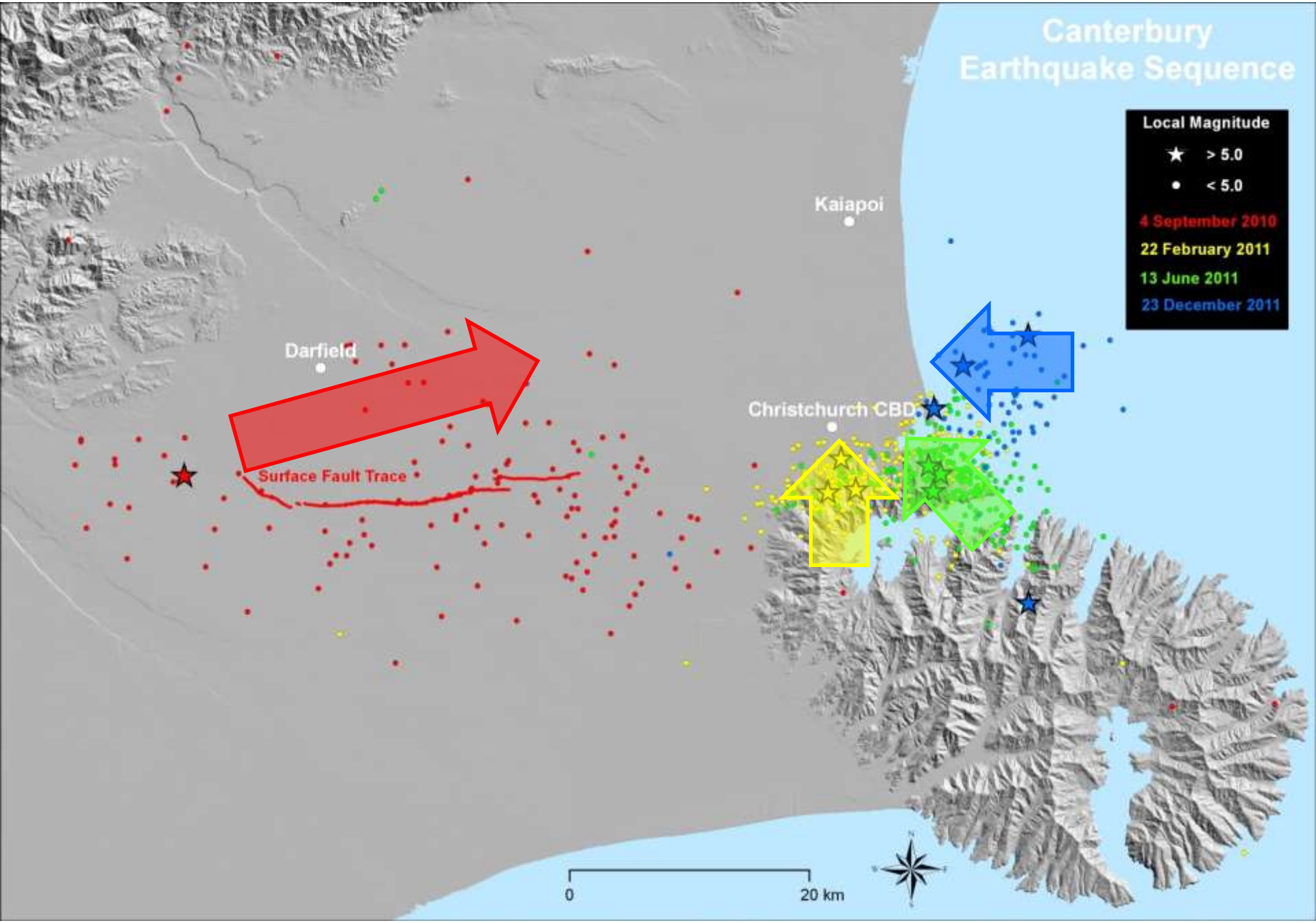
UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

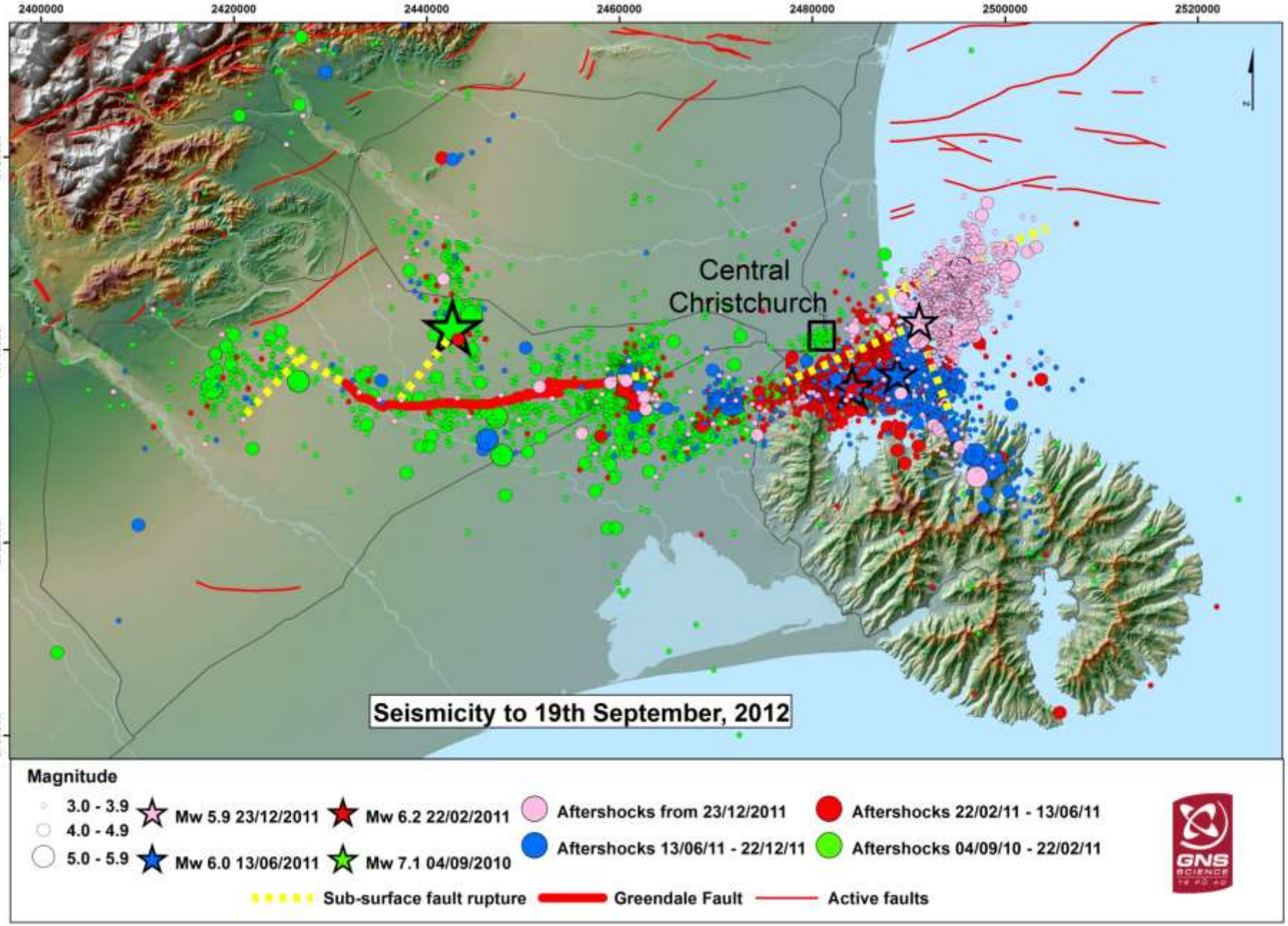

Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
0
20 km


Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
Surface Fault Trace
0
20 km

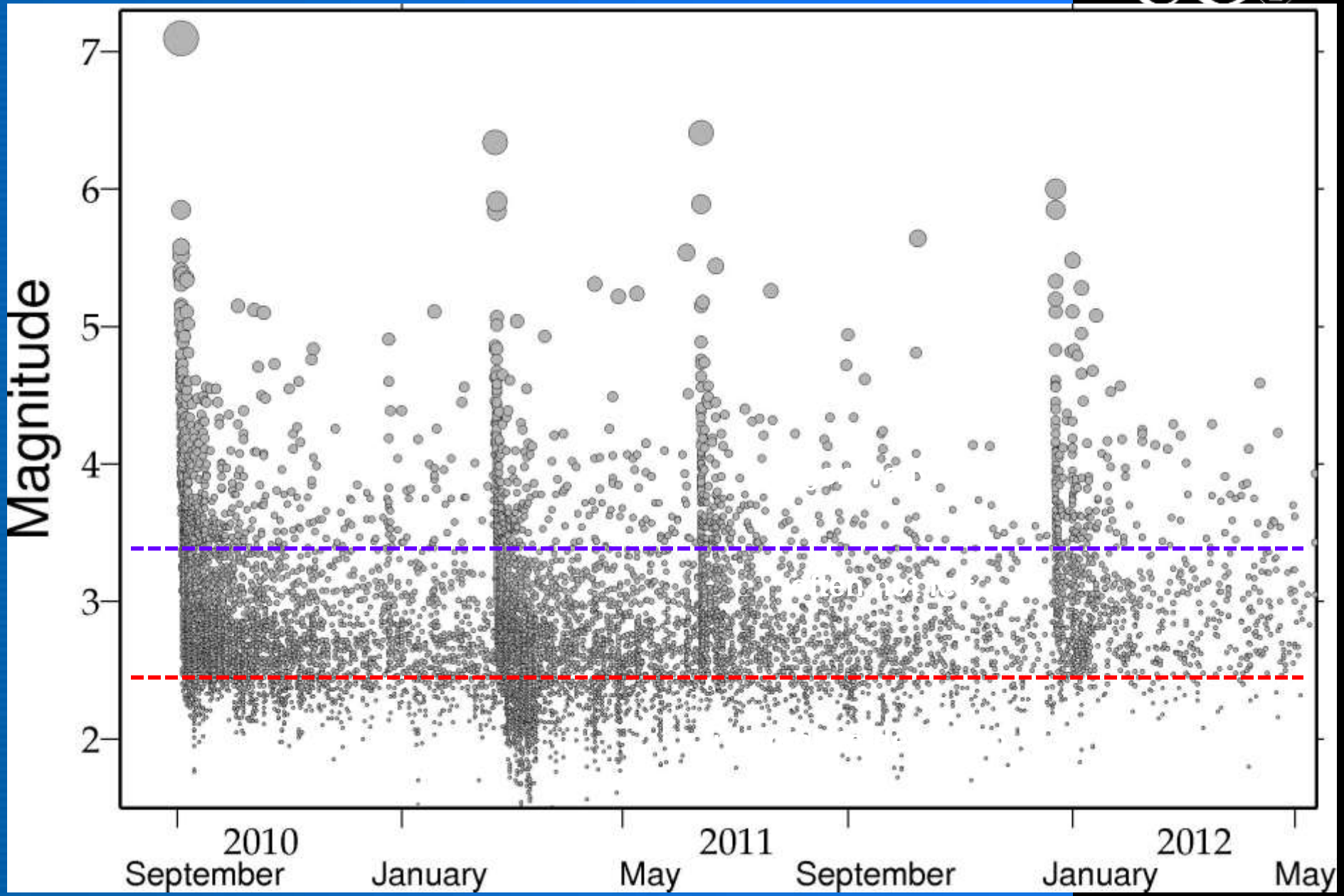

Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
Surface Fault Trace
0
20 km


Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
Surface Fault Trace
0
20 km


Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
Surface Fault Trace
0
20 km


2400000
2420000
2440000
2460000
2480000
2500000
2520000
5760000
5740000
5720000
5700000
Central
Christchurch
Seismicity to 19th September, 2012
Magnitude
3.0 - 3.9
4.0 - 4.9
5.0 - 5.9
Mw 5.9 23/12/2011
Mw 6.2 22/02/2011
Mw 6.0 13/06/2011
Mw 7.1 04/09/2010
Aftershocks from 23/12/2011
Aftershocks 22/02/11 - 13/06/11
Aftershocks 13/06/11 - 22/12/11
Aftershocks 04/09/10 - 22/02/11
Sub-surface fault rupture
Greendale Fault
Active faults
GNS SCIENCE

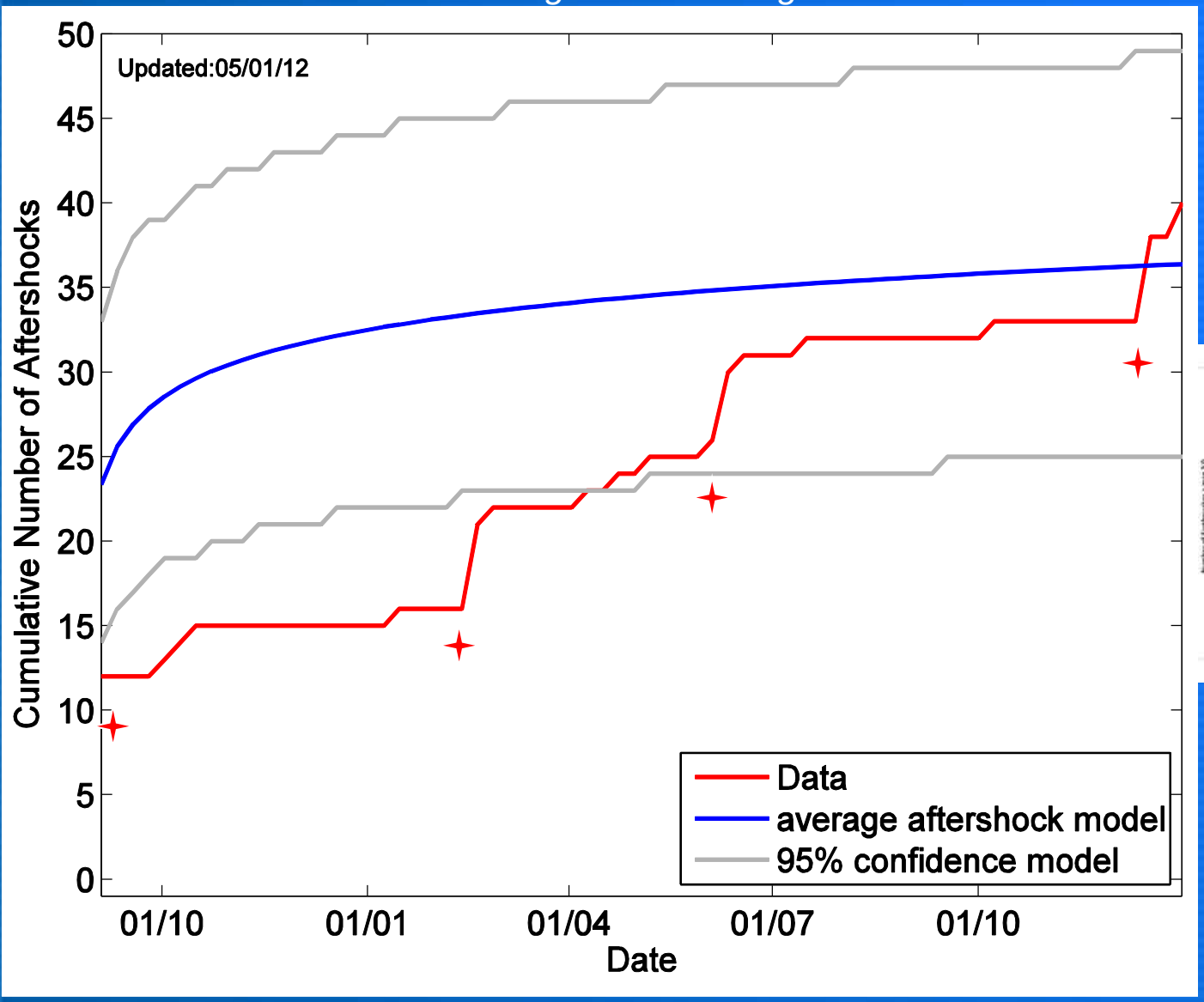
# Magnitude/Time plot of the earthquake sequenc



# Aftershock Decay Sequence for Canterbury

*- Magnitude 3 and greater*

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND



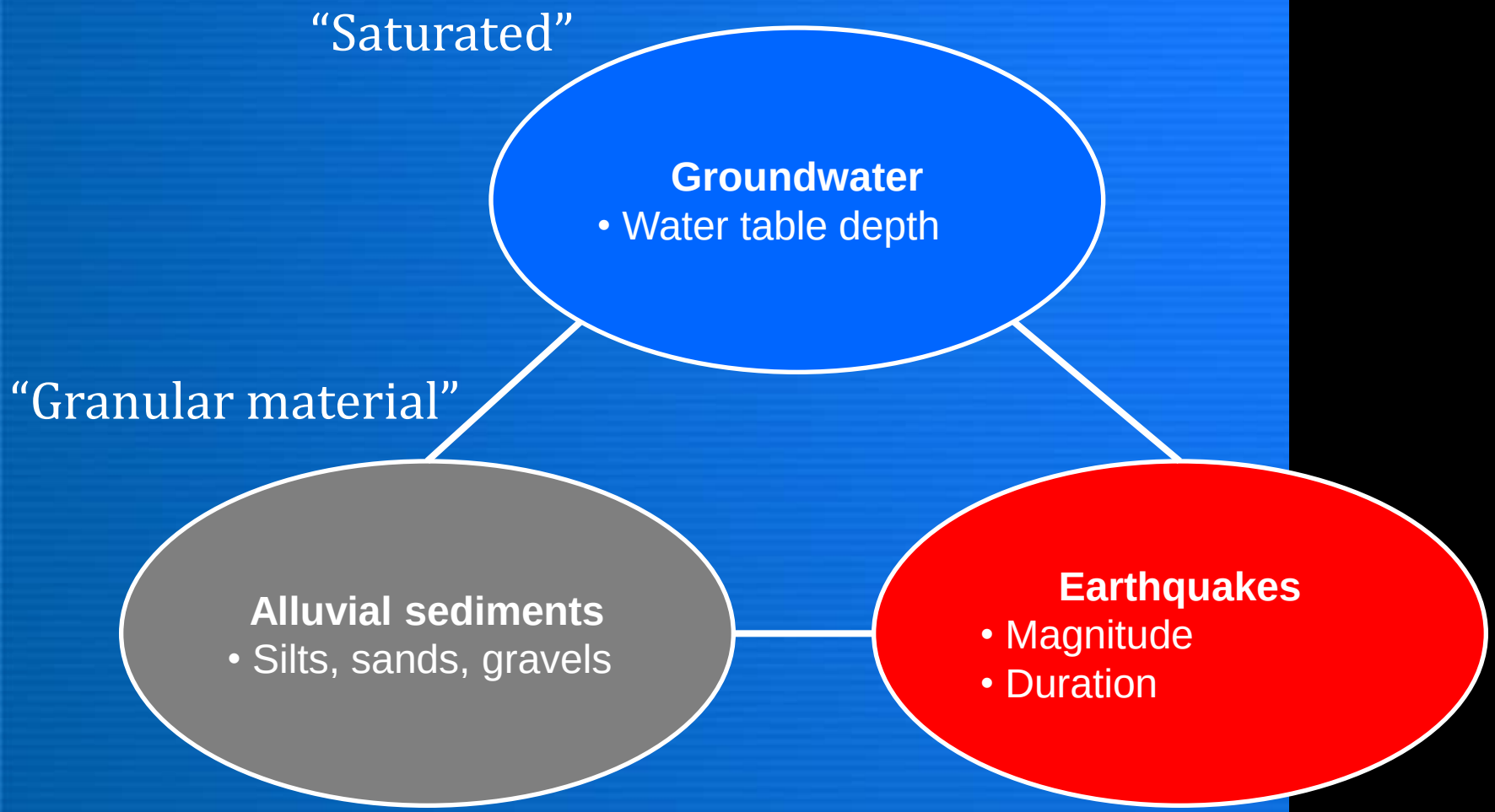


*Source: www.geonet.org.nz*

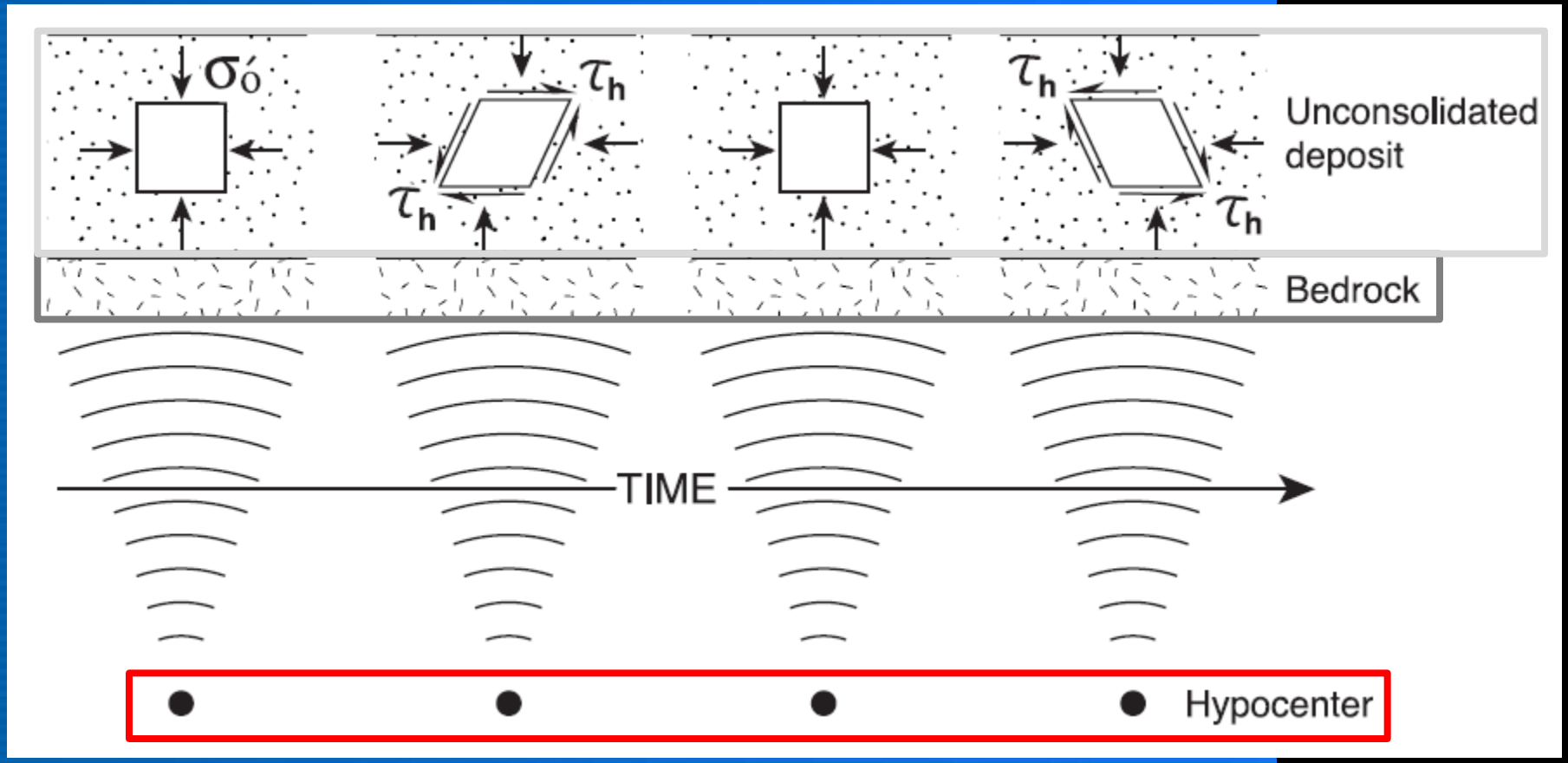
Graph depicts the significant effect of the February, June and December 2011 earthquakes re-energising the Darfield aftershock sequence (Source: GNS Science).

# Liquefaction

"Transformation of a saturated granular material from a solid to a liquefied state"

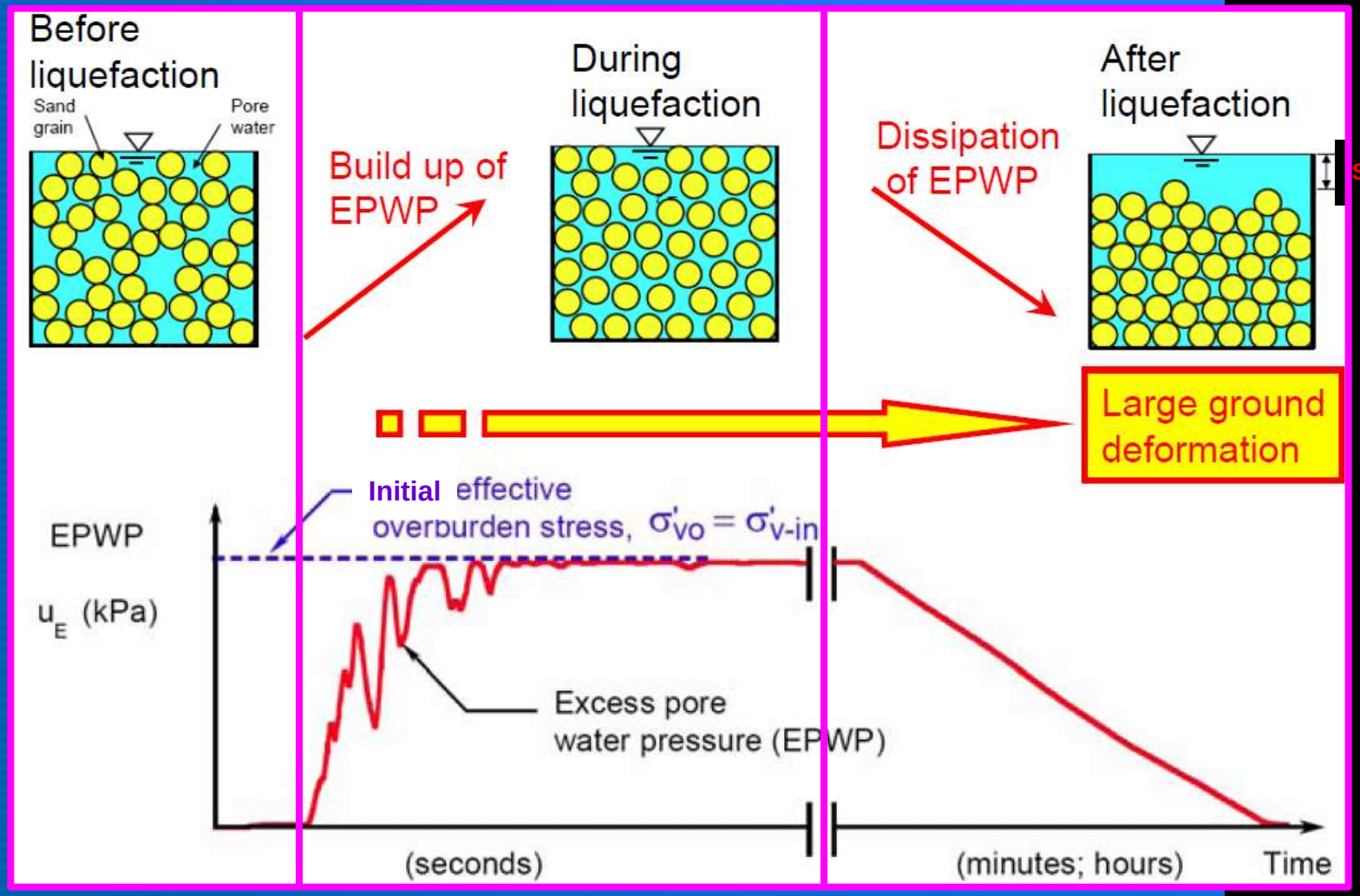


# Liquefaction



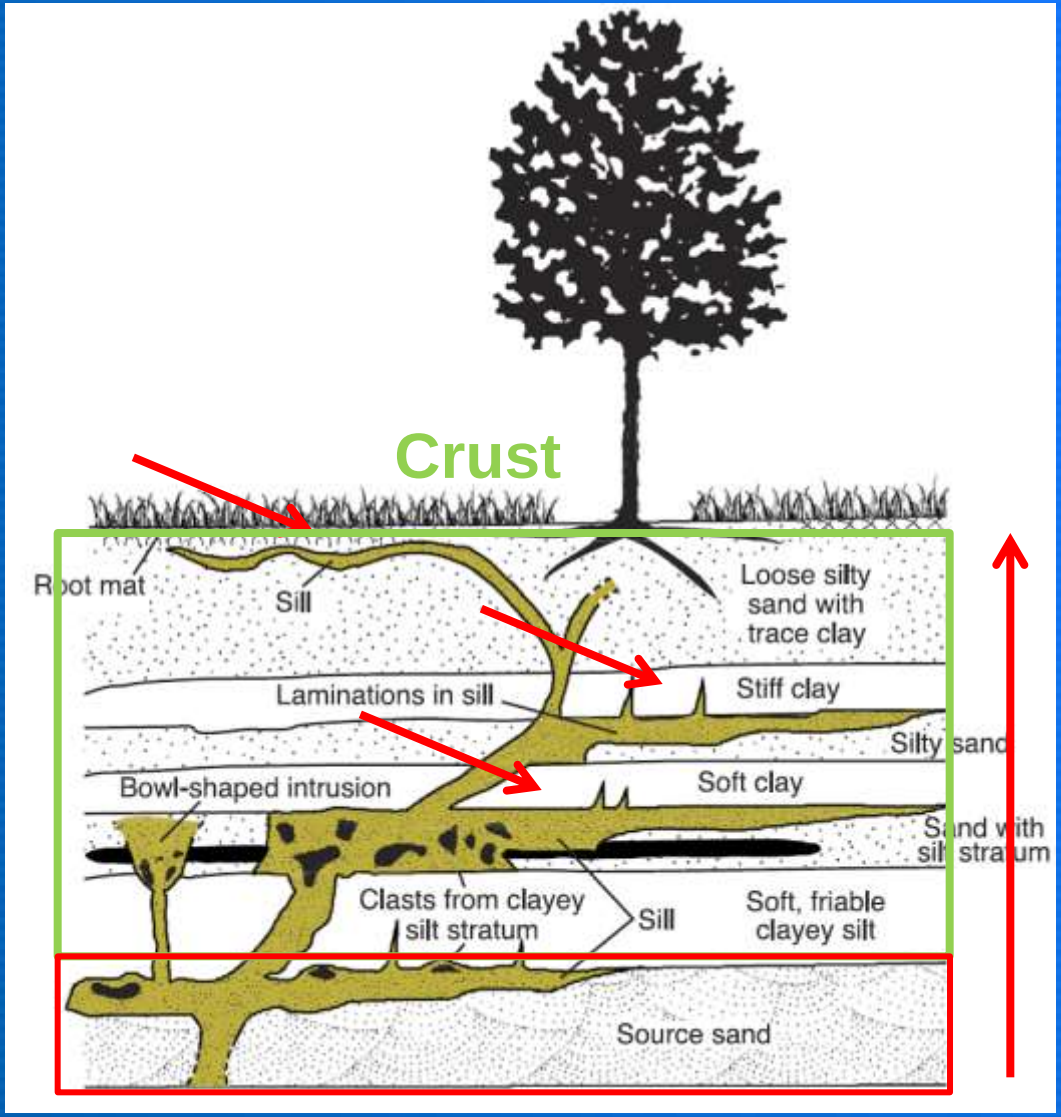

Obermeier et al. (2005). Field occurrences of liquefaction-induced features: a primer for engineering geologic analysis of paleoseismic shaking. Engineering Geology 76, 209–234.

# Liquefaction



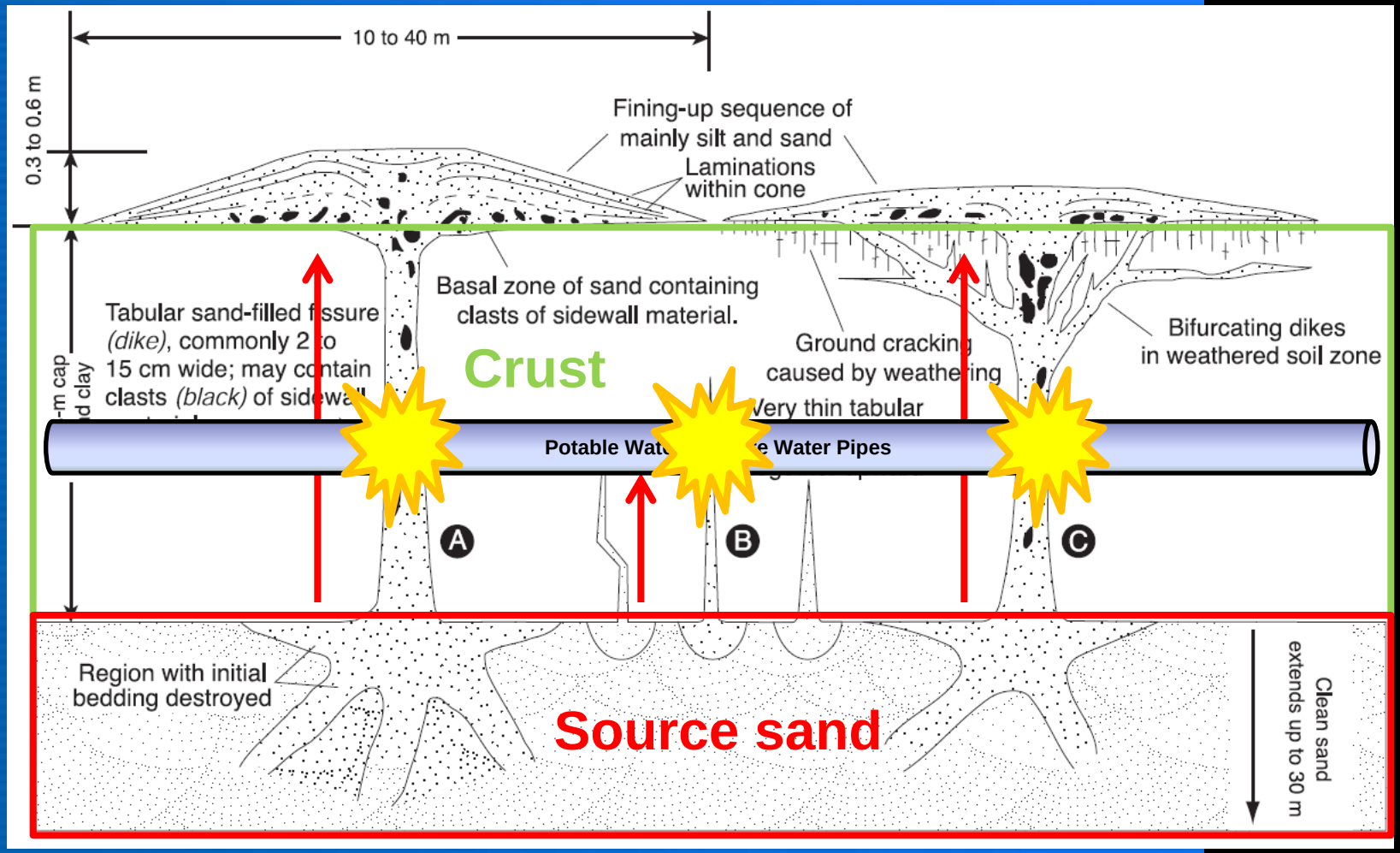

Courtesy Misko Cubrinovski

# Liquefaction

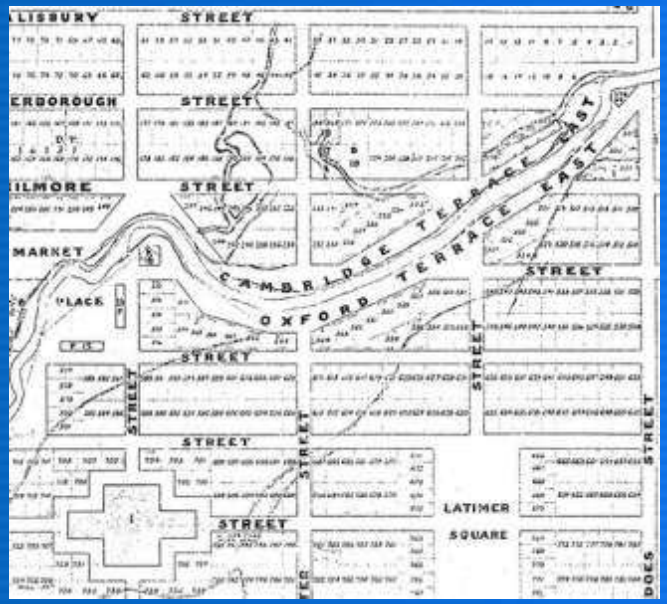



Obermeier et al. (2005). Field occurrences of liquefaction-induced features: a primer for engineering geologic analysis of paleoseismic shaking. Engineering Geology 76, 209–234.

# Liquefaction




Obermeier et al. (2005). Field occurrences of liquefaction-induced features: a primer for engineering geologic analysis of paleoseismic shaking. Engineering Geology 76, 209–234.




UC
UNIVERSITY OF
CANTERBURY
*Te Whare Wānanga o Waitaha*
CHRISTCHURCH NEW ZEALAND

Liquefaction – Christchurch East, June 2011

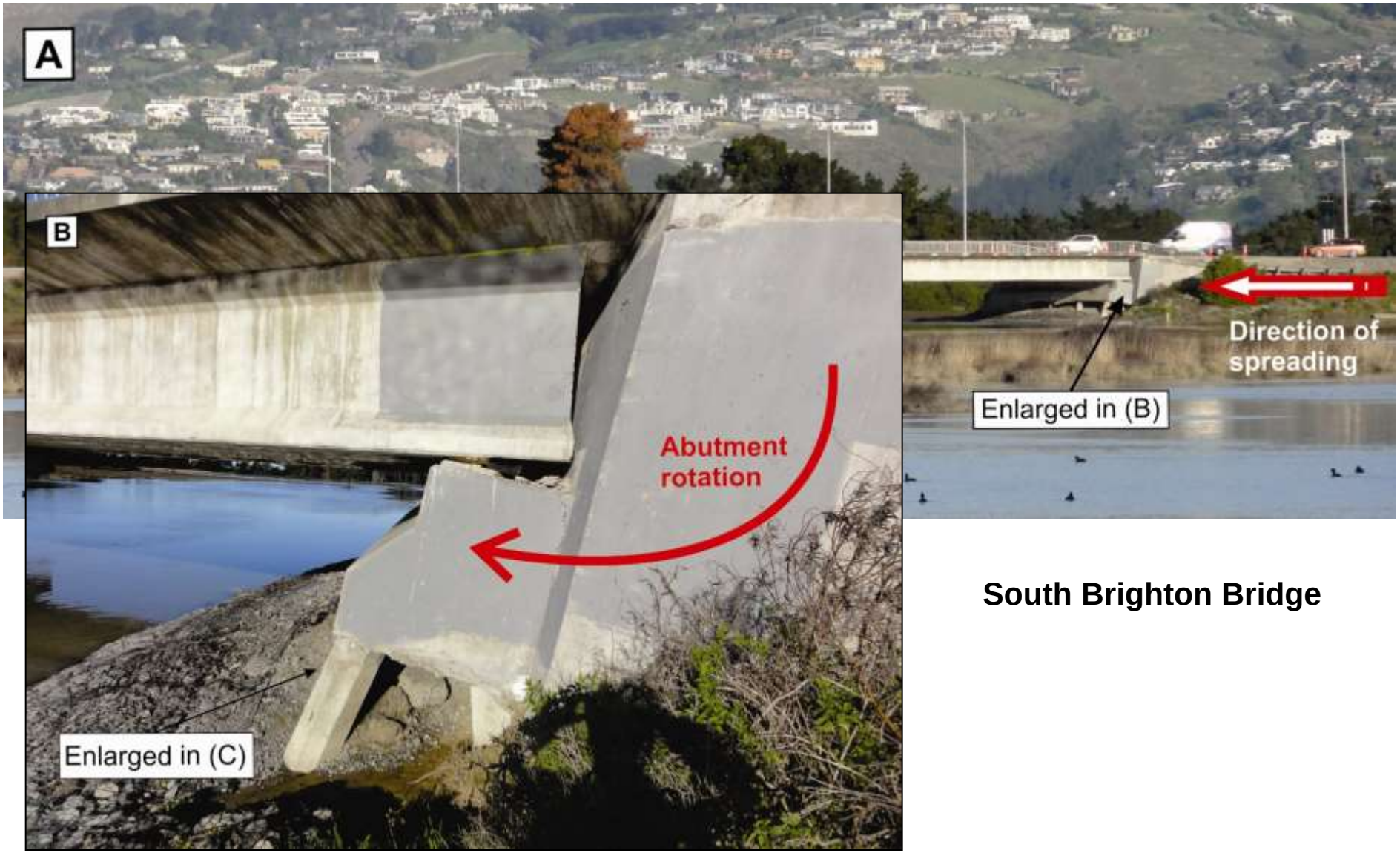
**Liquefaction – Christchurch East, June 2011**

**Liquefaction – Christchurch East, June 2011**

**Liquefaction – Christchurch East, June 2011 (Courtesy Merrick Taylor)**

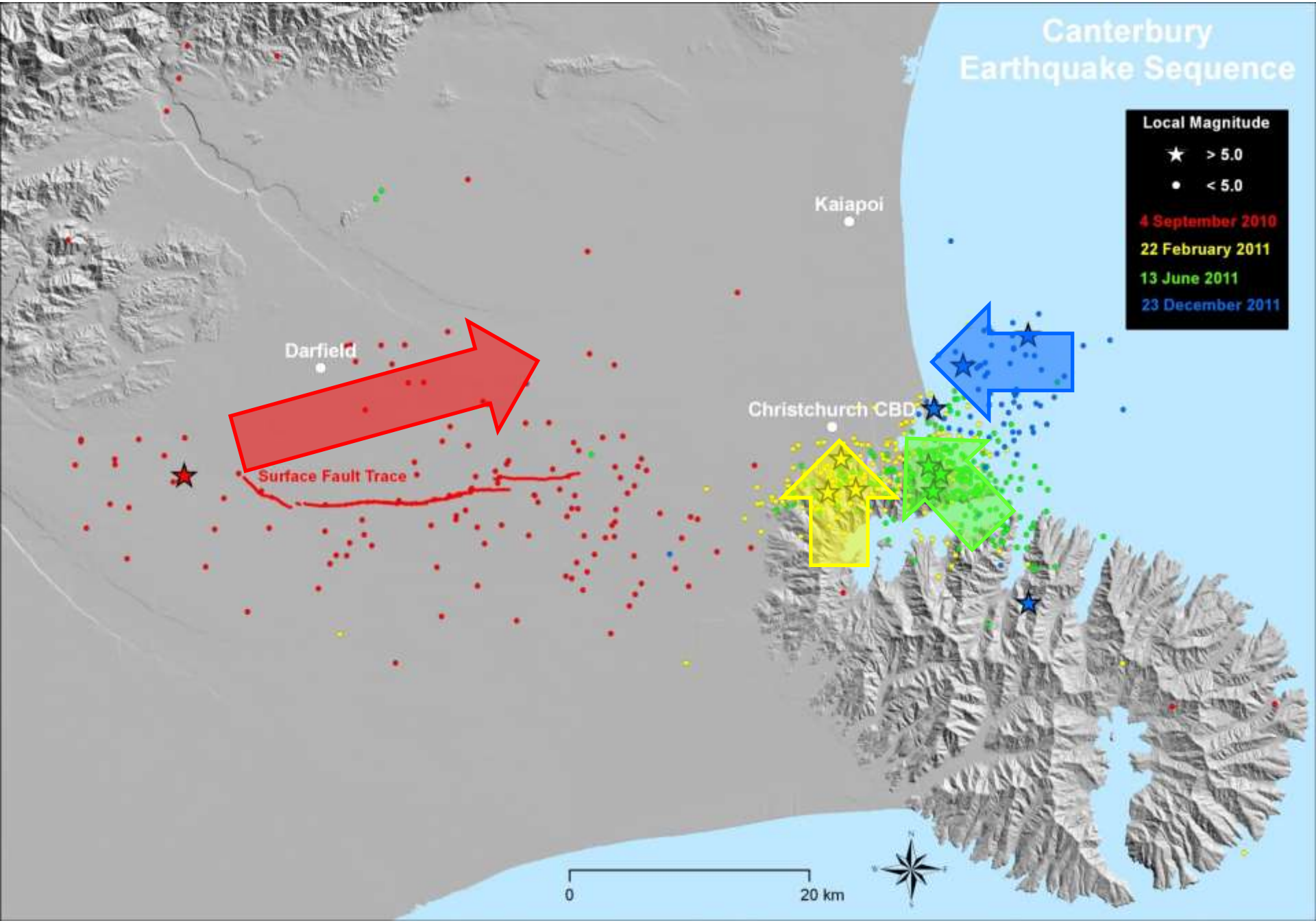

Lateral spreading – liquefaction-induced slumping of banks into rivers

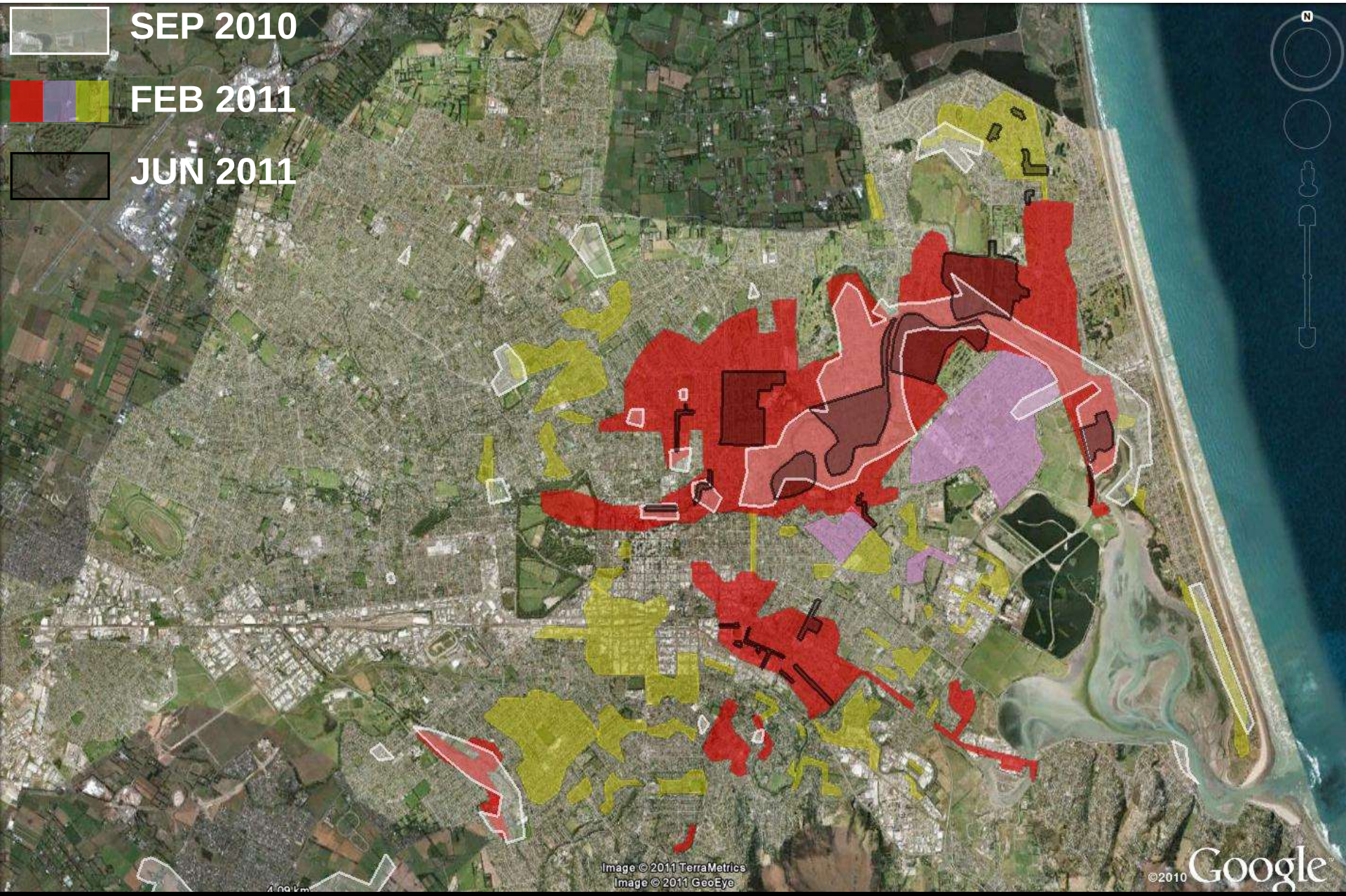
Cubrinovski et al. (2012). Lateral spreading and its impacts in urban areas in the 2010-2011 Christchurch earthquakes. *New Zealand Journal of Geology and Geophysics*.



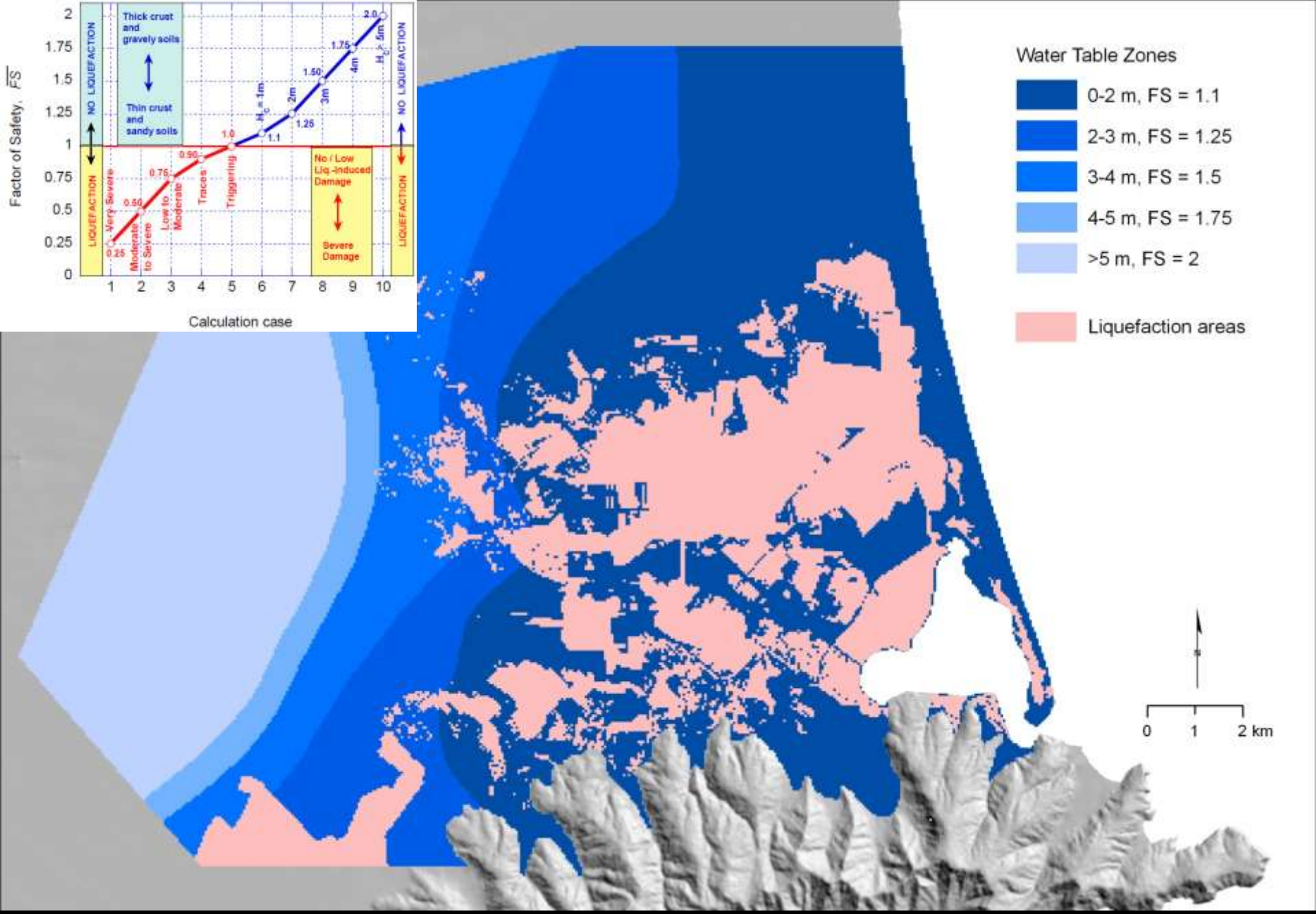

**South Brighton Bridge**

**Lateral spreading – liquefaction-induced slumping of banks into rivers**


Canterbury
Earthquake Sequence
Local Magnitude
> 5.0
< 5.0
4 September 2010
22 February 2011
13 June 2011
23 December 2011
Kaiapoi
Darfield
Christchurch CBD
Surface Fault Trace
0
20 km



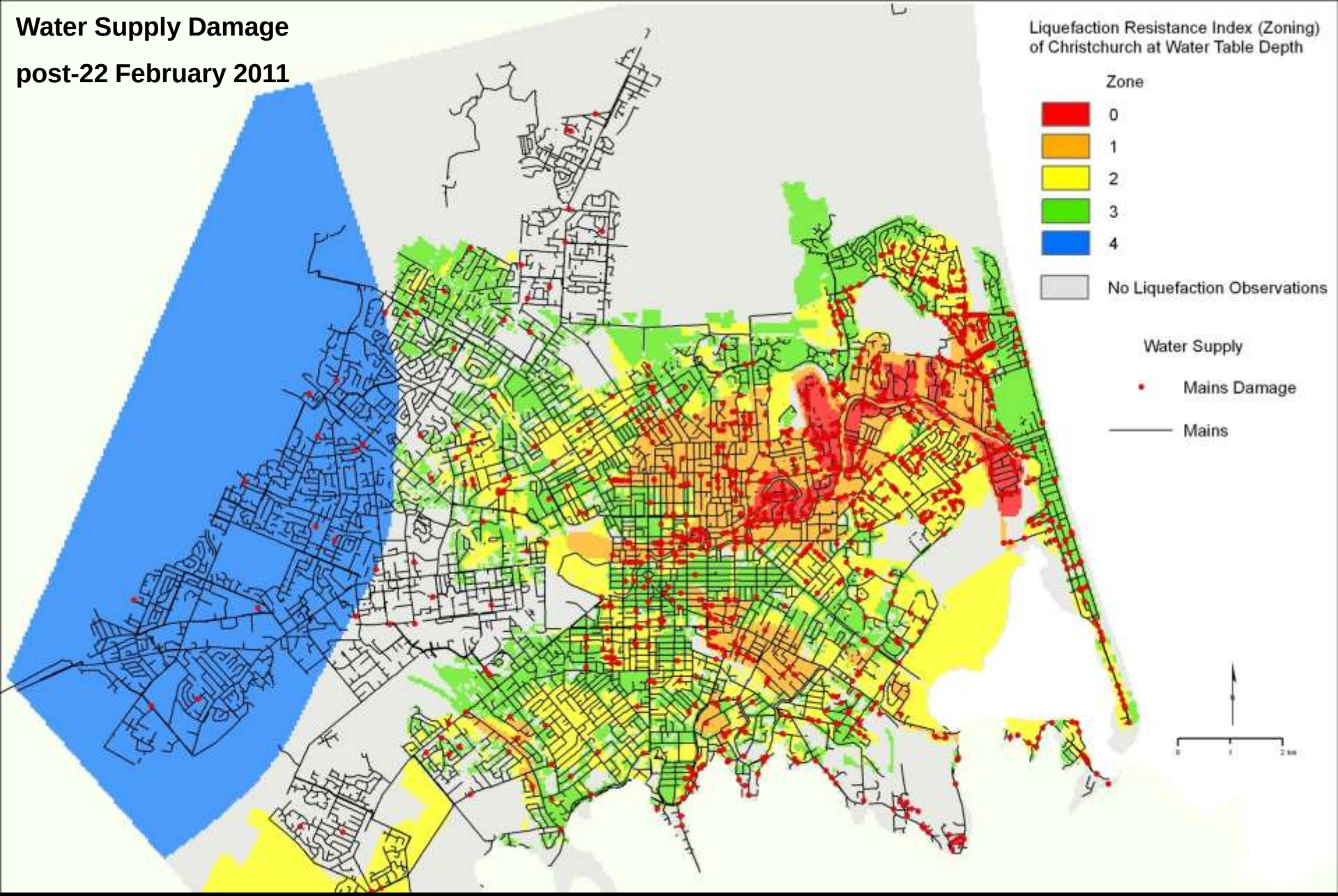

Mapped Liquefaction - University of Canterbury




**Water Table – Factor of Safety Against Liquefaction beyond areas of mapped liquefaction**

**Water Supply Damage**

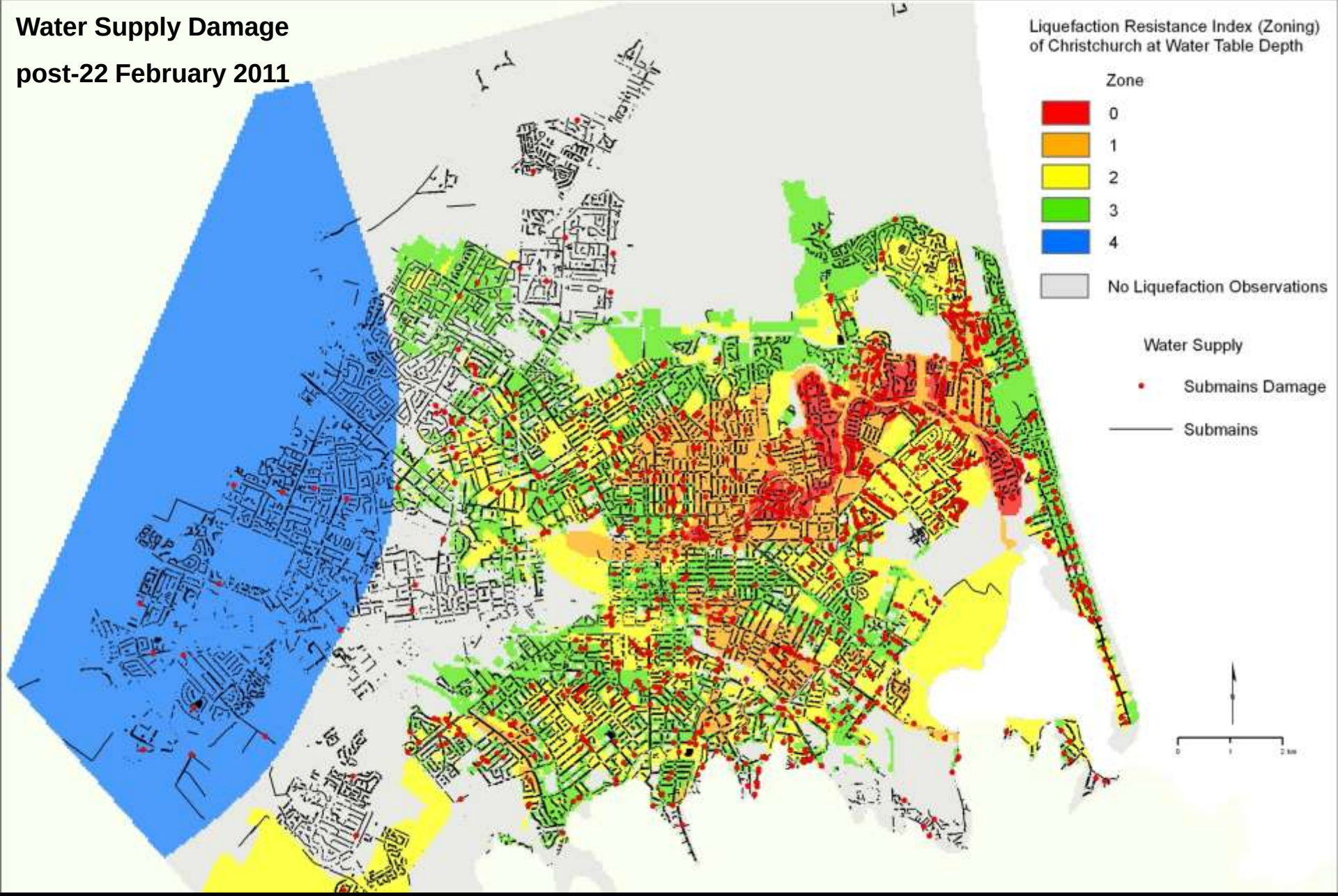
**post-22 February 2011**




Cubrinovski et al. (2011). Liquefaction Impacts on Pipe Networks. Short Term Recovery Project No. 6, Natural Hazards Platform, December 2011, University of Canterbury

**Water Supply Damage**

**post-22 February 2011**

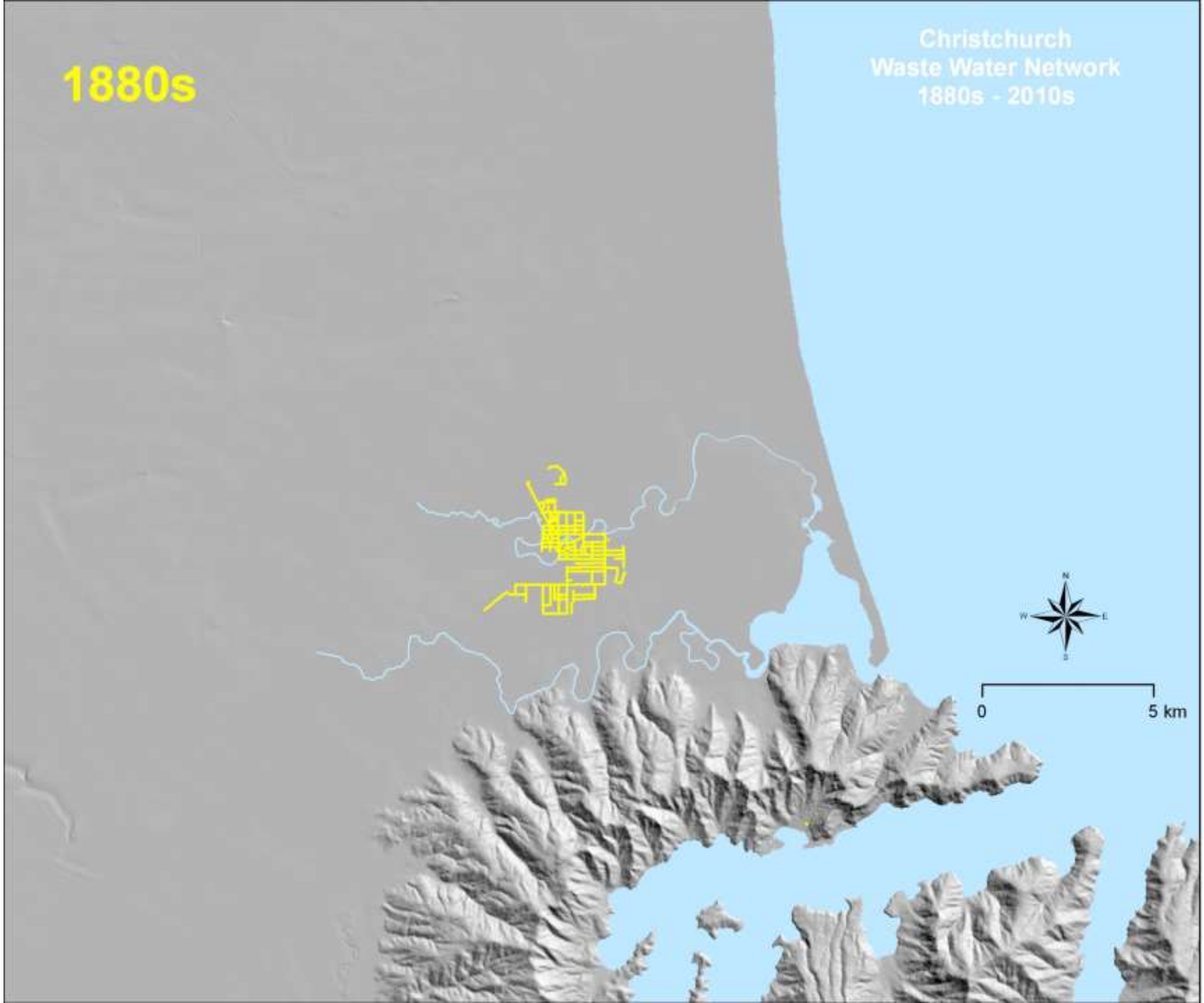


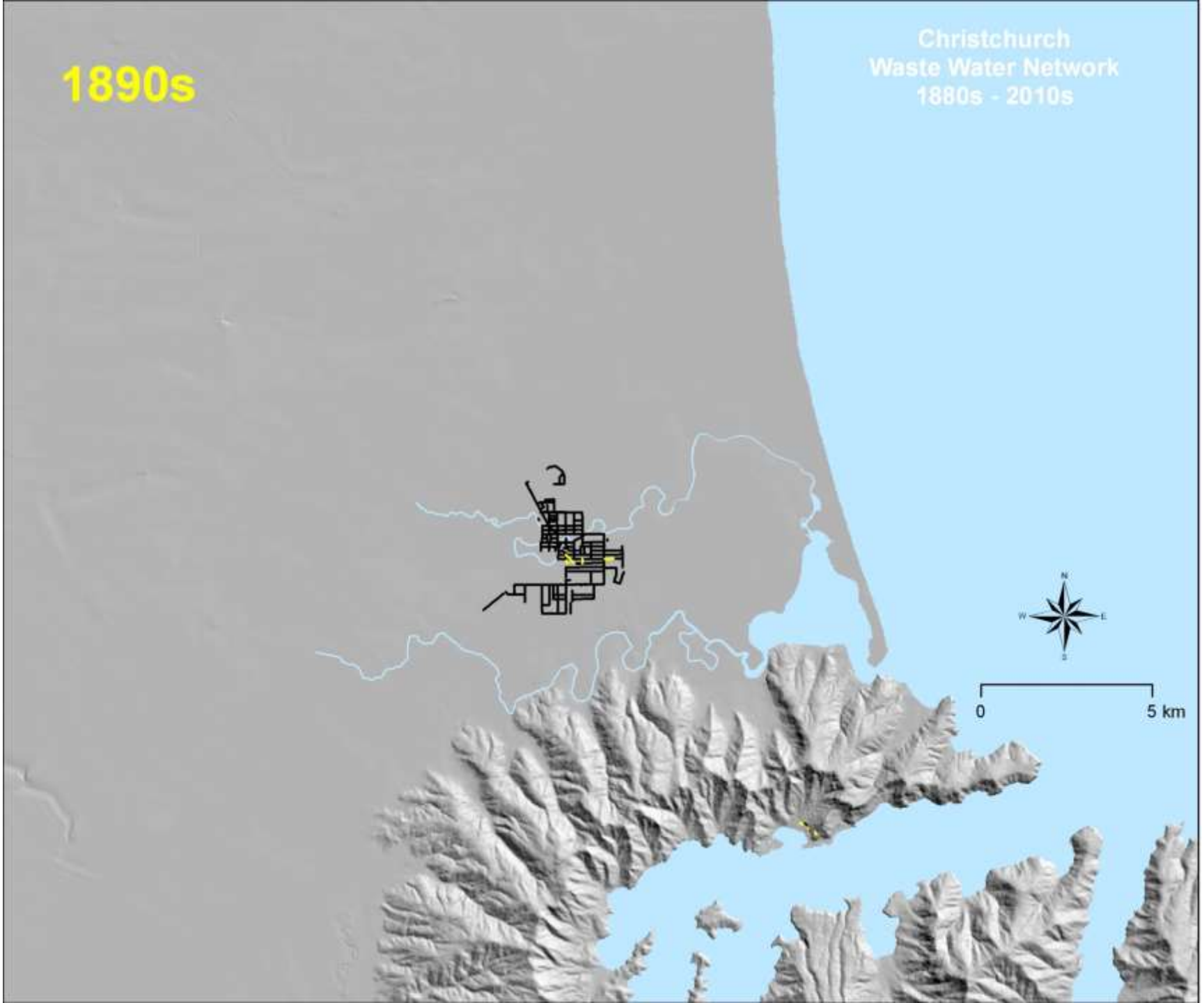

Cubrinovski et al. (2011). Liquefaction Impacts on Pipe Networks. Short Term Recovery Project No. 6, Natural Hazards Platform, December 2011, University of Canterbury

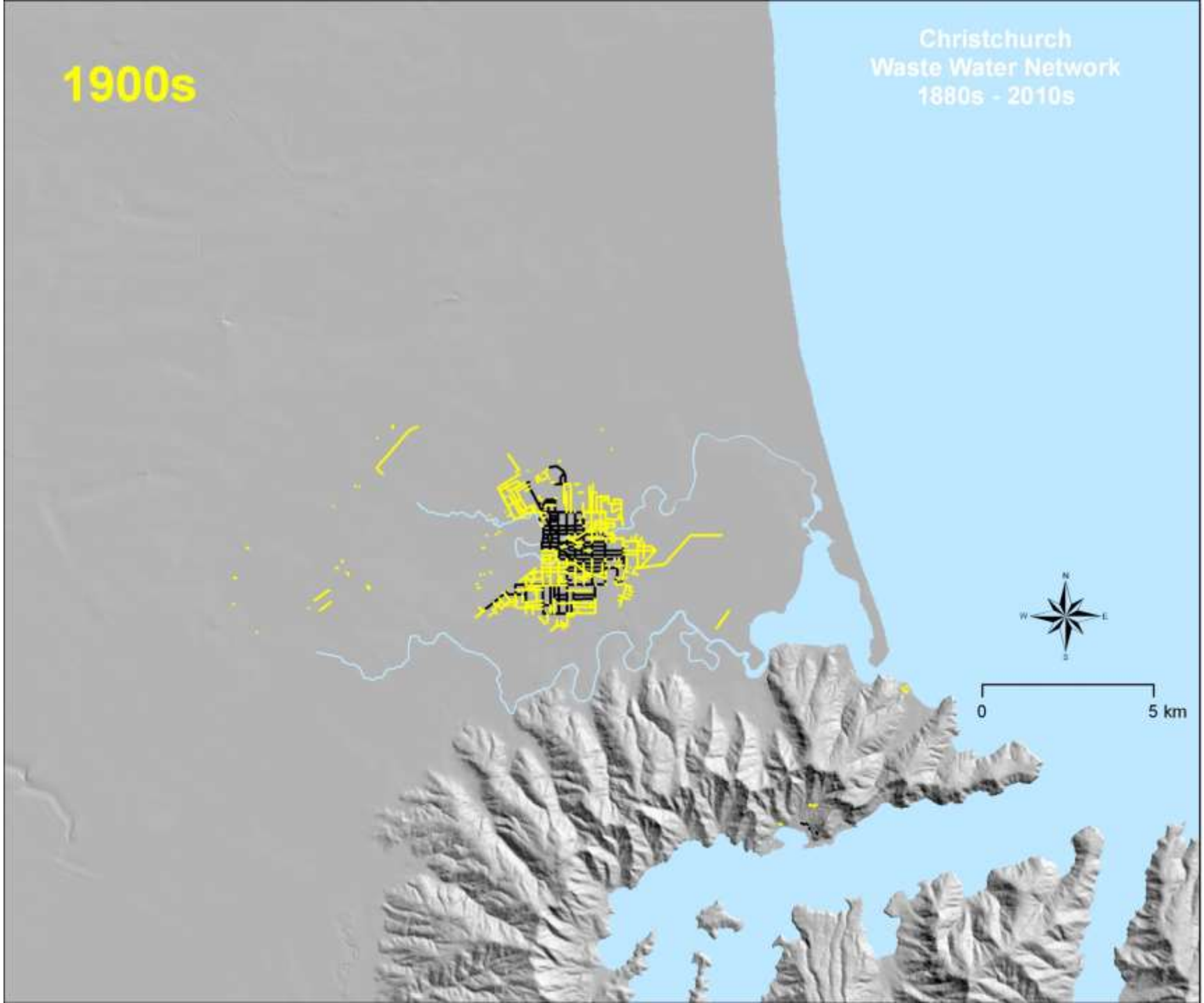
# Waste Water

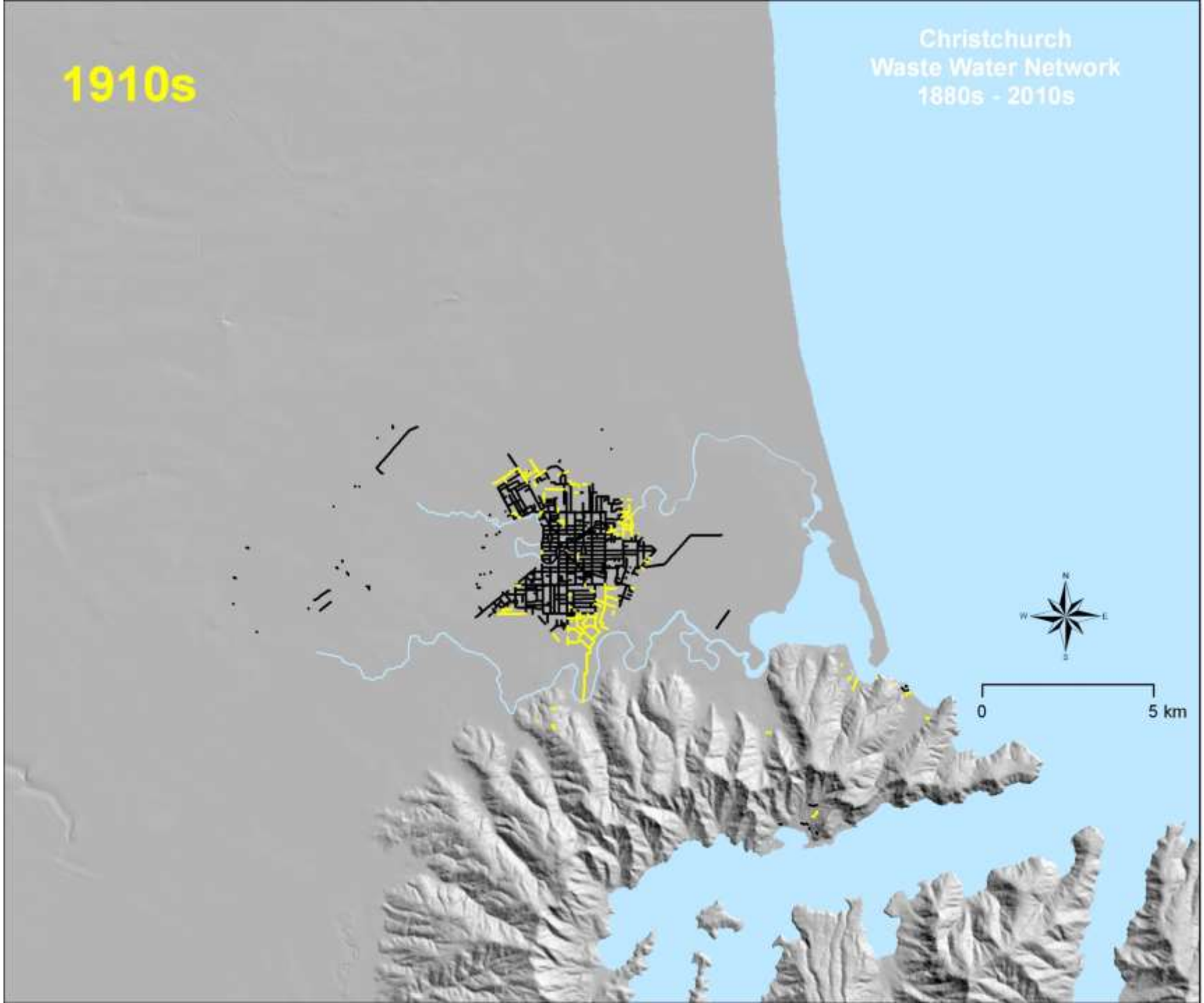
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

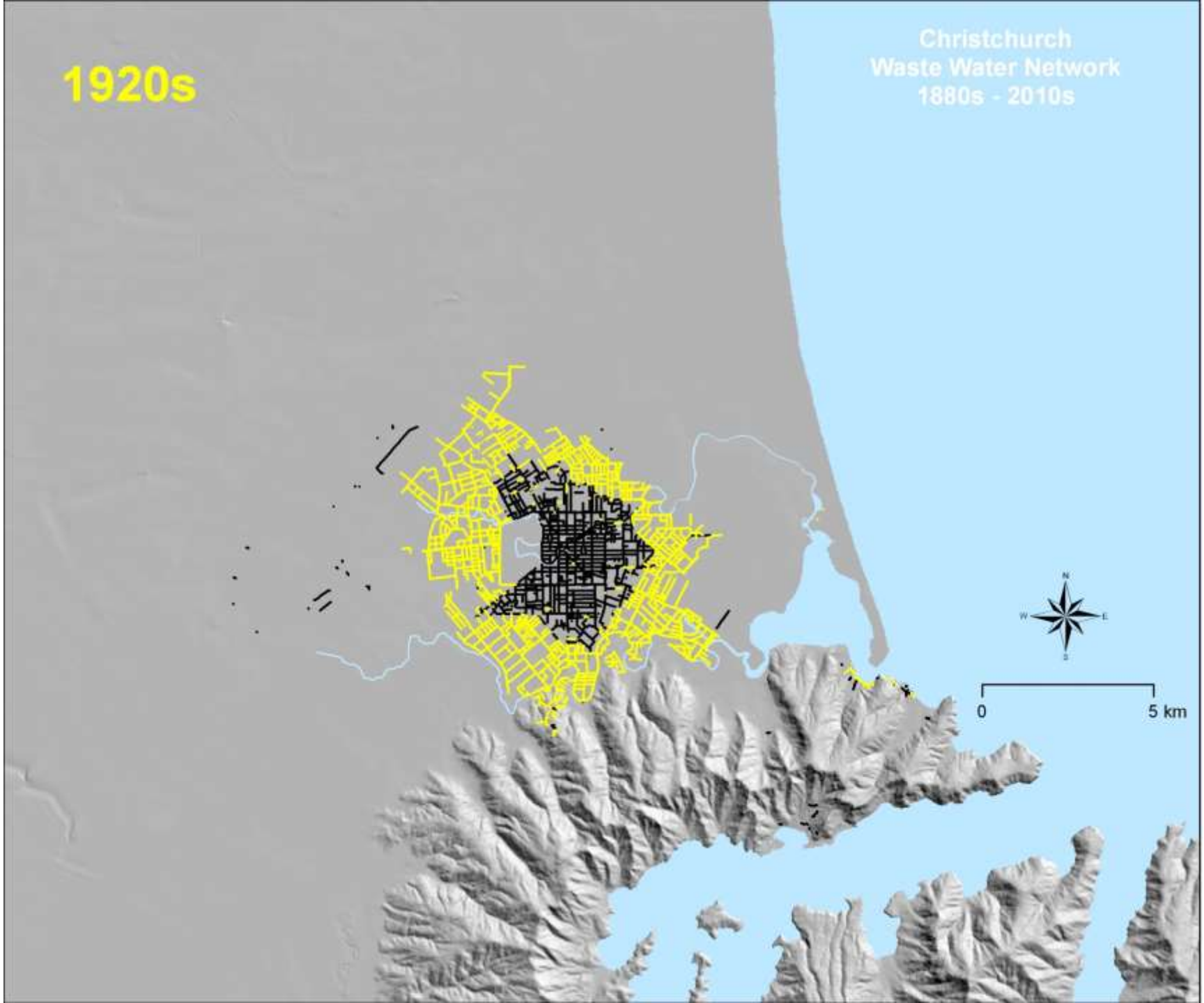
# Growth of a city:
# Subterranean expansion

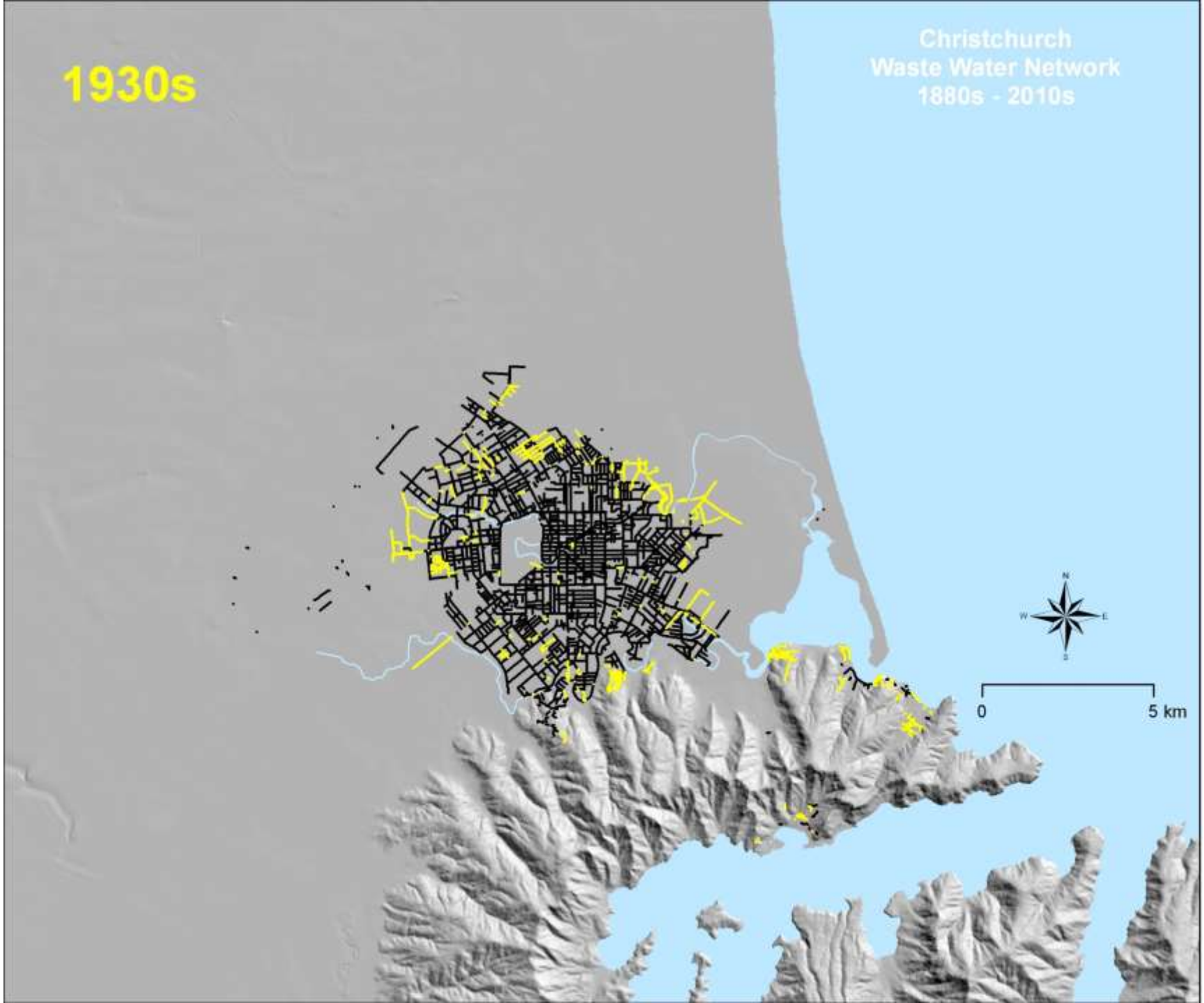

1880s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km


1890s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km


1900s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

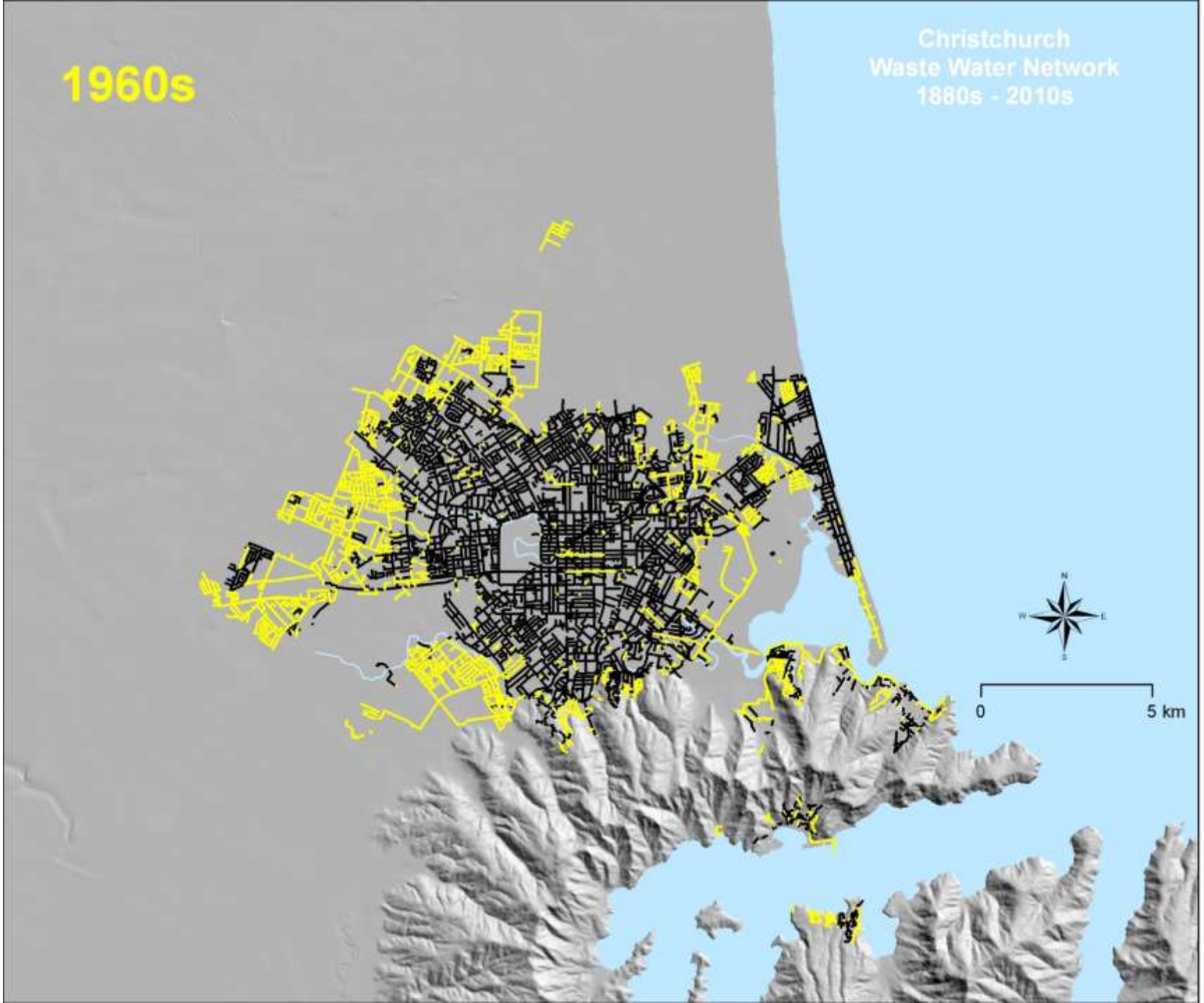

1910s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

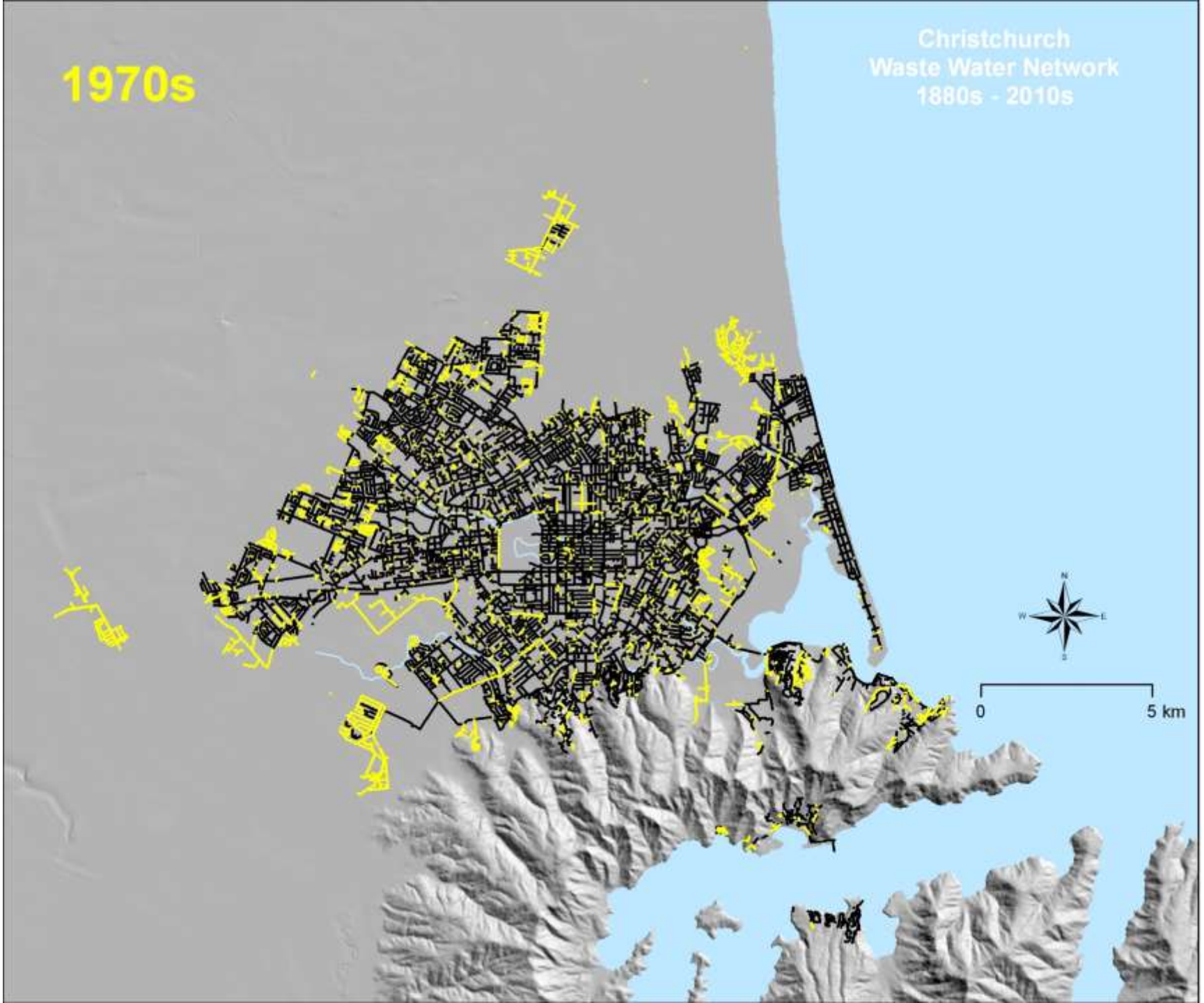

1920s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

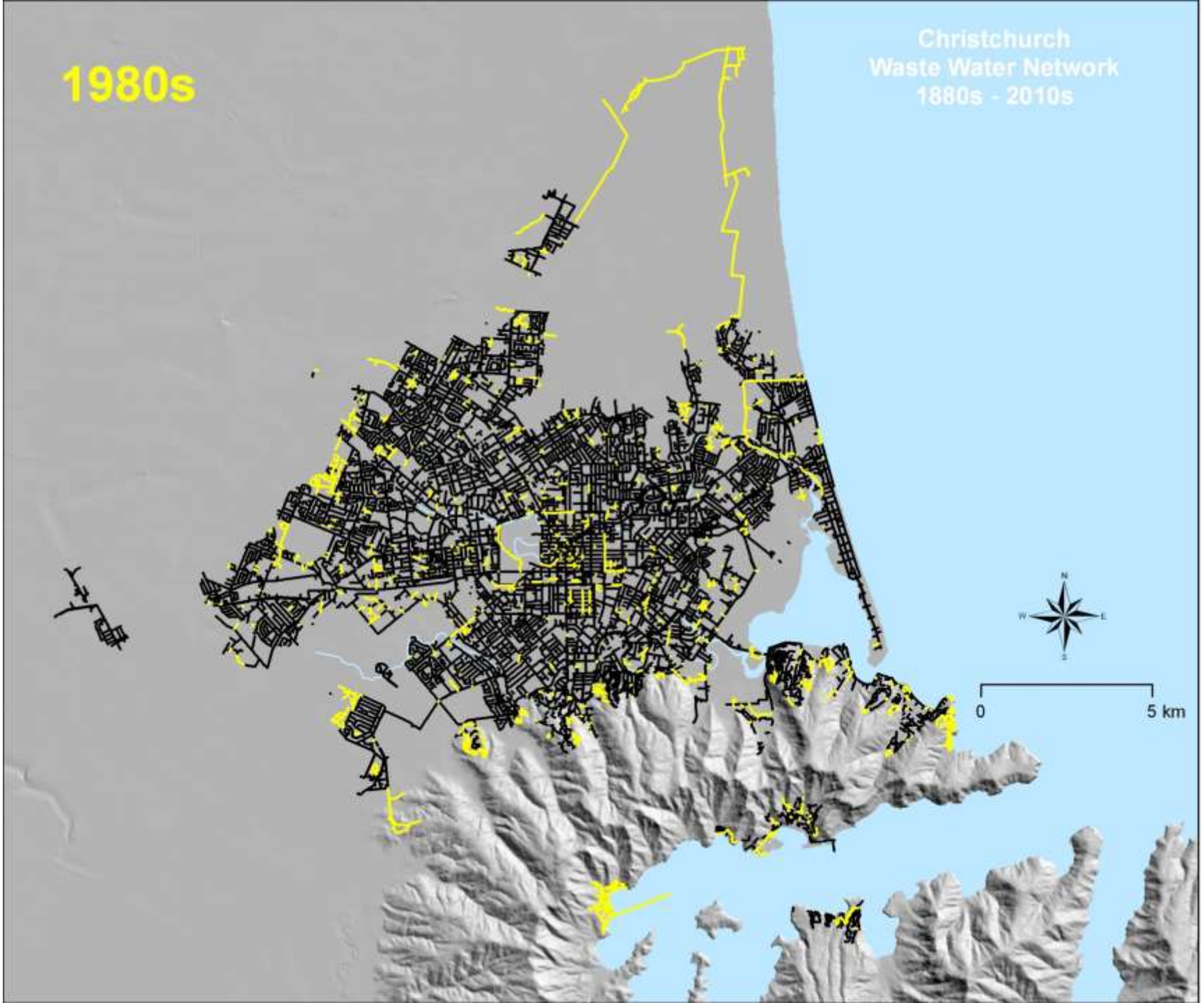

1930s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

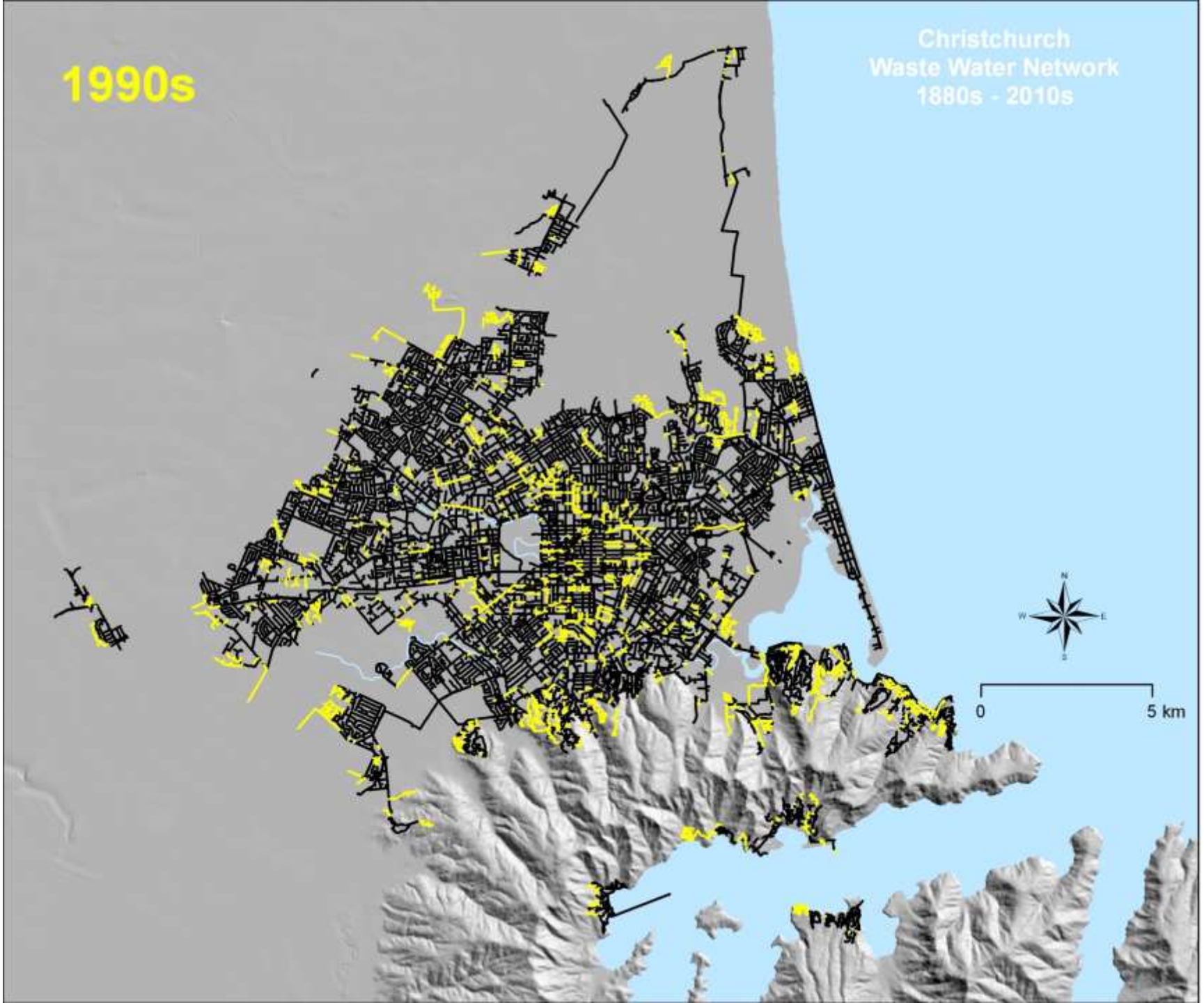

1940s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

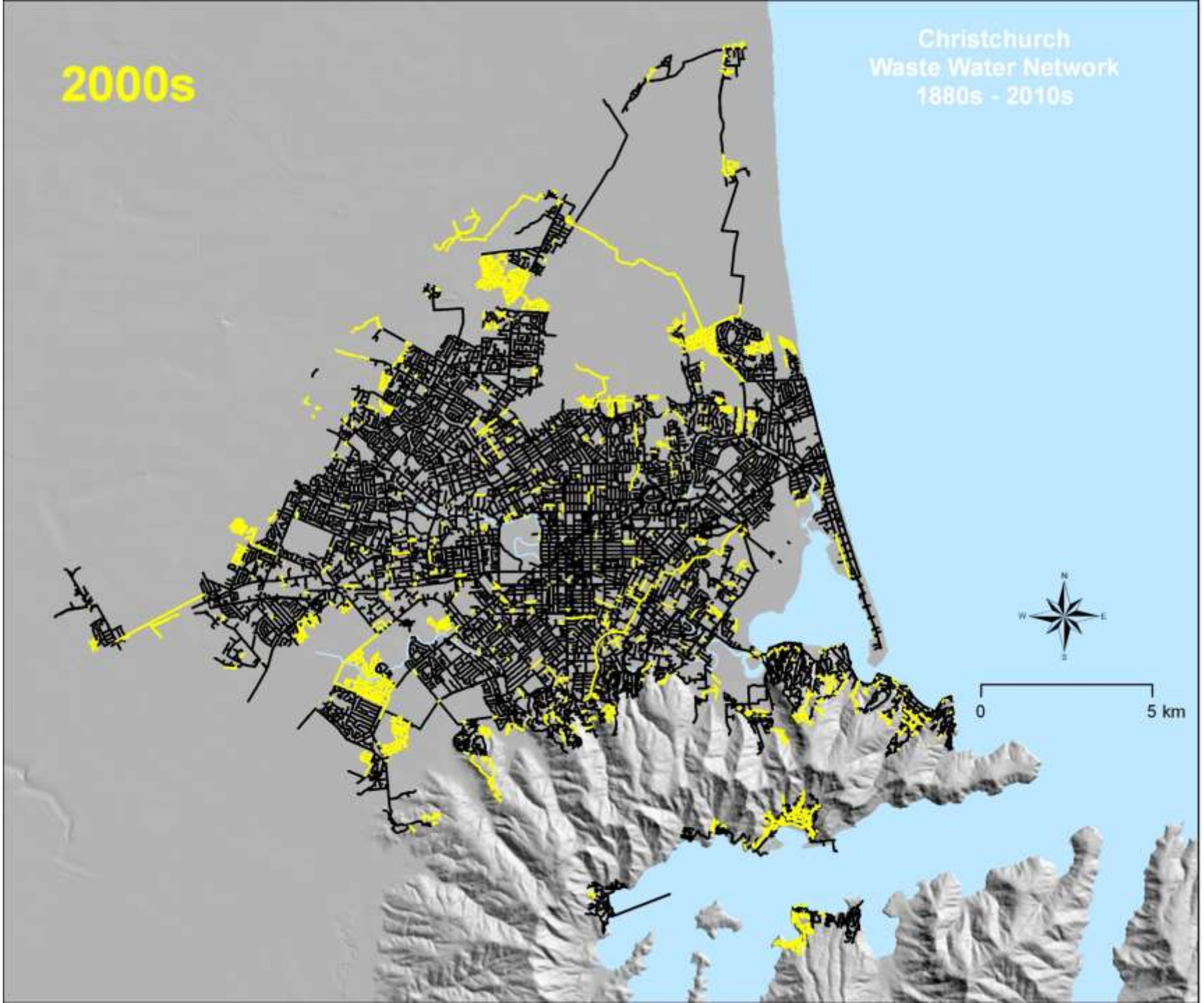

1950s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

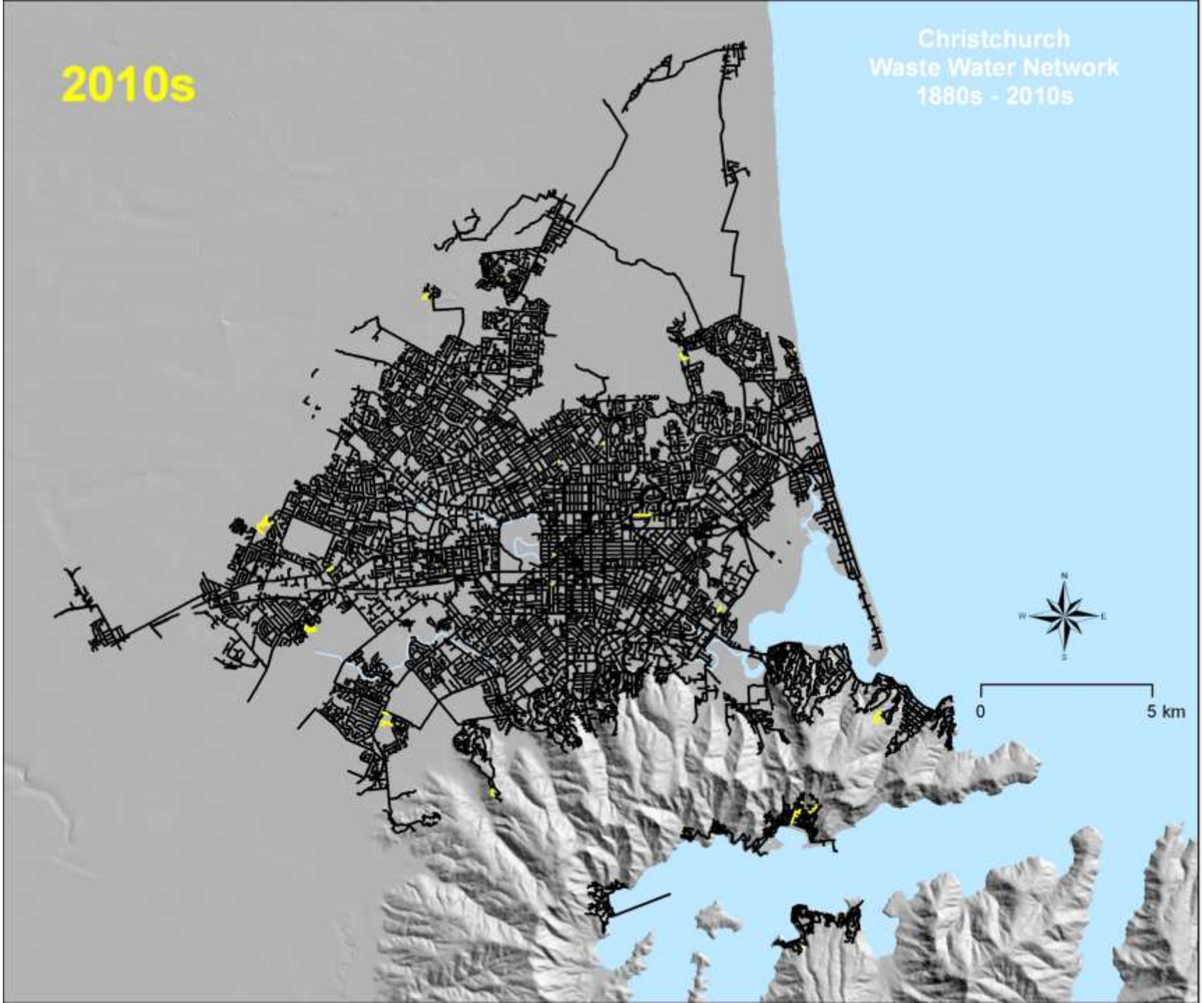

1960s
Christchurch
Waste Water Network
1880s - 2010s
0
5 km

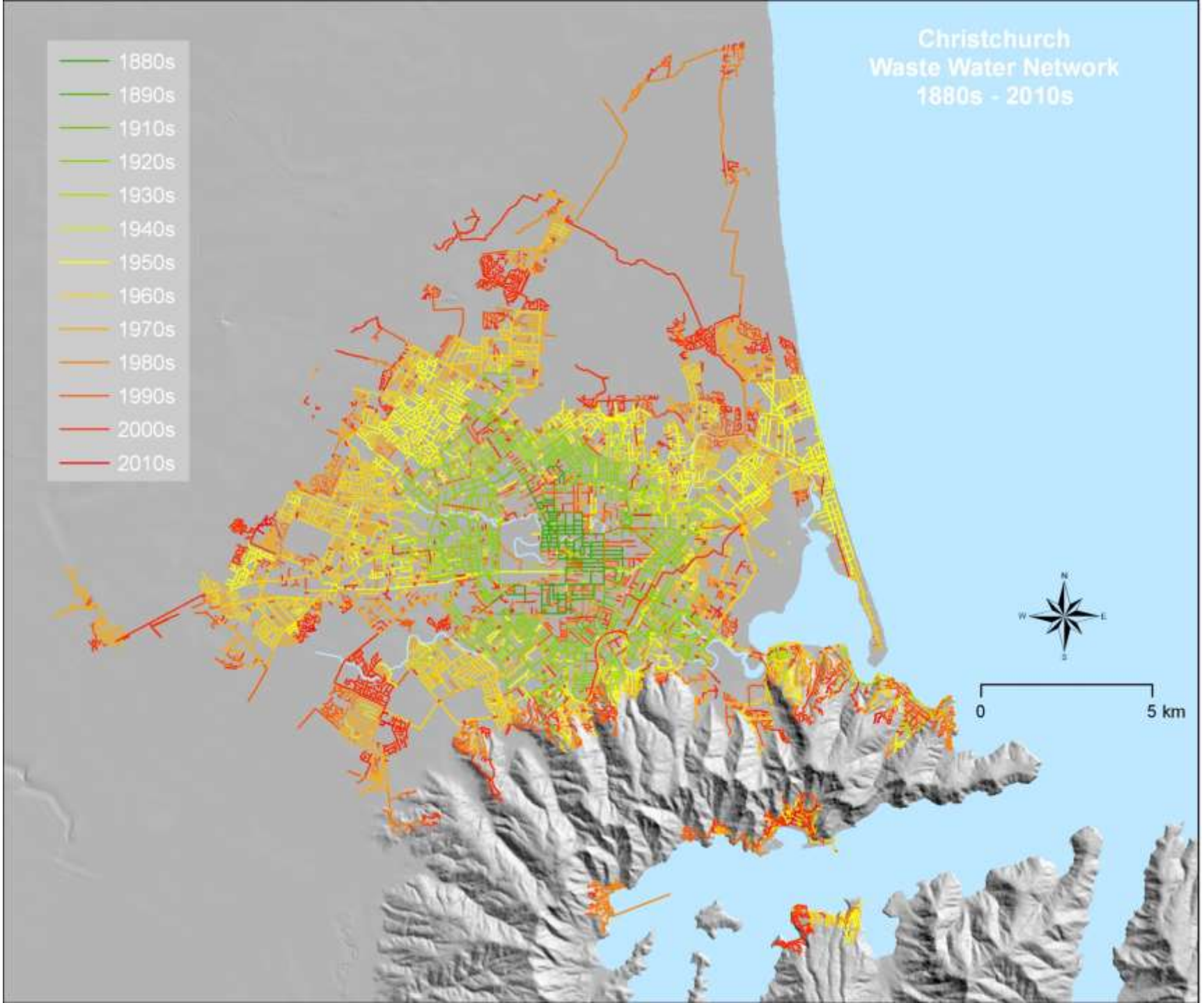

1970s
Christchurch
Waste Water Network
1880s - 2010s
0
5 km

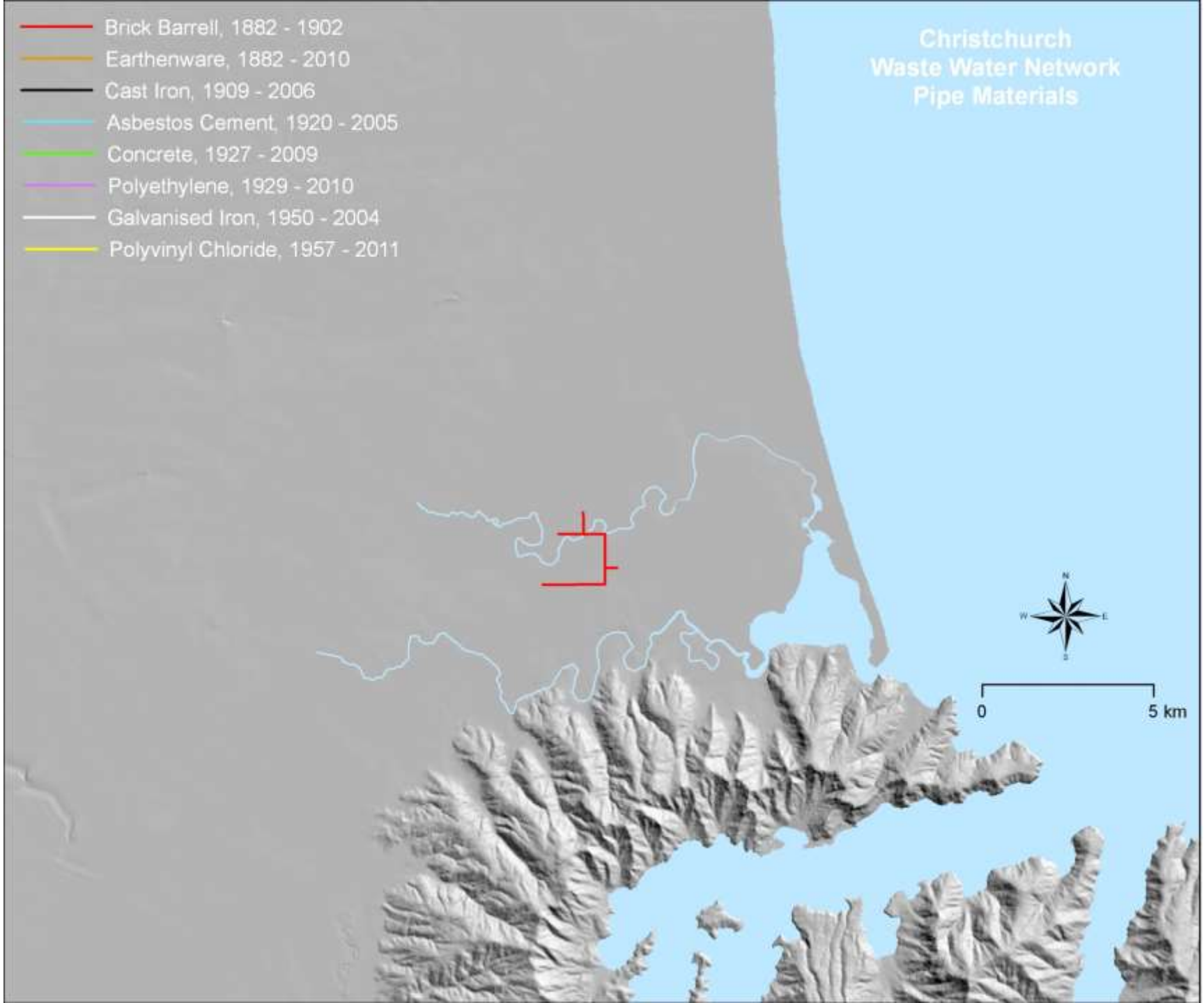

1980s
Christchurch
Waste Water Network
1880s - 2010s
0
5 km

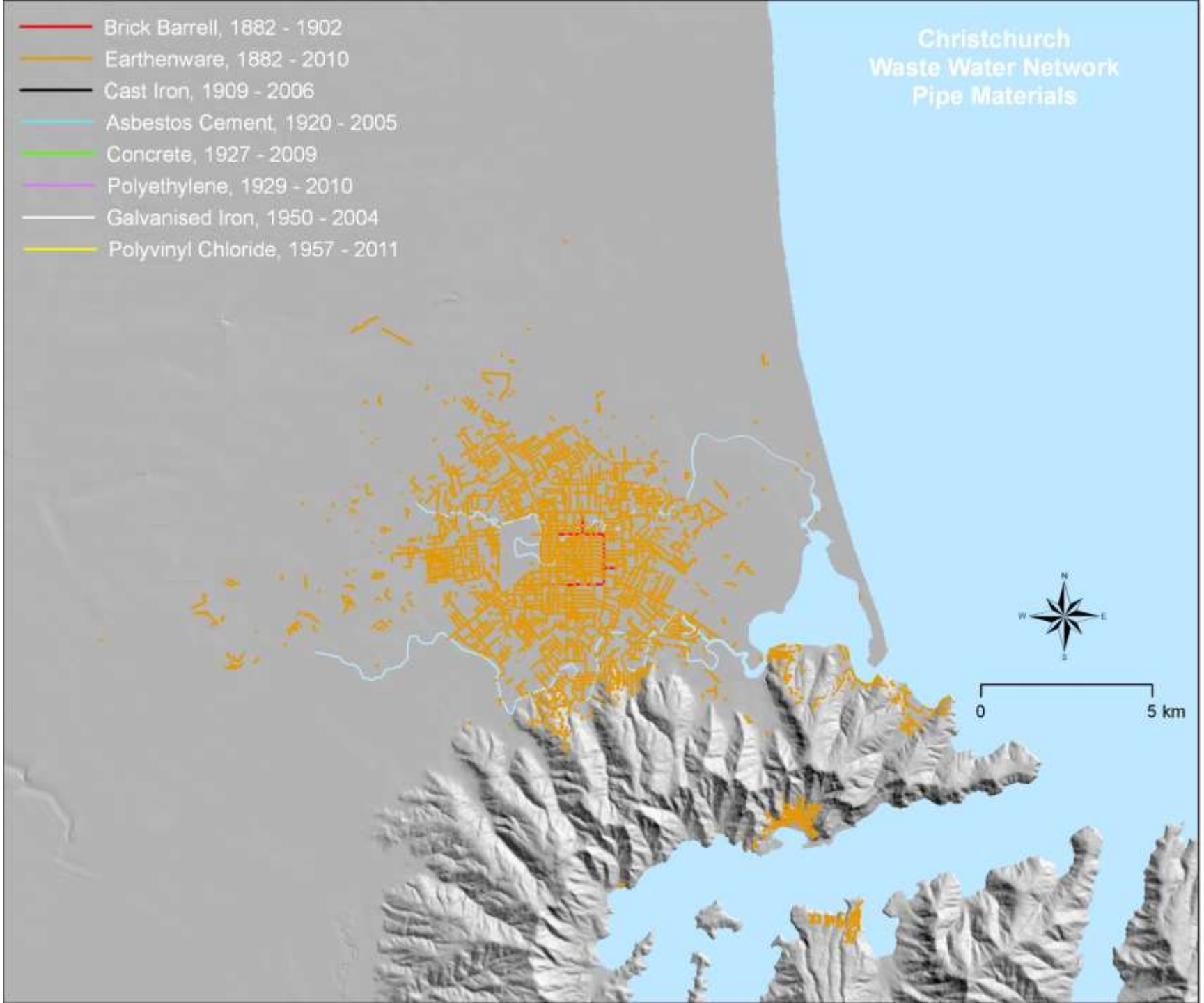

1990s
Christchurch
Waste Water Network
1880s - 2010s
0
5 km

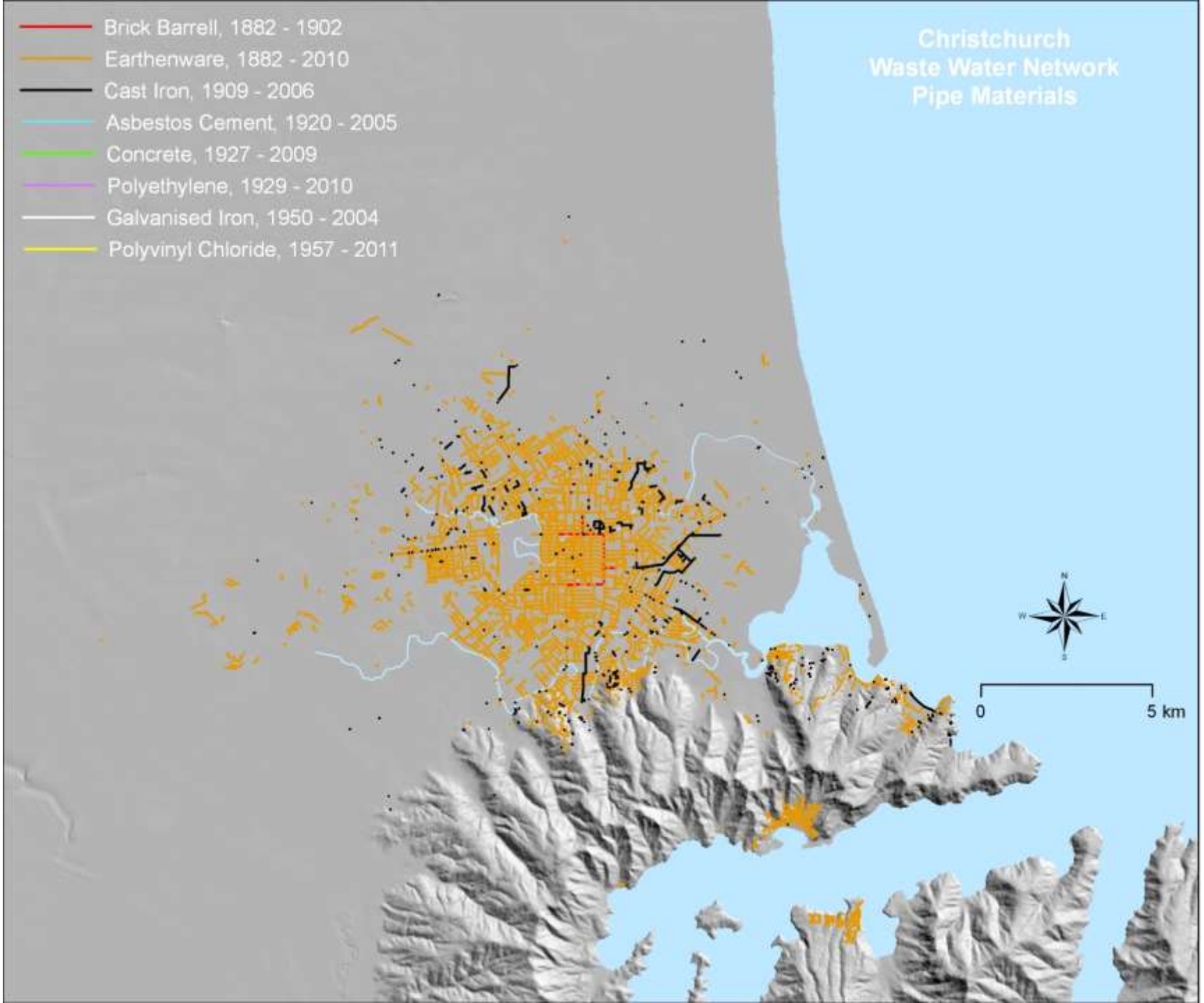

2000s
Christchurch
Waste Water Network
1880s - 2010s
0
5 km

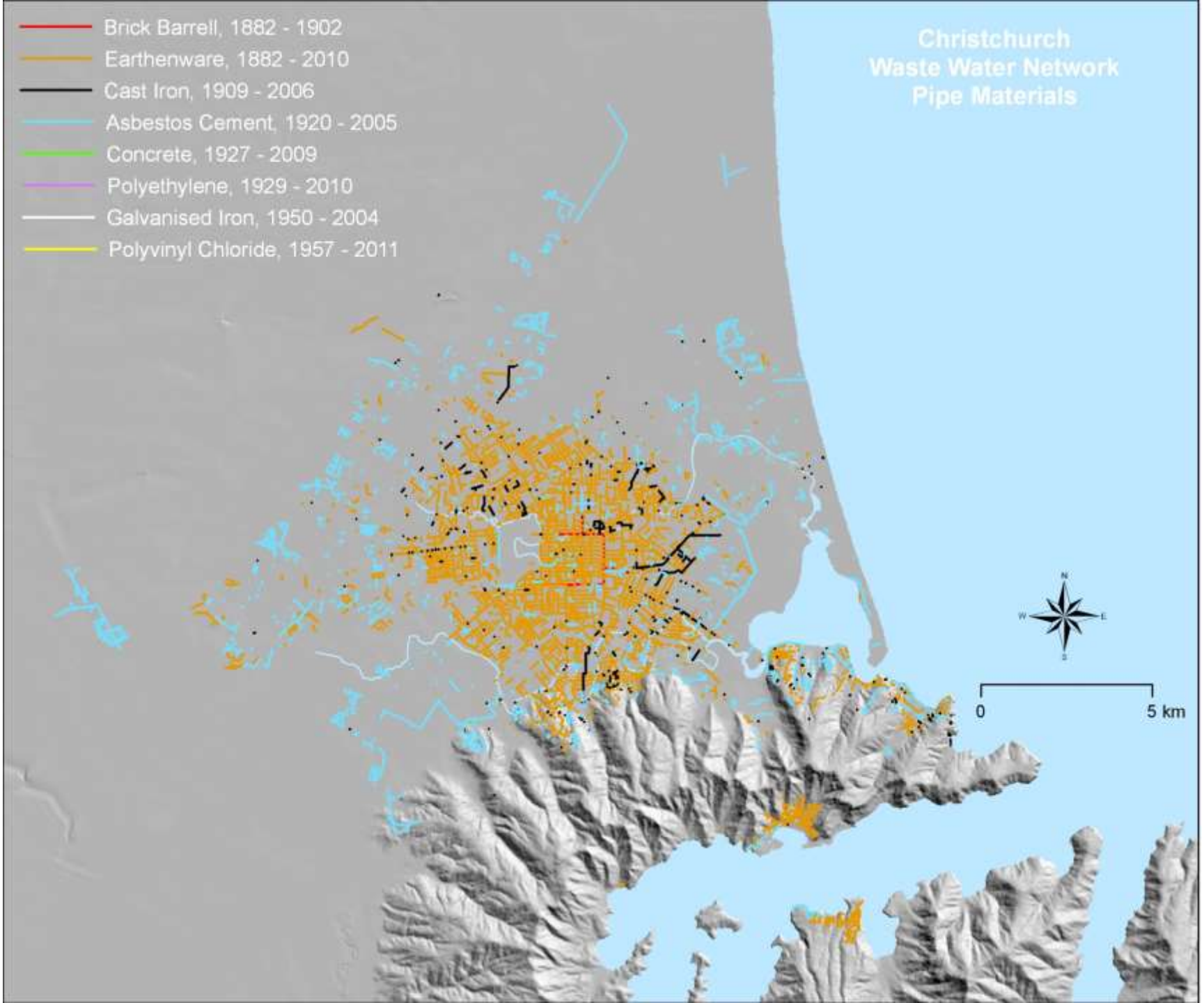

2010s
Christchurch
Waste Water Network
1880s - 2010s
N
W
E
S
0
5 km

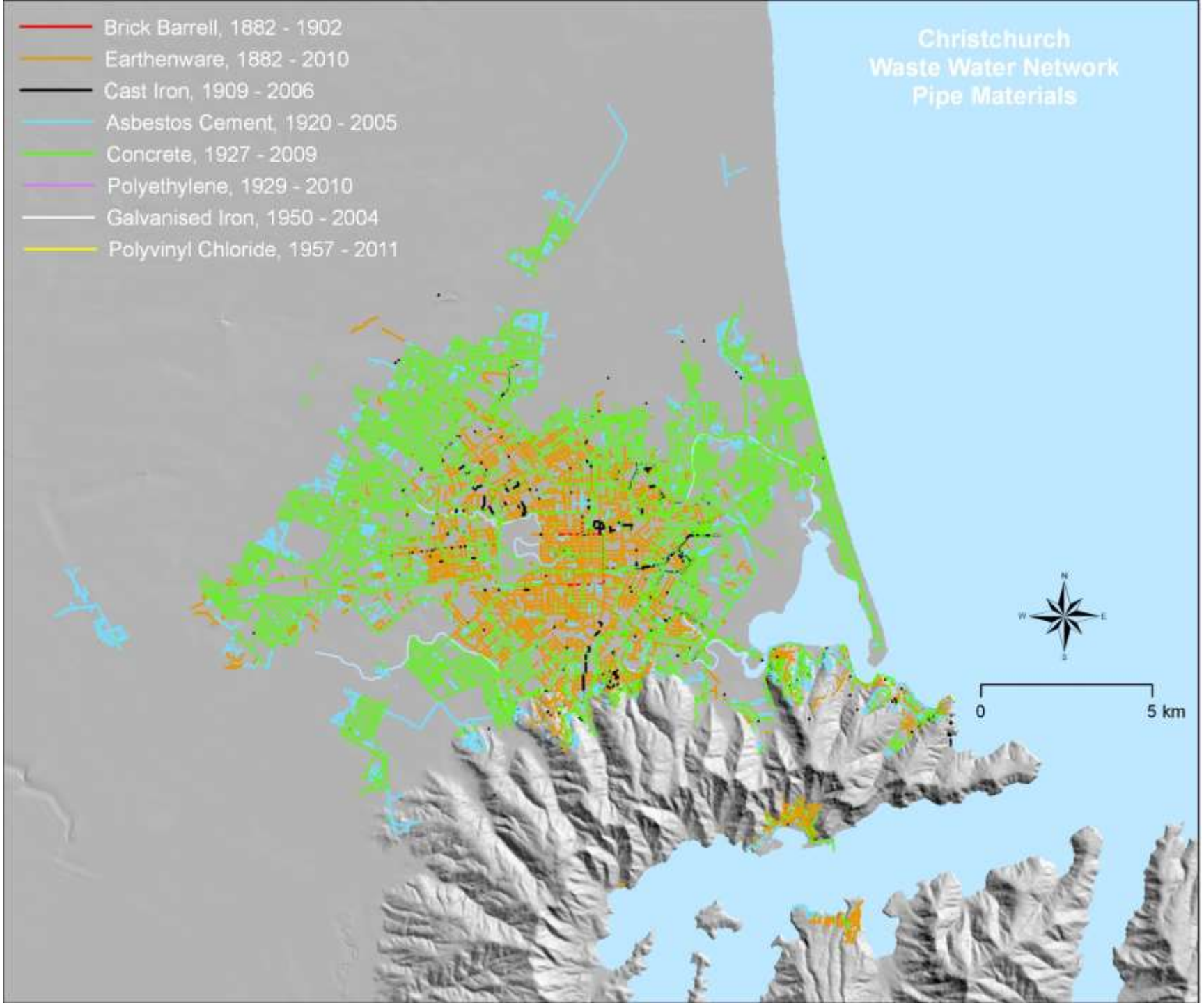

Christchurch
Waste Water Network
1880s - 2010s
1880s
1890s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s
N
W
E
S
0
5 km

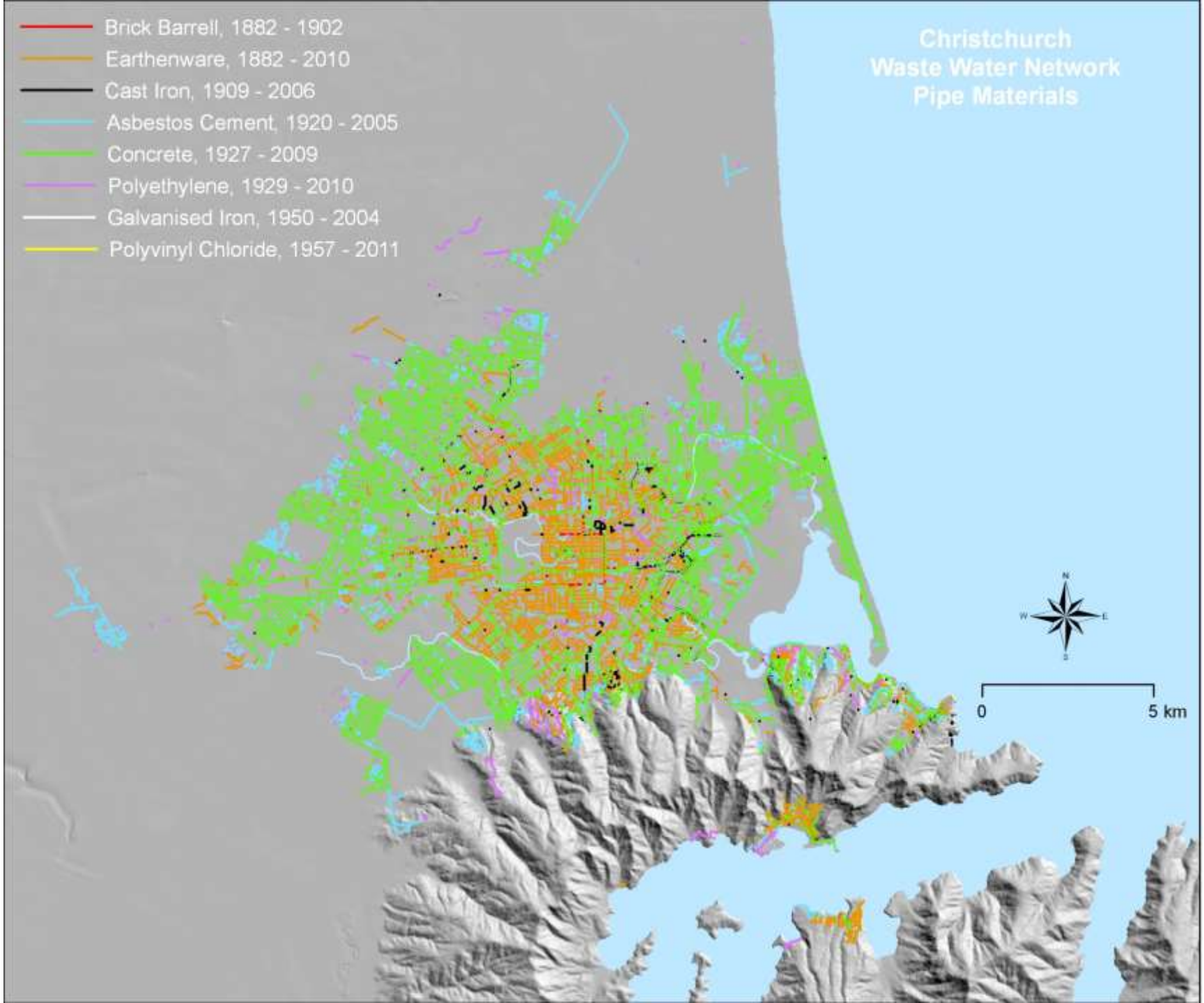

Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km

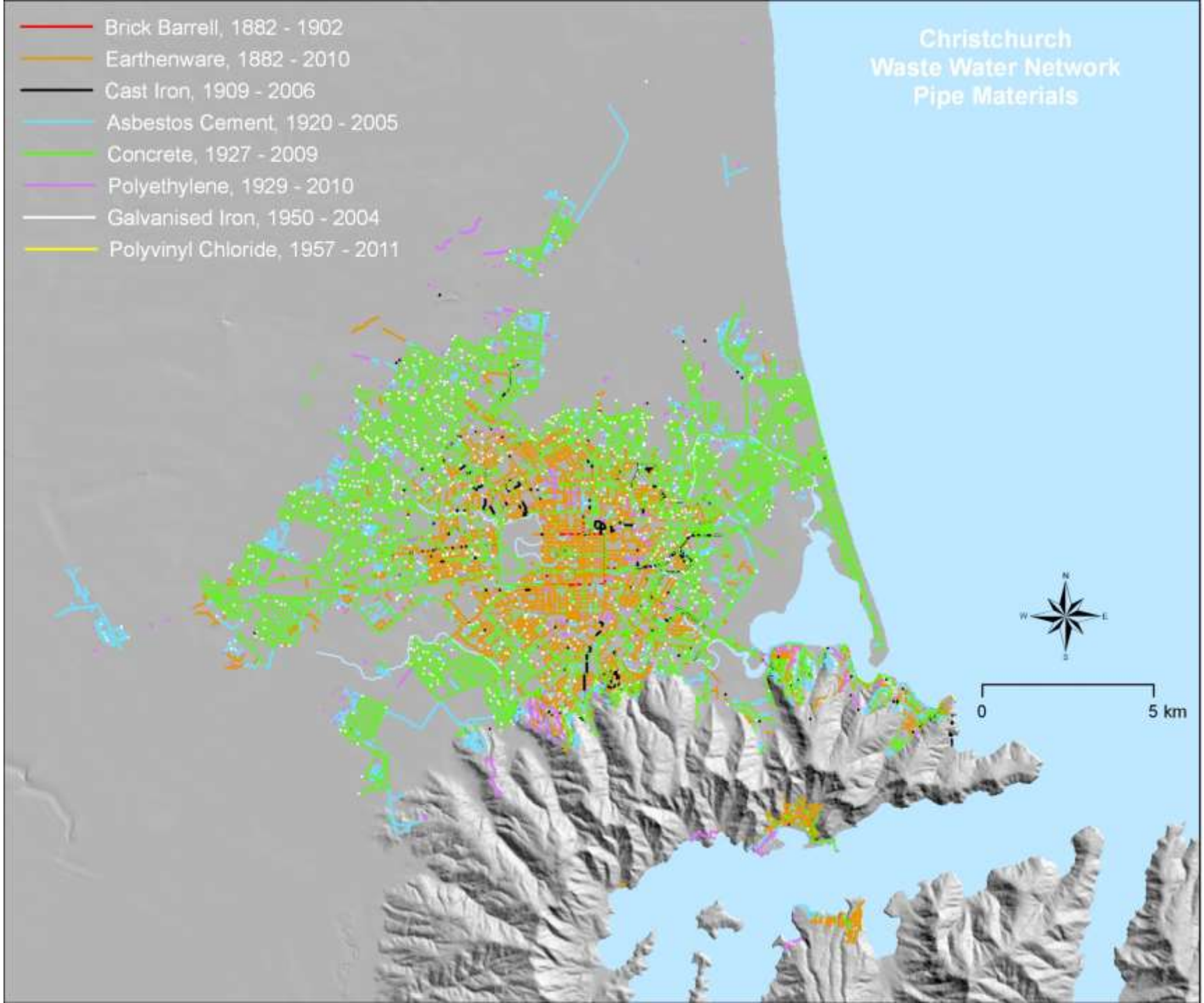

Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km

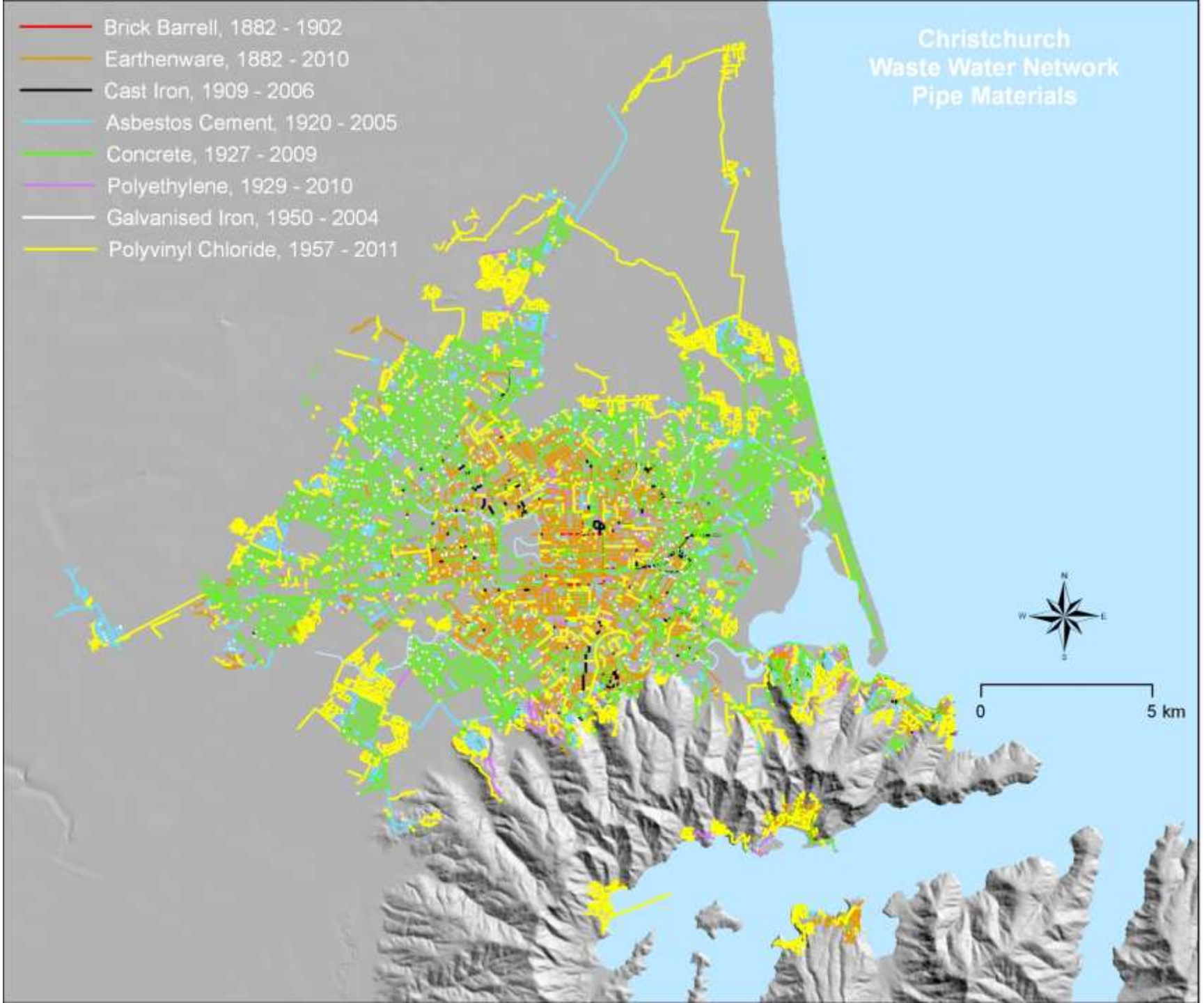

Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km


Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km


Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km


Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km


Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km


Brick Barrell, 1882 - 1902
Earthenware, 1882 - 2010
Cast Iron, 1909 - 2006
Asbestos Cement, 1920 - 2005
Concrete, 1927 - 2009
Polyethylene, 1929 - 2010
Galvanised Iron, 1950 - 2004
Polyvinyl Chloride, 1957 - 2011
Christchurch
Waste Water Network
Pipe Materials
N
W
E
S
0
5 km

**Waste Water Pipe Collapse and Ground Failure**

Photos and comments courtesy of Ben Pritchard, SCIRT

**Edgeware Road - Wastewater Northern Relief Trunk Main**

• Large and fast flow (~1 cumec), large amount of sediment transported through broken pipe.

• This section of the Northern Relief caused ~3 months delay during construction due to poor ground conditions and groundwater issues.

**Waste Water Pipe Collapse and Ground Failure**

Photos and comments courtesy of Ben Pritchard, SCIRT

**Edgeware Road - Wastewater Northern Relief Trunk Main**

• Large and fast flow (~1 cumec), large amount of sediment transported through broken pipe.

• This section of the Northern Relief caused ~3 months delay during construction due to poor ground conditions and groundwater issues.

**Waste Water Pipe Collapse and Ground Failure**

Photos and comments courtesy of Ben Pritchard, SCIRT

**Vienna St, Waltham, shortly after 22 February 2011**

• Service to the large upstream catchment (most of Beckenham) was still able to be provided by pumping the downstream manhole – natural conduit formed due to high flows?

**Waste Water Pipe Collapse and Ground Failure**

Photos and comments courtesy of Ben Pritchard, SCIRT


**Alexandra St, Lower Richmond during winter snowfall, 2011**

Rain and snow events caused new holes/cavities to open up overnight.

**Waste Water Pipe Collapse and Ground Failure**

Photos and comments courtesy of Ben Pritchard, SCIRT


**Alexandra St, Lower Richmond during winter snowfall, 2011**

Rain and snow events caused new holes/cavities to open up overnight.

UC
UNIVERSITY OF
CANTERBURY
*Te Whare Wānanga o Waitaha*
CHRISTCHURCH NEW ZEALAND

UC
UNIVERSITY OF
CANTERBURY
*Te Whare Wānanga o Waitaha*
CHRISTCHURCH NEW ZEALAND

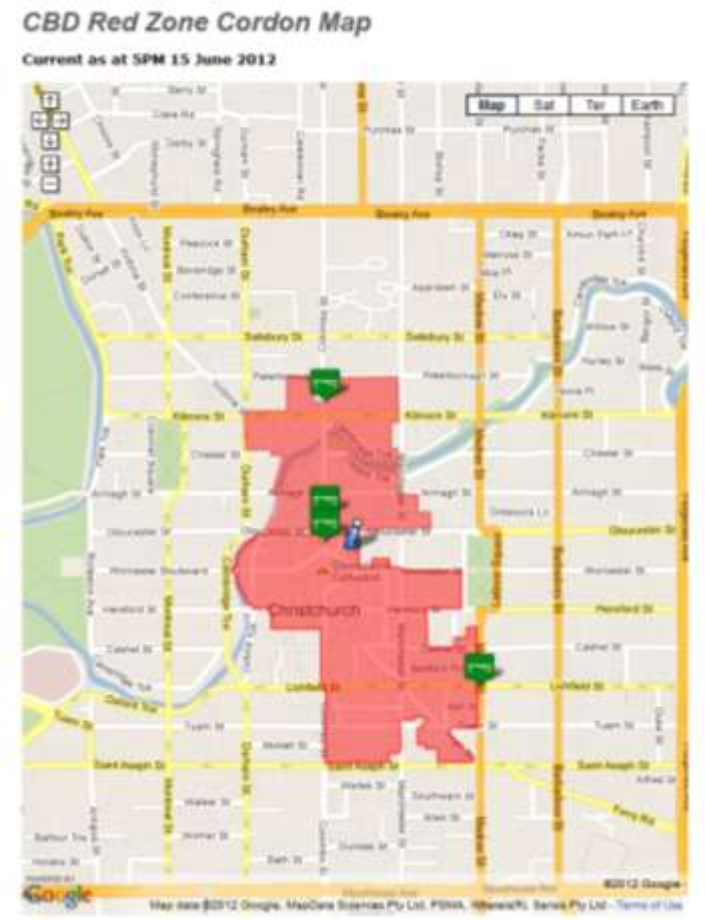
UC
UNIVERSITY OF
CANTERBURY
*Te Whare Wānanga o Waitaha*
CHRISTCHURCH NEW ZEALAND

# 2: Consequences – the numbers

- A large (for NZ) natural hazard event in a small economy
  - 10% of NZ's 4.5 million people directly impacted
  - Total loss estimates c. $30B NZD – about 10-12% GDP
- 10,000's homes damaged and >1,100 buildings demolished
  - Reduced habitability and strained city's ability to accommodate it's residents
  - 7,500 residential properties retired: ~5% of total housing stock
  - Central Business District closed for months: 800 buildings demolished over 40 Ha (85%)
- New Zealand's largest short-term migration
  - 70,000 people evacuated: 19% of population
  - 7,000-9,000 net long term migration: <3% of population
- 8 millions tonnes of disaster waste: 40 years of Chch waste
- One of the greatest geotechnical disasters of the modern age
  - Liquefaction ground damage - flats
  - Slope stability – (Port) Hills


# The CBD problem

- 6000 businesses and over 51,000 workers.
  - Social and economic hub
- The closure of the CBD caused 100% stoppage of economic activity within the cordon.
  - Building types, neighbourhood effect, organisational vulnerabilities
- Approximately 1300 buildings (over 60% of commercial buildings in Chch CBD) have been marked for demolition
  - Not because a significant danger, but deemed uneconomic to repair
- Major relocation to hubs/clusters
  - Access to services, Confidence in buildings




*All DOOM and GLOOM…???*
*Well, not really…*

Regional economy continued to be strong (based on agriculture)

- Port, airport, road and rail networks had very little downtime
- 95% of businesses are still operating albeit with downturn in tourism, education, and hospitality
- Some migration away from Canterbury especially immediately after event
  - Net migration about 9,000 persons,
  - 30,000 new workers needed for rebuild
- Communities remained largely intact
  - There was no need for widespread evacuation from Christchurch
- Early government support for local business continuity and workforce

# Insurance Perspectives - Recent Major Earthquake Events

USD billion (at 2011 prices)

| Event Date | Country | Economic Losses US$B | Economic losses as %GDP | Insured Losses | Insurance Industry Contribution |
|---|---|---|---|---|---|
| 11 March 11 | Japan | up to 300 | up to 5.4% | 35 | up to 17% |
| 27 Feb 10 | Chile | 30 | 18.6% | 8 | 27% |
| 22 Feb 11 | NZ | 15 | 10% | 12 | 80% |
| 12 Jan 10 | Haiti | 8 | 121% | 0.1 | 1% |
| 04 Sept 10 | NZ | 6 | 5.3% | 5 | 81% |
| 06 April 09 | Italy | 4 | 0.2% | 0.5 | 14% |
| 23 Oct 11 | Turkey | 0.75 | 0.1% | 0.03 | 4% |
| 04 April 10 | Mexico | 0.95 | 0.09% | 0.2 | 21% |

Source: Swiss Re *sigma* catastrophe database

# Lessons from the Canterbury Earthquake Sequence

- **Success and limitations of geoscience...**
- **What can we unpack from this?**
- Very difficult situation
  - Sustained earthquake sequence in a previously seismically ‘quiet’ region
  - Unmapped faults
  - Sequence has migrated across an major urban area
  - Most damaging EQ since the 1931 Napier earthquake