# The Application of Risk-based Drinking-water Source protection and an ArcGIS platform for Integrated Catchment Management to Deliver Improved Water Safety Planning and Public Health Outcomes in the Pacific Islands

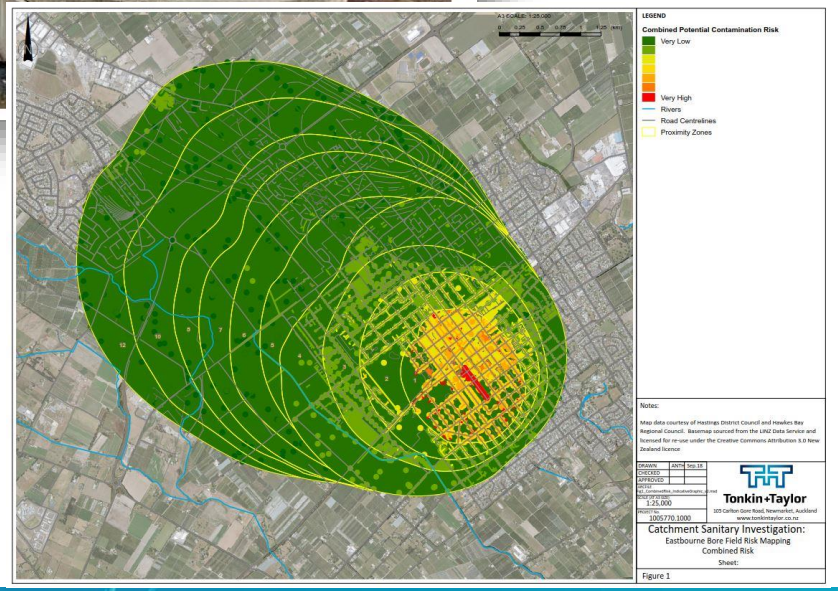
12th Pacific Water and Wastewater Conference & Expo, Warwick le Lagon, Port Vila, Vanuatu 5-9 August 2019

Tony Cussins, Principal Consultant – Water Security, Technical Director - Hydrogeology, Tonkin + Taylor International Ltd

# Case Studies:

## Case Study 1 – Havelock North *Campylobacter* outbreak


## Case Study 2 - Source Protection Zones (SPZs) for Hastings District Council's urban and rural water supplies



# Case Study 1 – Havelock North *Campylobacter* outbreak

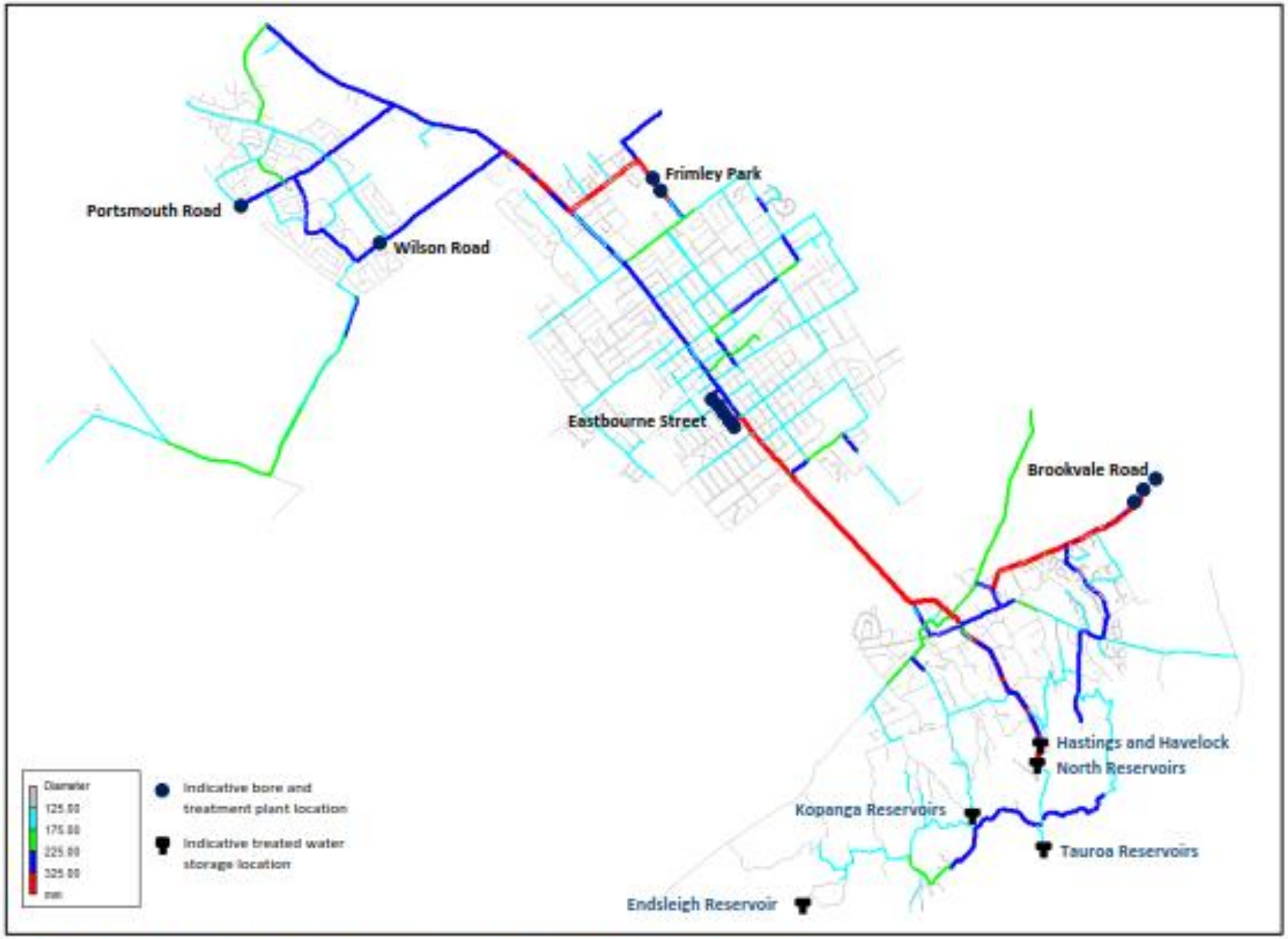




*Figure 2-1: Layout of the Hastings Water Supply System (excluding Paki Paki zone)*

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# Hastings DC water supply

Tummy bug outbreak linked to Havelock North water supply

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Campylobacter confirmed in Havelock North water, 4100 affected

# Timeline: NZ's worst waterborne outbreak

Over 4000 sick from Campylobacter in NZ water

Gastro: Second death linked to campylobacter outbreak in Havelock North

Havelock North water crisis sparks call for all drinking supplies to be chlorinated

# Thursday 18th August 2016

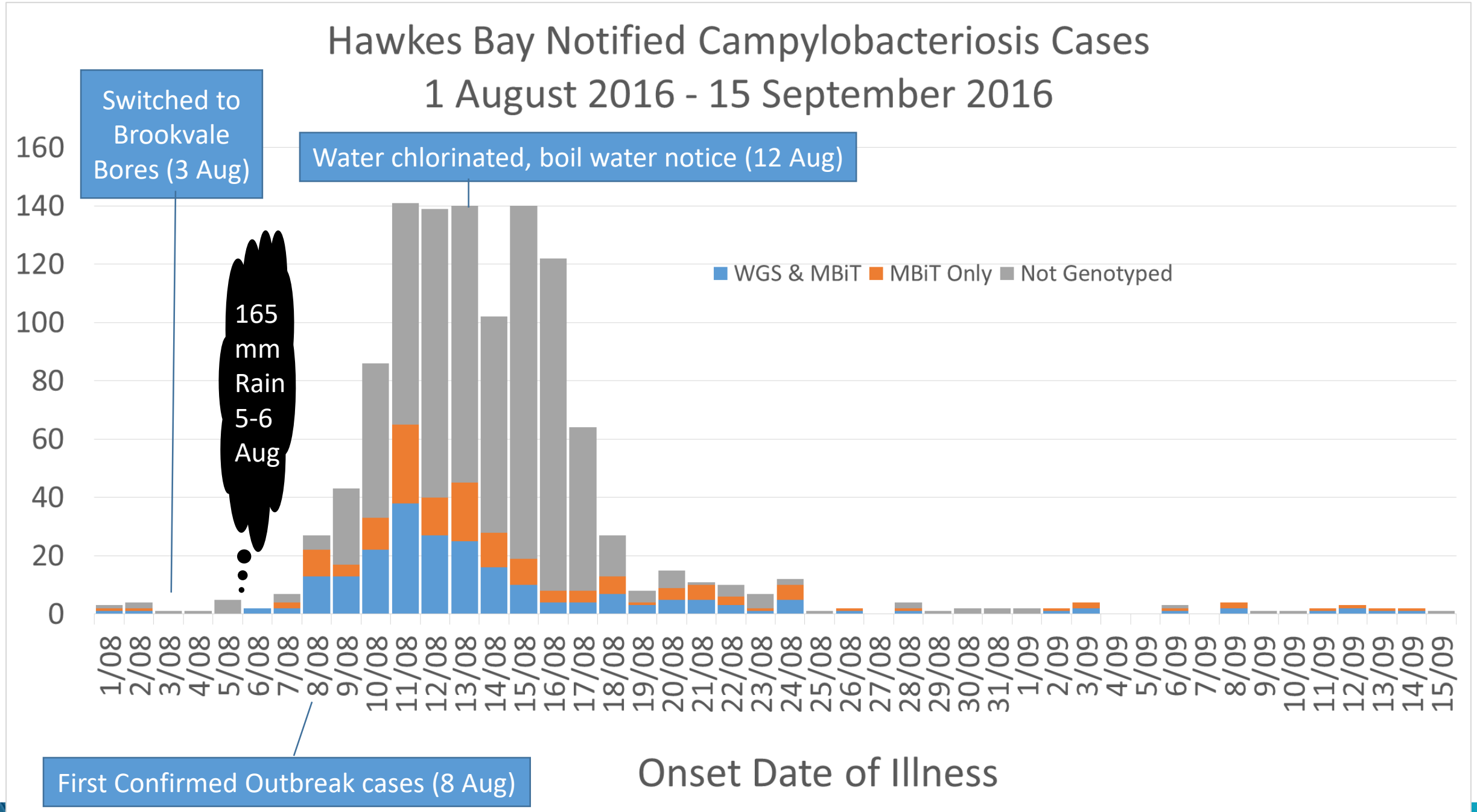
# The Havelock North outbreak

- Havelock North public water supply suffered a significant *Campylobacter* contamination event in August 2016 – followed heavy rainfall

- Source of the contamination was the nearby Brookvale Road bore field - part of the HDC water supply system

- Estimated 5,500 residents became ill with campylobacteriosis - 45 hospitalised, possible contribution to four fatalities

Government Inquiry into Havelock North Drinking-Water - the catalyst for major reforms in the drinking-water sector


Hawkes Bay Notified Campylobacteriosis Cases
1 August 2016 - 15 September 2016
Switched to Brookvale Bores (3 Aug)
Water chlorinated, boil water notice (12 Aug)
165 mm Rain 5-6 Aug
First Confirmed Outbreak cases (8 Aug)
WGS & MBiT
MBiT Only
Not Genotyped
160
140
120
100
80
60
40
20
0
1/08
2/08
3/08
4/08
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6/09
7/09
8/09
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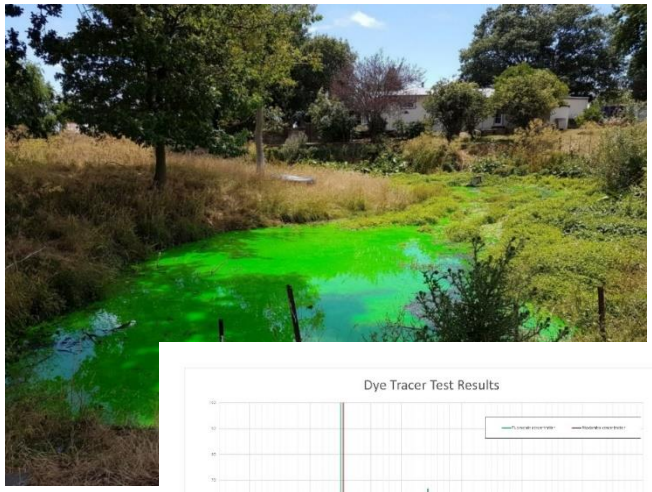
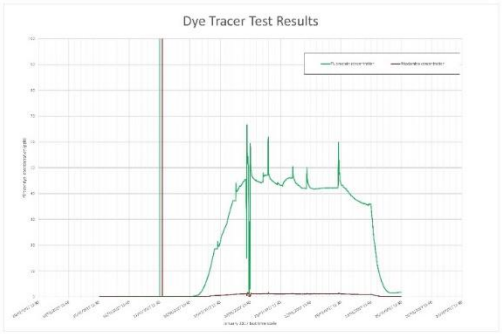
13/09
14/09
15/09
Onset Date of Illness

# Importance of good science…


- Contamination/ hydrogeology investigations
- Rainfall runoff modelling
- Geophysics
- Groundwater modelling
- Contaminant fate & transport
- Dye tracer tests
- Genotyping (ESR)





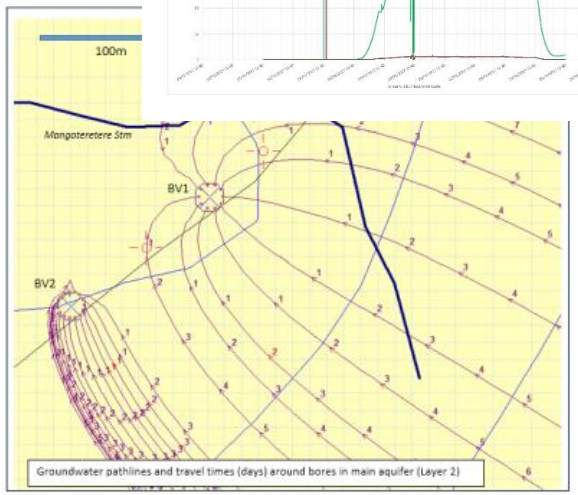
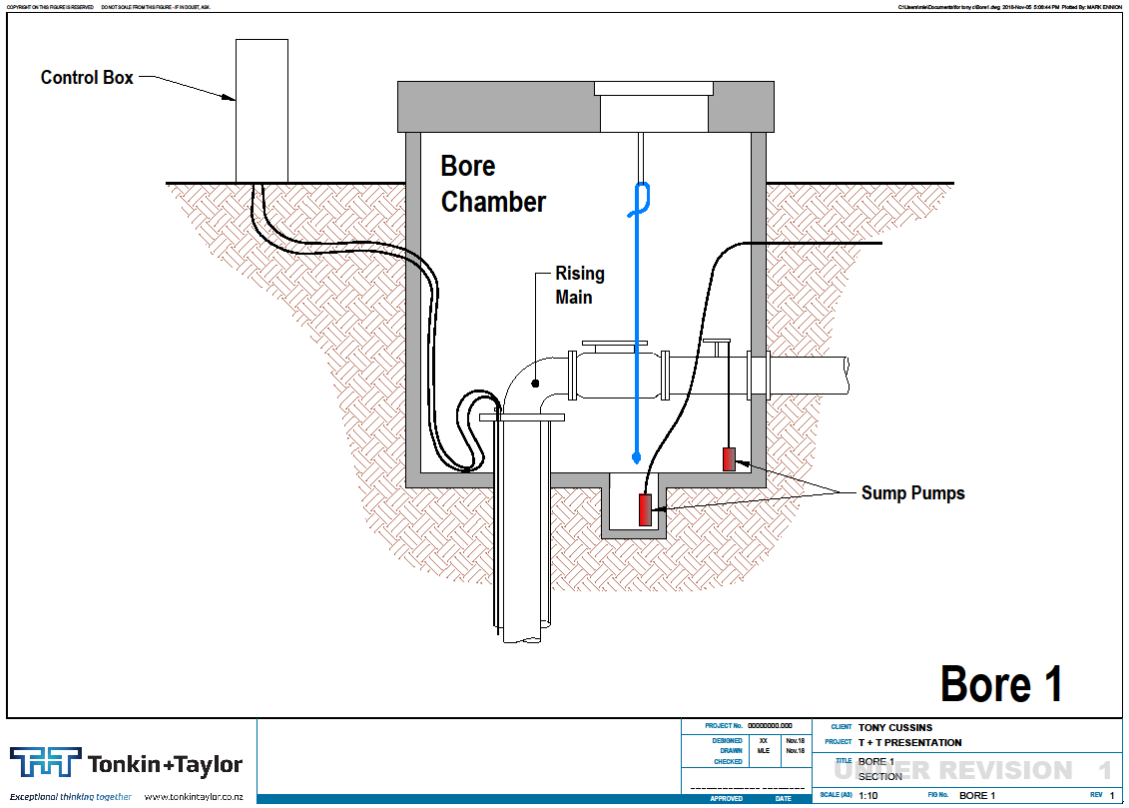
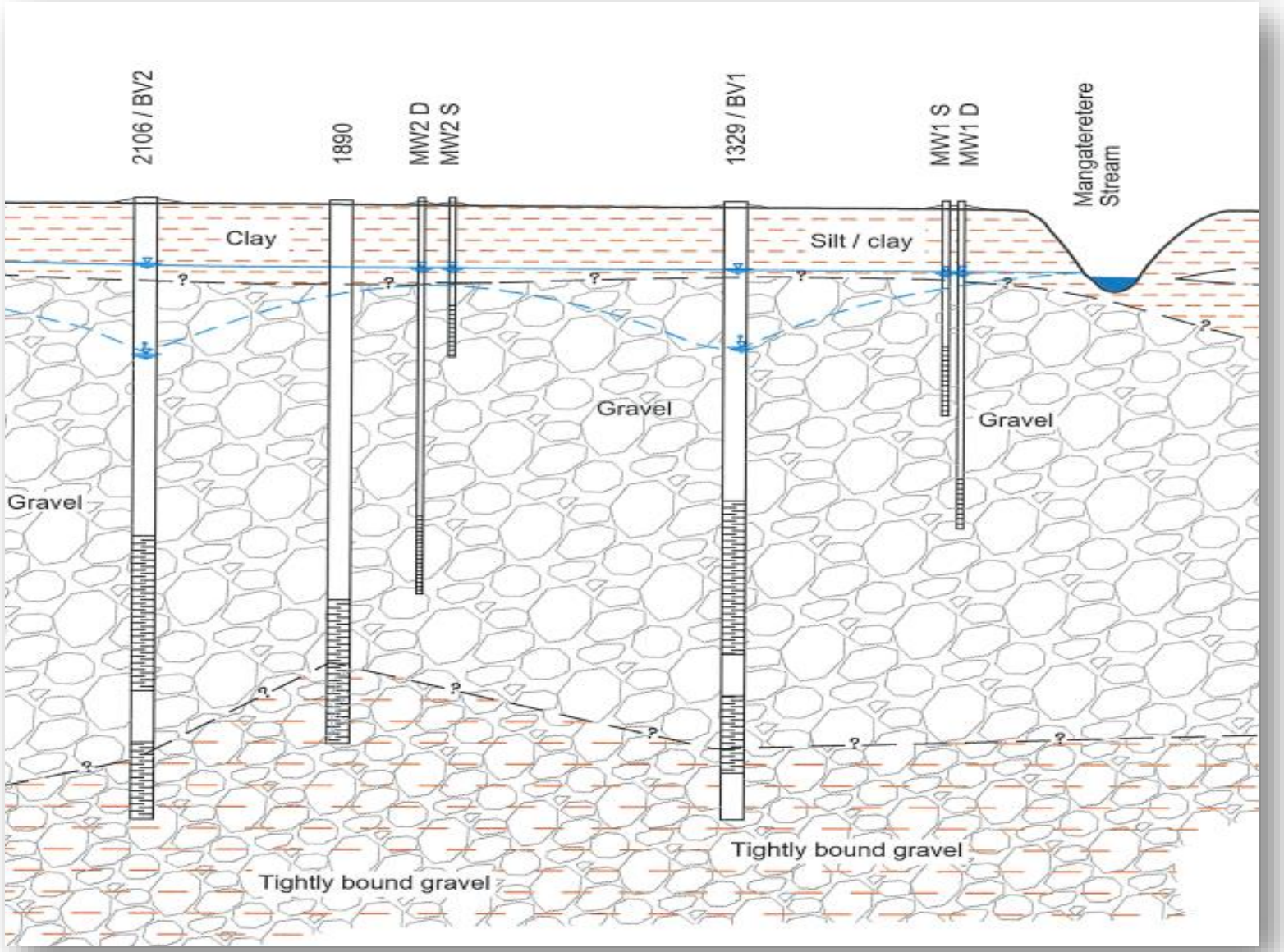




**Figure 16:** Simulated path lines and captures zones and travel times for BV1 and BV2 using an effective porosity of 0.02. BV 1 pumping at 90 L/sec, BV2 pumping at 15 L/sec.

# Brookvale Bore 1




# Conceptual hydrogeological model



# Age-tracer data (GNS)

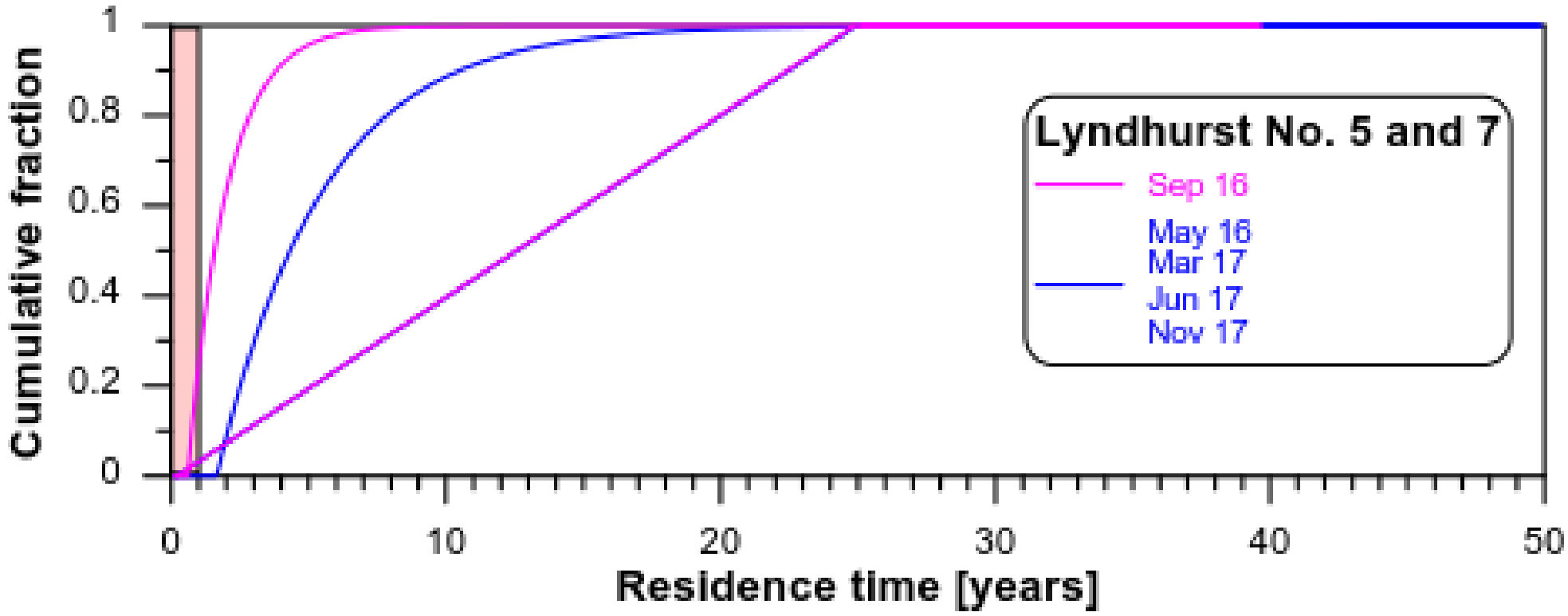



Figure 3.2 Modelled cumulative residence time distribution for the Lyndhurst No.5 and No.7 wells.

# HDC Broad scale Investigation

- 100+ sites evaluated, 140ha investigation area
- 10 priority sites identified for more detailed assessment, including:
  - Significant land disturbance, landfilling
  - Numerous uncapped bores
  - Potential areas of contaminated runoff
- Vulnerability of untreated water supply to contamination if non-secure

# Geophysics: Electromagnetic Induction (EM-34)

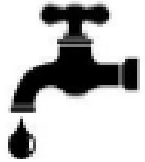

ScanTec Geophysical Consultants
PO Box 999, Whangarei, NEW ZEALAND
Tel +64 9 436 3966, Tel 021 376 644, info@scantec.co.nz
www.scantec.co.nz

| | |
|---|---|
| CLIENT | HDC, |
| PROJECT | Geophysical Surveys |
| DATE | Sep 2016 |
| PERSONNEL | MW, JM |
| EQUIPMENT | GPR 200MHz, 400MHz, EM34-3XL |
| CONTACT 1 | matt@scantec.co.nz |
| CONTACT 2 | 021-376-644 |

**Figure 3**

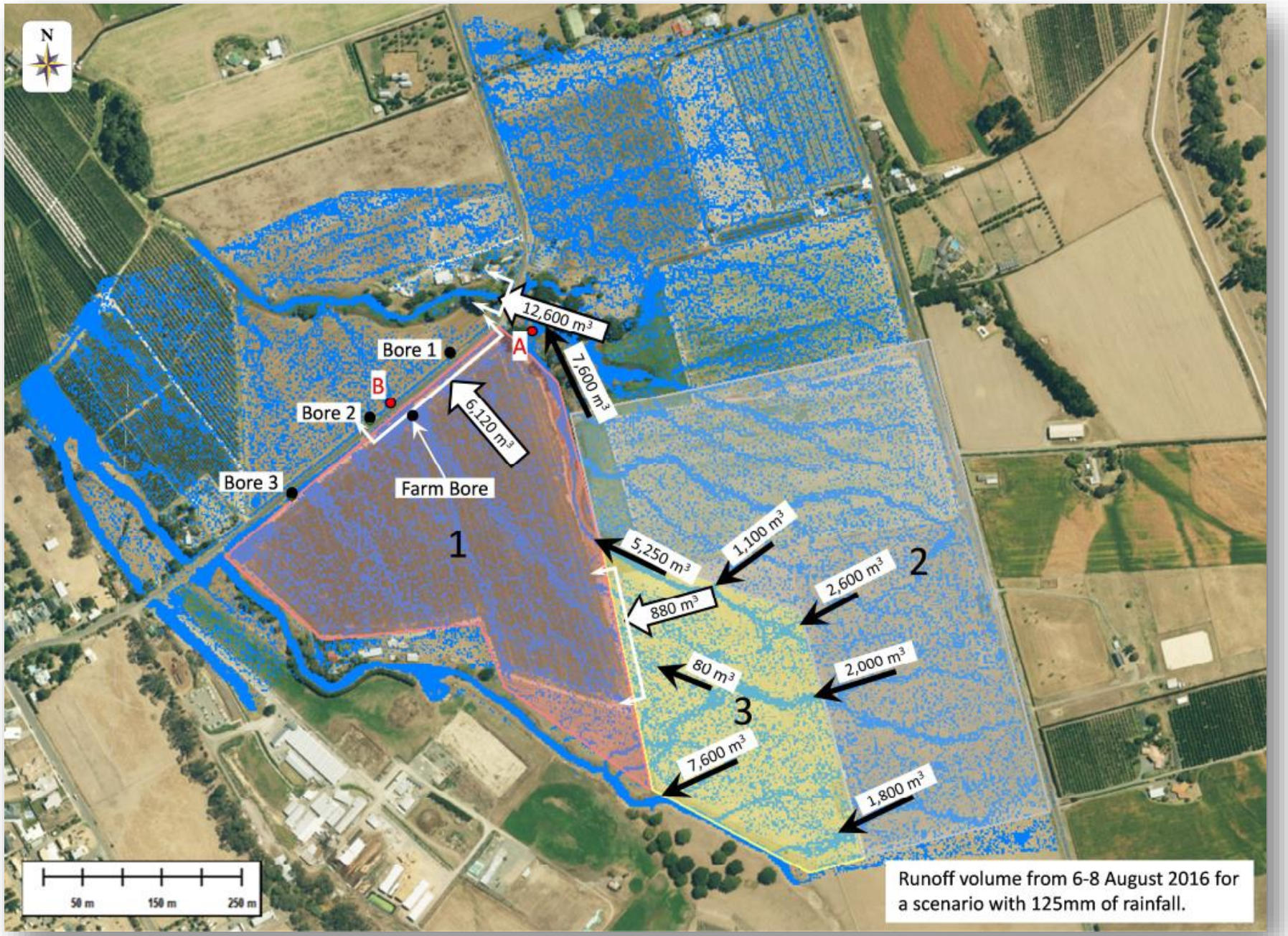
**Apparent Conductivity Map (Average values for 0-10m depth range) Measured using Electromagnetic Induction (EM-34)**

# Table 1: Summary of key genotypes of *Campylobacter* observed among samples of Havelock North

| Genotype Cluster | Source (numbers indicate the number of isolates analysed by MBiT, with in brackets, the number of those whole genome sequenced) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Human[1] | Reticulated water (12/8) | # | Bore | # | Animal Faecal (23/8) | # | Environmental | # |
| |  |  | |  | |  | |  | |
| CJ-16-001 ST42A/B | 98 (38) 49% | 41 Hikanui Dr<br>31 Endsleigh<br>Library | 1 (1)<br>7 (3)<br>3 (1) | Bore 1 (19/8) | 2 (1) | Sheep 96, Paddock 2<br>Sheep 98, Paddock 2 | 2 (1)<br>3 (1) | Drain 55204 (30/8) | 3 (1) |
| CJ-16-002 ST3610-A | 47 (19) 23% | - | - | - | - | Sheep 84, Paddock 2<br>Sheep 97, Paddock 2<br>Sheep 100, Paddock 2 | 3 (1)<br>3 (1)<br>2 (1) | Drain 55077 (16/8) | 4 (1) |
| CJ-16-003 ST8398-A | - | - | - | Bore 1 (12/8)<br>Bore 2 (12/8) | | - | - | Drain 55151 (24/8)<br>Pit 54536 (23/8) | 3 (1)<br>5 (1) |
| CJ-16-005 ST1517-A | 9 (4) 4% | 92 Endsleigh<br>Library | 4 (1)<br>1 (0) | Bore 1 (24/8) | 11 (1) | - | - | - | - |
| CJ-16-006 ST474-A | 9 (2) 4% | - | - | - | - | Sheep 93, Paddock 1 | 1 (1) | - | - |
| CJ-16-007 ST50-A | 3 (1) 2% | 41 Hikanui Dr | 6 (2) | - | - | - | - | - | - |

[1]Only emaining cases may also

Source: ESR Evaluation of water and animal faecal samples from Havelock North, August & September 2016.

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# Rainfall runoff

# Groundwater modelling

- Groundwater numerical modelling using MODFLOW and MODPATH
- Modelling results indicated a 1-2 day travel time between the Mangateretere Stream and Bore 1
- Contaminant fate & transport indicated *Campylobacter* survival in groundwater
- Viability supported by ESR (Dr Brent Gilpin)

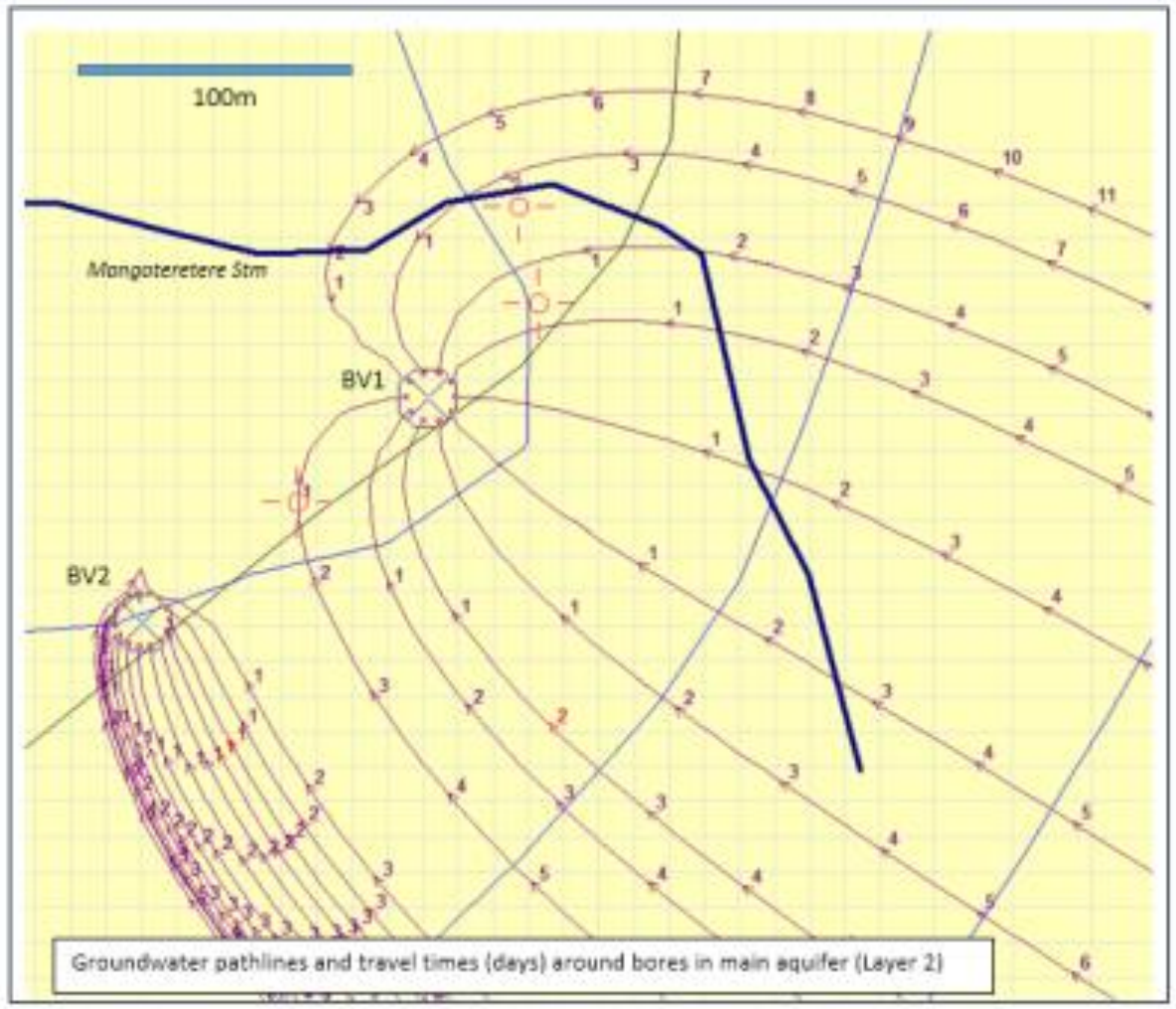
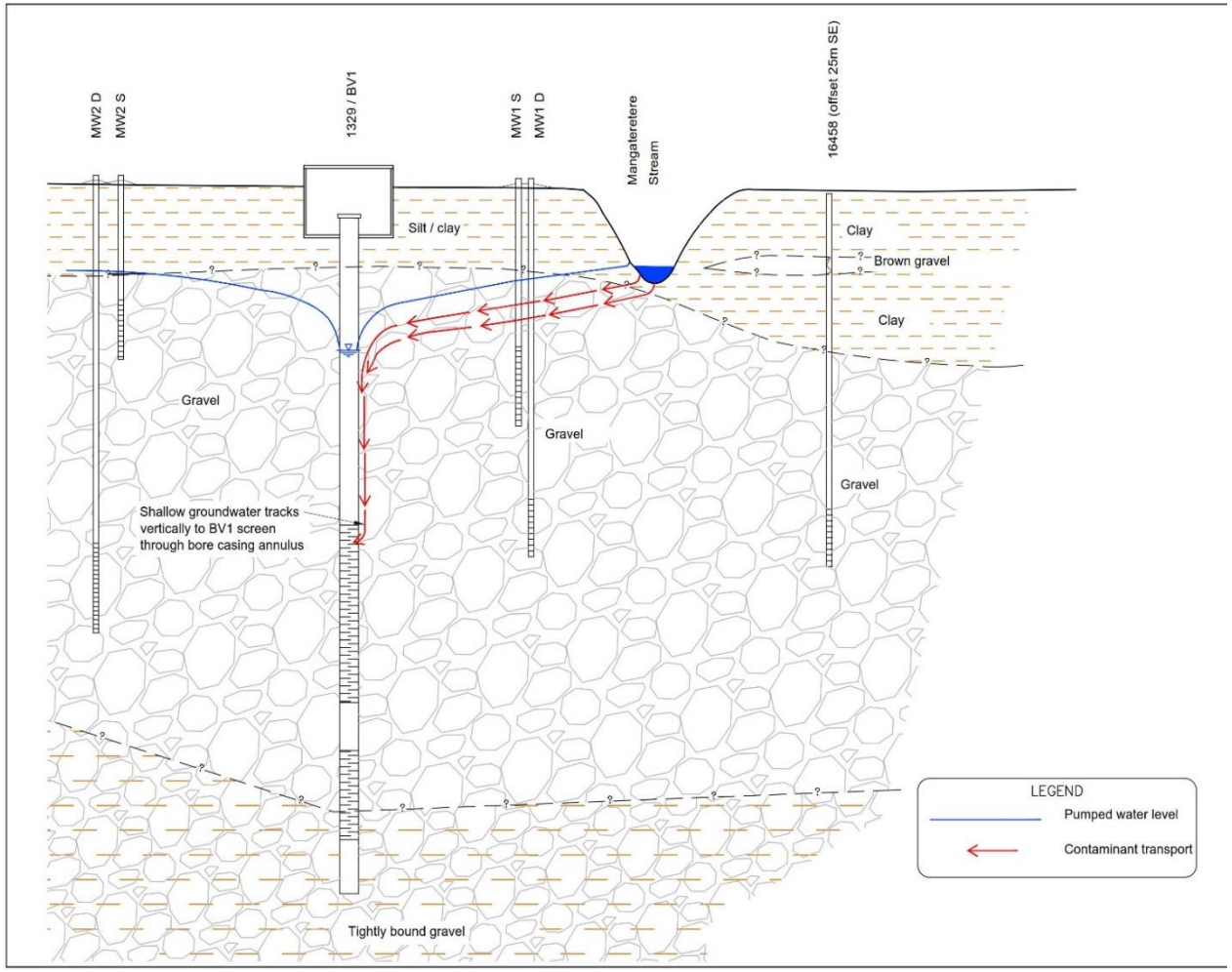



**Figure 16:** Simulated path lines and captures zones and travel times for BV1 and BV2 using an effective porosity of 0.02. BV 1 pumping at 90 L/sec, BV2 pumping at 15 L/sec.

# Key question: "Could *viable* pathogenic micro-organisms have travelled from the Mangateretere Stream ponded area to Bore 1?":

- Outbreak timeframe to match epidemiology (2 days)
- Concentration of > 5 MPN/100ml (Dr Brent Gilpin's estimate)
- Pathogenic micro-organisms in the monitoring bores, and pond including *E. coli*, *Campylobacter,* total coliforms
- O157:H7 in pond water



# Fluorescent dye tracer tests

- Dye tracer test undertaken in January 2017, with the following refinements:
  - Water levels in pond raised, 8kg of mass of fluorescein dye used
  - Pumping regimes (BV1 and BV2) synchronised to outbreak
  - Testing of a range of parameters including *E. coli, Campylobacter*, total coliforms
  - Rhodamine WT dye was used to assess a potential contaminant migration

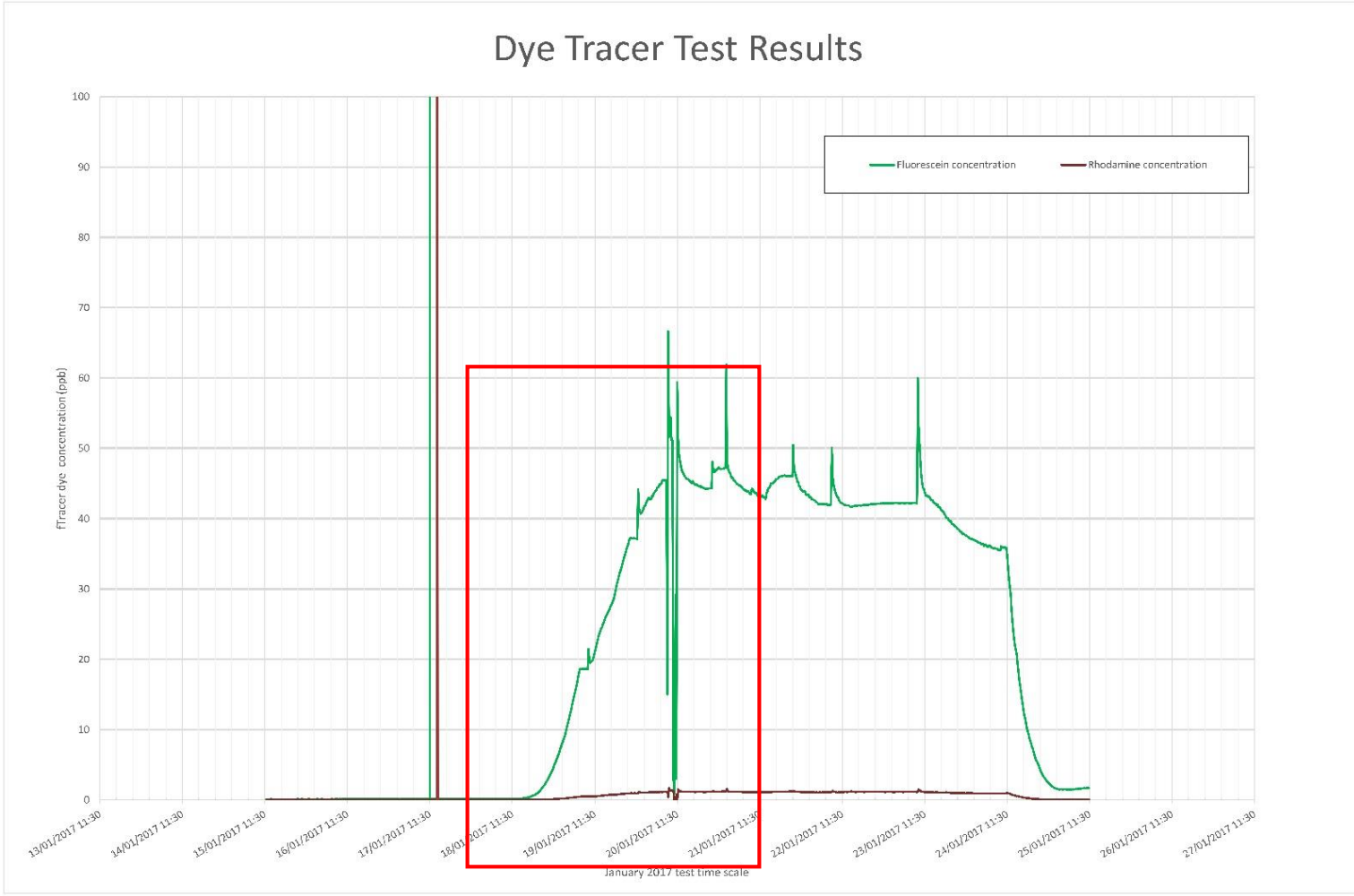

Dye Injection
Brookvale Bore 1
Approx. 95m

# Results of dye tracer tests

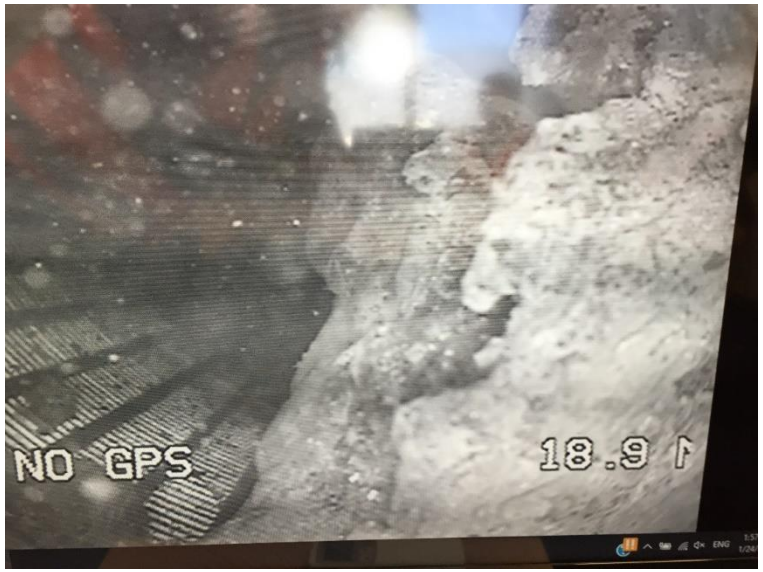
Fluorescein dye first appeared in Bore 1 approximately 29 hours after injection into the Mangateretere pond

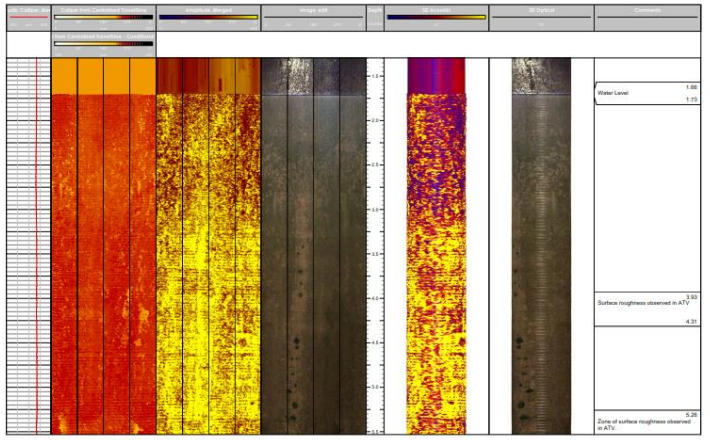
Strongly supported by contaminant data, including:

- *E.coli*
- *Campylobacter*
- *Total coliforms*
- O157:H7 pathogenic *E.coli* strain in pond



# Bore / casing assessments




High level float switch operation, casing integrity, downhole geophysics demonstrated casing integrity

# Outbreaks due to contaminated water sources

| Year | Location | Water Type | Pathogens | Cases Confirmed | Total Cases Estimated | Comments |
|---|---|---|---|---|---|---|
| 2000 | Walkerton, ON, Canada | Groundwater | *E. coli* O157:H7, *Campylobacter* | 163 (E)<br>105 (C)<br>12 both | 2,300<br>27 HUS<br>7 deaths | Cattle manure<br>Rainfall<br>Treatment failure |
| 2000–2001 | Asikkala, Finland | Groundwater | *Campylobacter jejuni* | 71 | 1450 | Rainfall<br>No treatment |
| 2002 | Transtrand, Sweden | Groundwater | Norwalk-like virus | 4 | ~500 | Leaking sewer pipe near bore<br>No treatment |
| 2001 | North Battleford, SK, Canada | Surface water | *Cryptosporidium parvum* type 1 | 375 | 5,800–7,100<br>50 hospitalised | Sewage discharges upstream drinking water intake |
| 2010 | Östersund, Sweden | Surface water | *Cryptosporidium* | >29 | 27,000<br>270 hospitalised | |

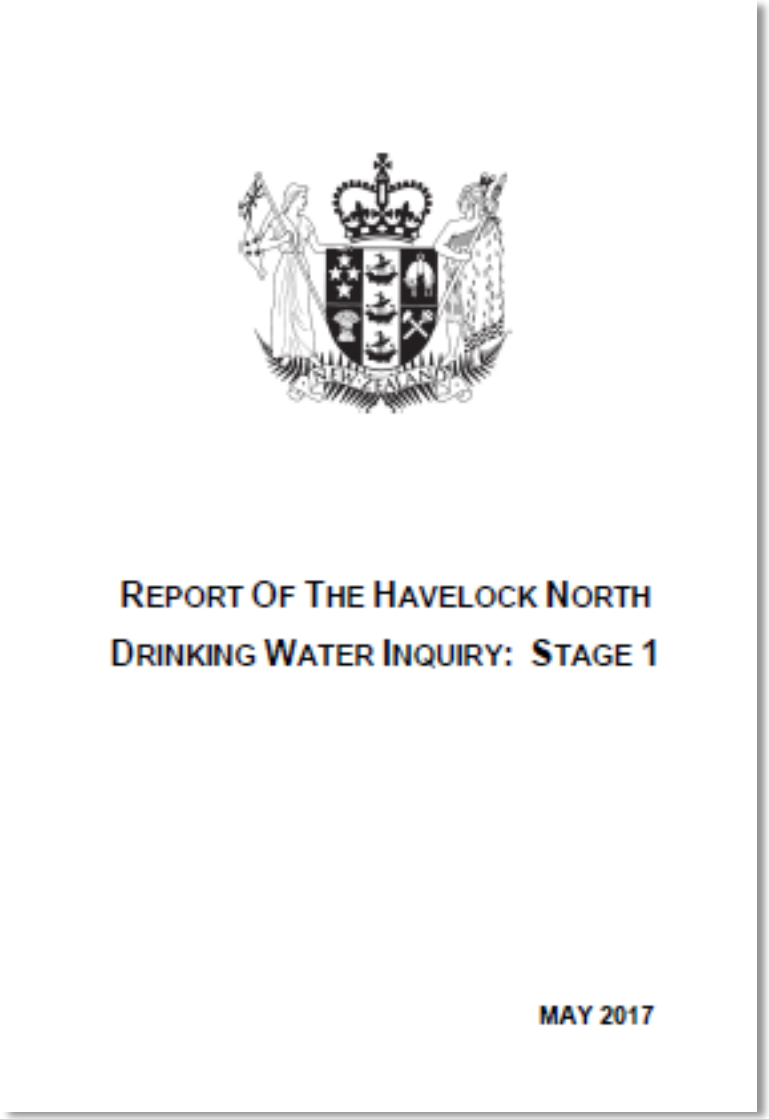
# Havelock North Drinking Water Inquiry – Stage 1 report key findings (s10)

*(a) Contaminated drinking water was the source of the campylobacter bacterium. Sheep faeces were the likely source of the campylobacter.*

*(b) Highly likely that after heavy rain on 5 and 6 August 2016, contaminated water in the pond entered the aquifer and flowed across to Brookvale Road bore 1.*

*(c) Contamination may also have entered drains adjacent to Brookvale Road bores 1 and/or 2, but much less likely.*

REPORT OF THE HAVELOCK NORTH DRINKING WATER INQUIRY: STAGE 1, May 2017



# Inquiry Stage 2 – Findings

- Systemic failures in water industry at all levels
- 700,000 New Zealanders potentially exposed to unsafe Drinking-water
- Competency/training/certification is lacking
- Enhanced monitoring required to demonstrate compliance with DWSNZ
- Drinking Water Standards NZ need reviewed
- Water Safety Plans require significant improvement – risk based, multi-barrier approach

REPORT OF THE HAVELOCK NORTH DRINKING WATER INQUIRY: STAGE 2

DECEMBER 2017

# Inquiry Stage 2 – Recommendations

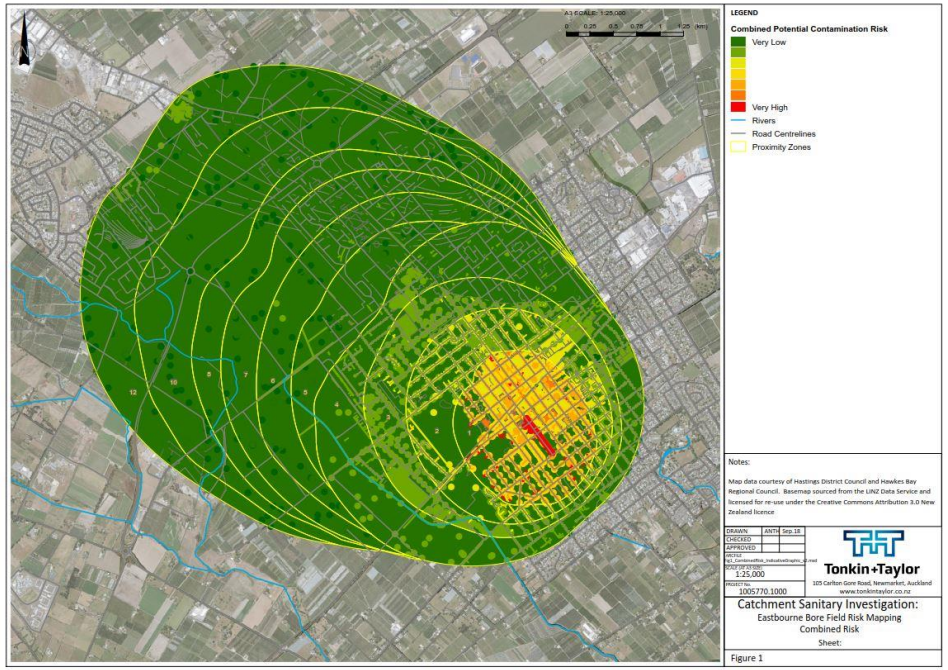
- All Drinking-water treated, including a residual disinfection
- Dedicated, independent Drinking water regulator
- Water suppliers should be licensed, aggregated
- Enforcement policy for safe drinking water
- Secure bore water classification should be abolished;
- Joint Working Groups will oversee Drinking-water safety in their region
- Design / construction / operation of bores

REPORT OF THE HAVELOCK NORTH
DRINKING WATER INQUIRY: STAGE 2

DECEMBER 2017

# Case Study 2: Risk based Groundwater Source Protection zones

- Catchment Sanitary Investigations (CSIs)
- Source protection zones (SPZs)
- Identify existing land uses and activities that may pose a risk to drinking water safety
- Develop risk matrix / heat map in ArcGIS
- Statutory controls to manage activities within catchments - level of risk posed to the drinking water supplies
- Direct risk management, including treatment/disinfection



# Applying risk management to drinking water supply systems…

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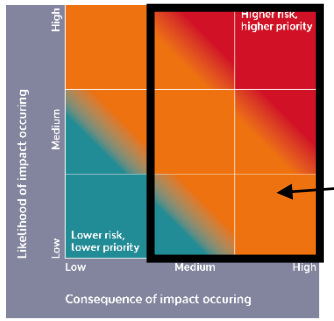
Raw Water Supply Systems
- Rivers
- Groundwater
- Dams
- Etc…

Water Treatment Systems
- Monitoring
- Filtration
- Disinfection
- Etc.

Water Distribution Systems
- Piping
- Pumping
- Storage
- Etc.

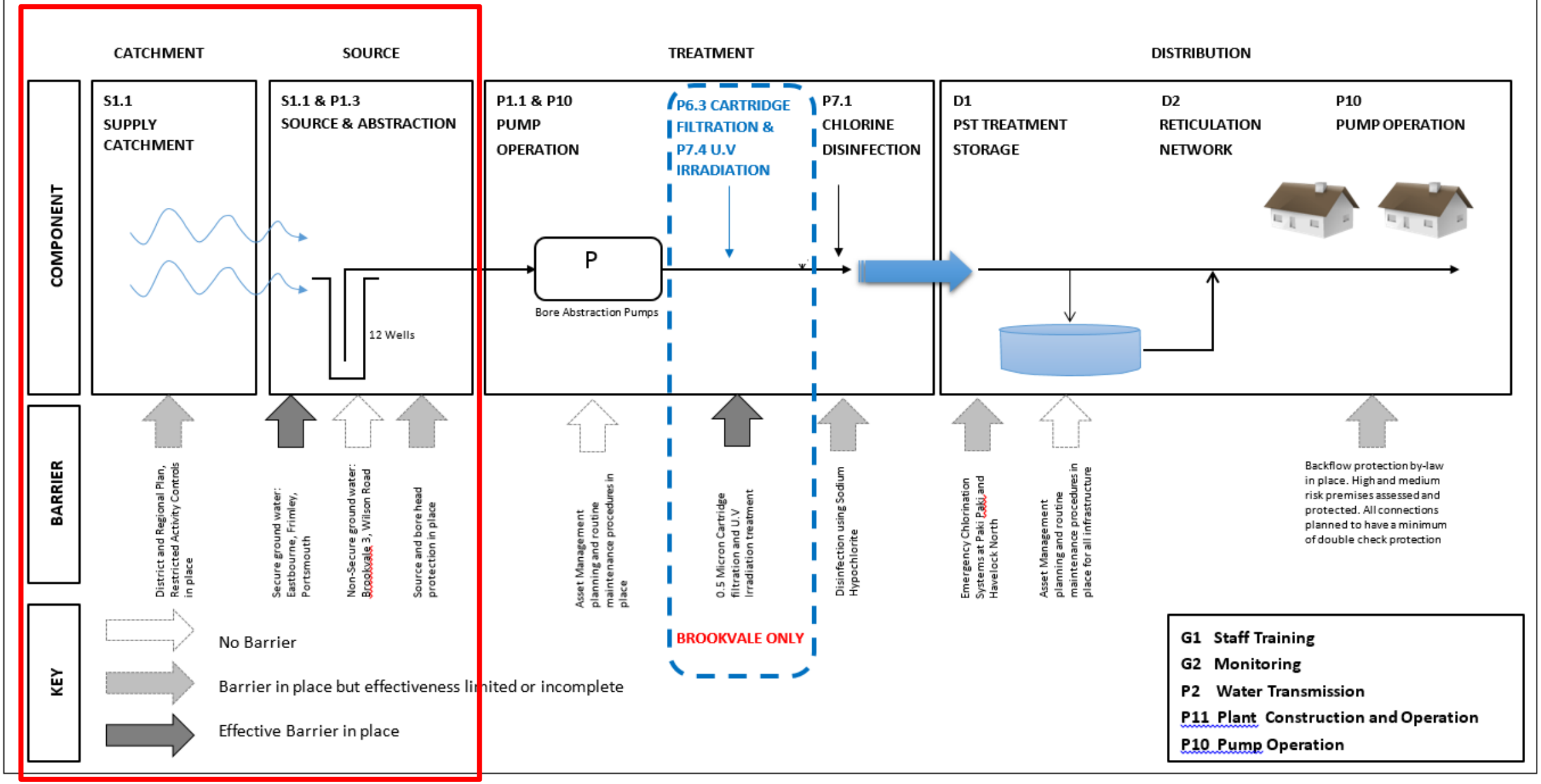
Direct from supply to consumption

*What are the risk and mitigation options for each step from supply to tap?*




Many argue that this entire area is red zone for drinking water…

# Hastings, Havelock North, Flaxmere, Bridge Pa and Paki Paki WSP



# Sources – surface water, groundwater

## Toxic algae bloom in Lake Taupo could cause breathing difficulties

8 Dec, 2017 1:22pm

4 minutes to read


## Havelock North – Brookvale Bore 3 WTP

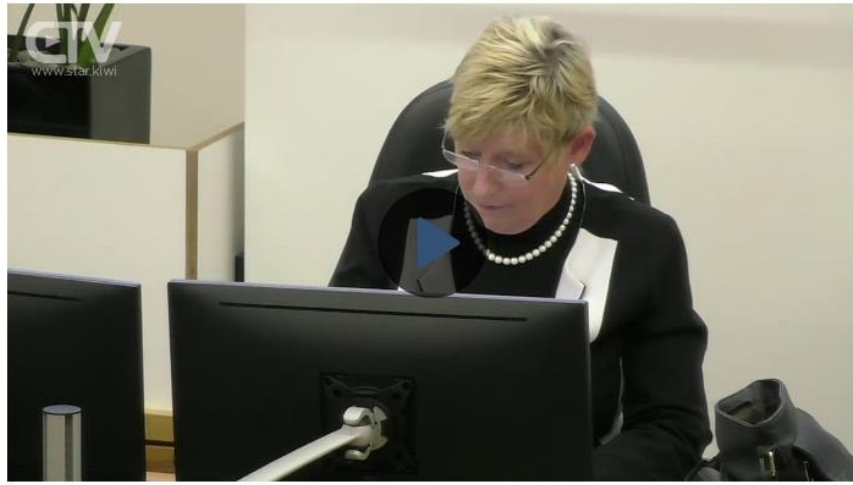
## Timaru District Council water supplies need upgrading

MATTHEW LITTLEWOOD
Last updated 15:34, April 6 2018

Stephen Barker/Stuff

Time is running out for Timaru district residents to have their say on a council proposal to meter water supplies.

## Fixing Christchurch City's drinking water comes with multi-million dollar price tag

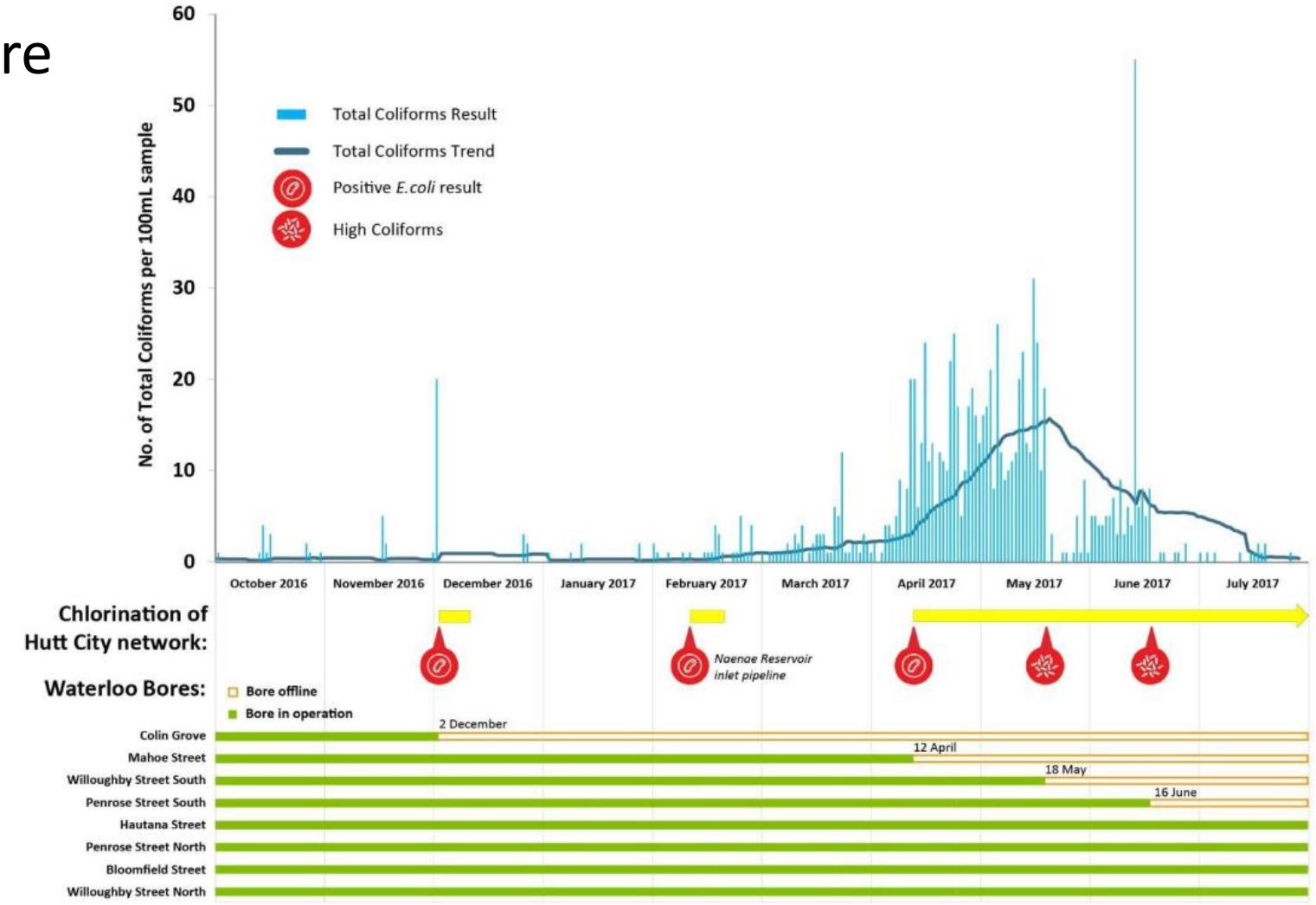



The multi-million dollar cost of fixing the city's well heads has been revealed.

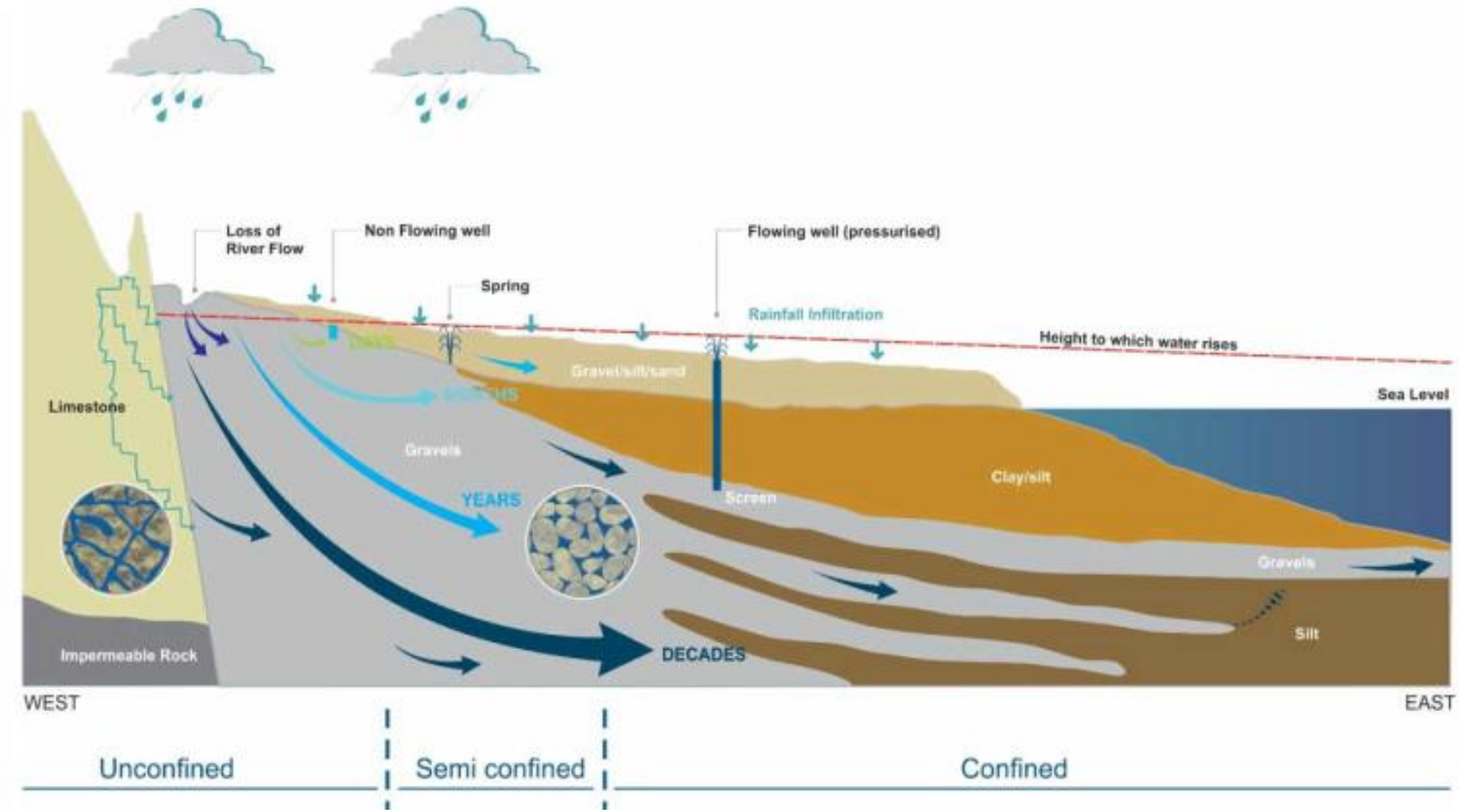
A city council report has shown two options to regain water secure status. The preferred will cost $21.5 million.

# Source contamination events

- Catchment management failure
- Bore security failure (widespread)
- Rainfall (Havelock North, Watercare and many others)
- Drought
- Major earthworks
- Earthquake (Christchurch, Waiwhetu Aquifer)
- Havelock North outbreak – “Swiss Cheese model”



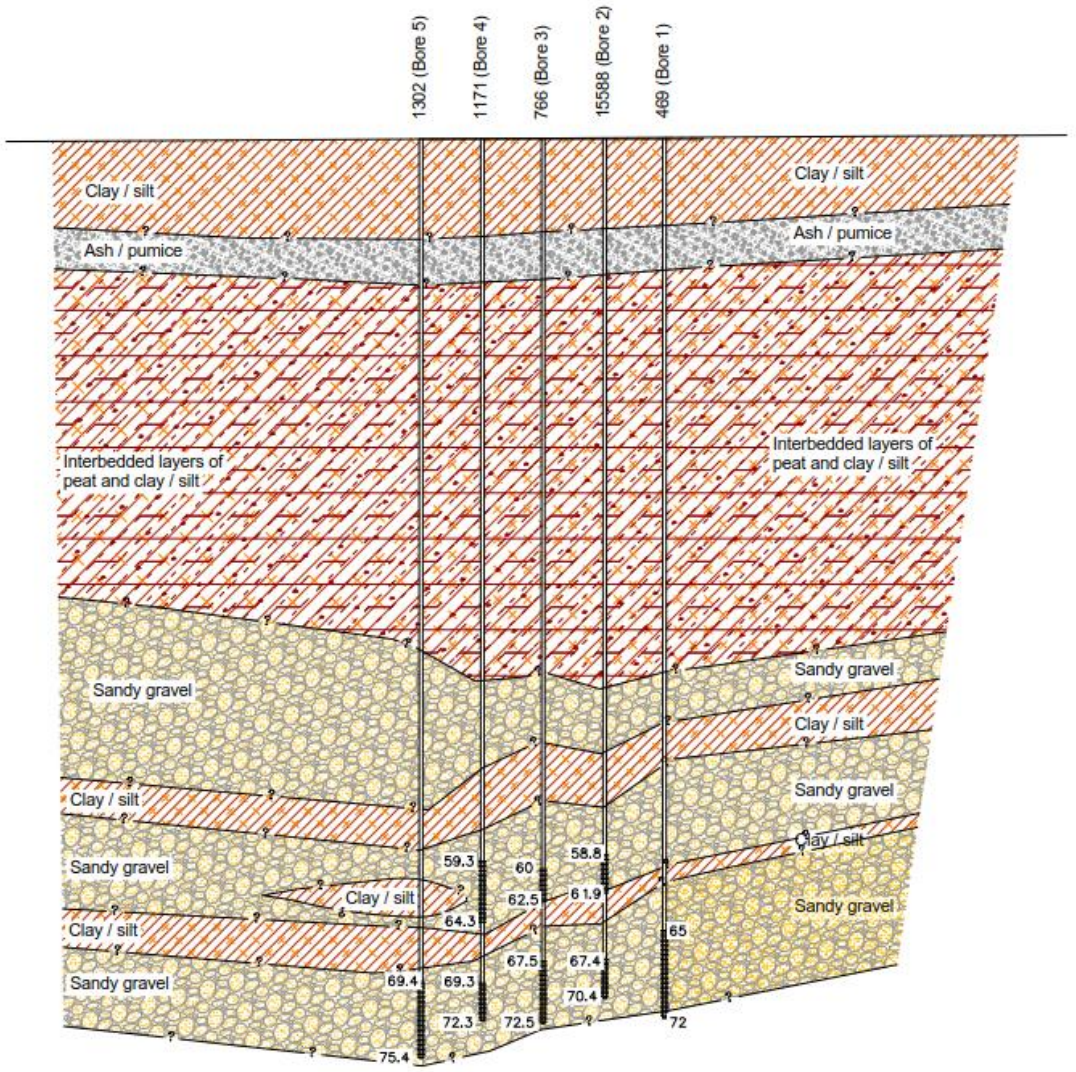
# Heretaunga Plains conceptual hydrogeology




*HBRC Report No. RM 1619 - 4803 (Groundwater Quality State of Environment; State and Trends; September 2016)*

# Eastbourne Street bore field

- Aquitards are not continuous
- 3 source aquifers are part of the same hydrogeological unit/aquifer (a leaky system)
- Potential for downward movement of groundwater from surface
- Evidence of influence of rainfall or mixed source water – trend is toward younger water

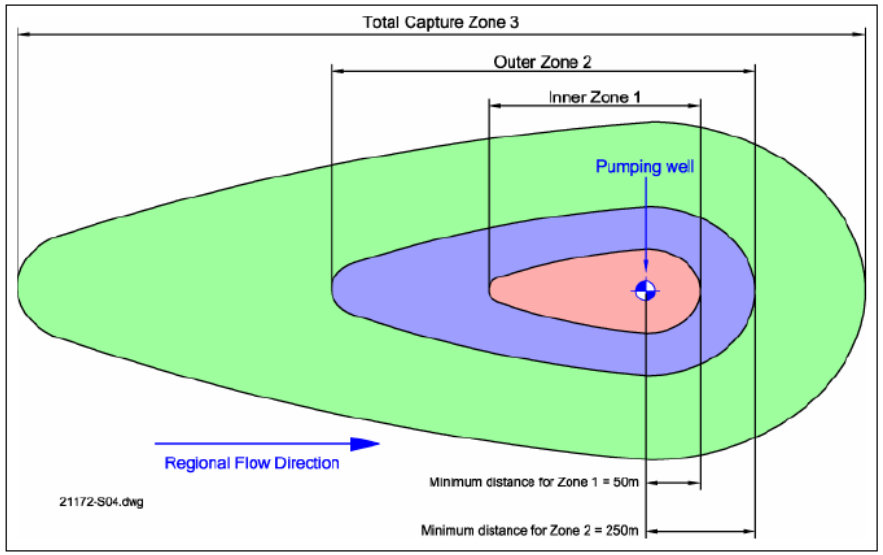


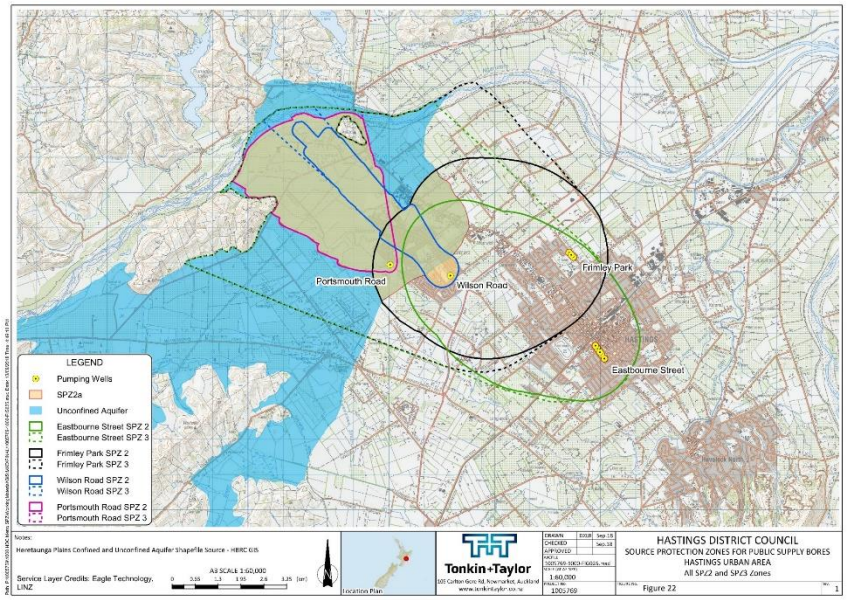
# Approach for developing SPZs

Adopted GNS Science (GNS) method to establish the SPZ's, comprising 3 individual zones for each bore field:

- **Immediate protection zone (SPZ1):** a 5m setback zone around each bore head to allow for specific control (by statute, regulation, planning rule)
- **Microbial protection zone (SPZ2):** analytical modelling represents a 1 year groundwater travel time from source to bore field
- **Capture zone (SPZ3):** the full capture zone

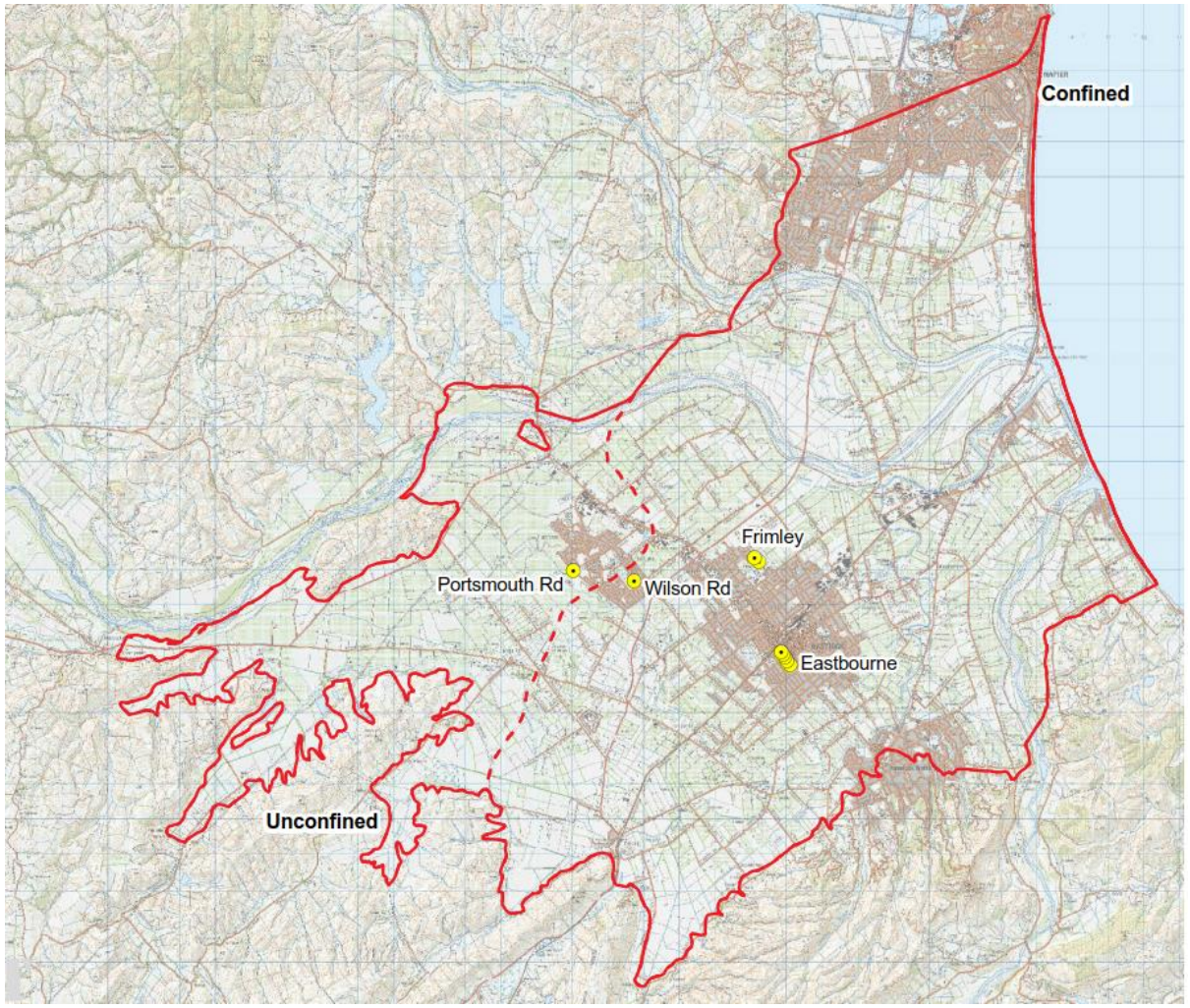
Source: *GNS Science, 2014. Envirolink Tools Project – Capture Zone Delineation – Technical Report, 2013/57.98p*.

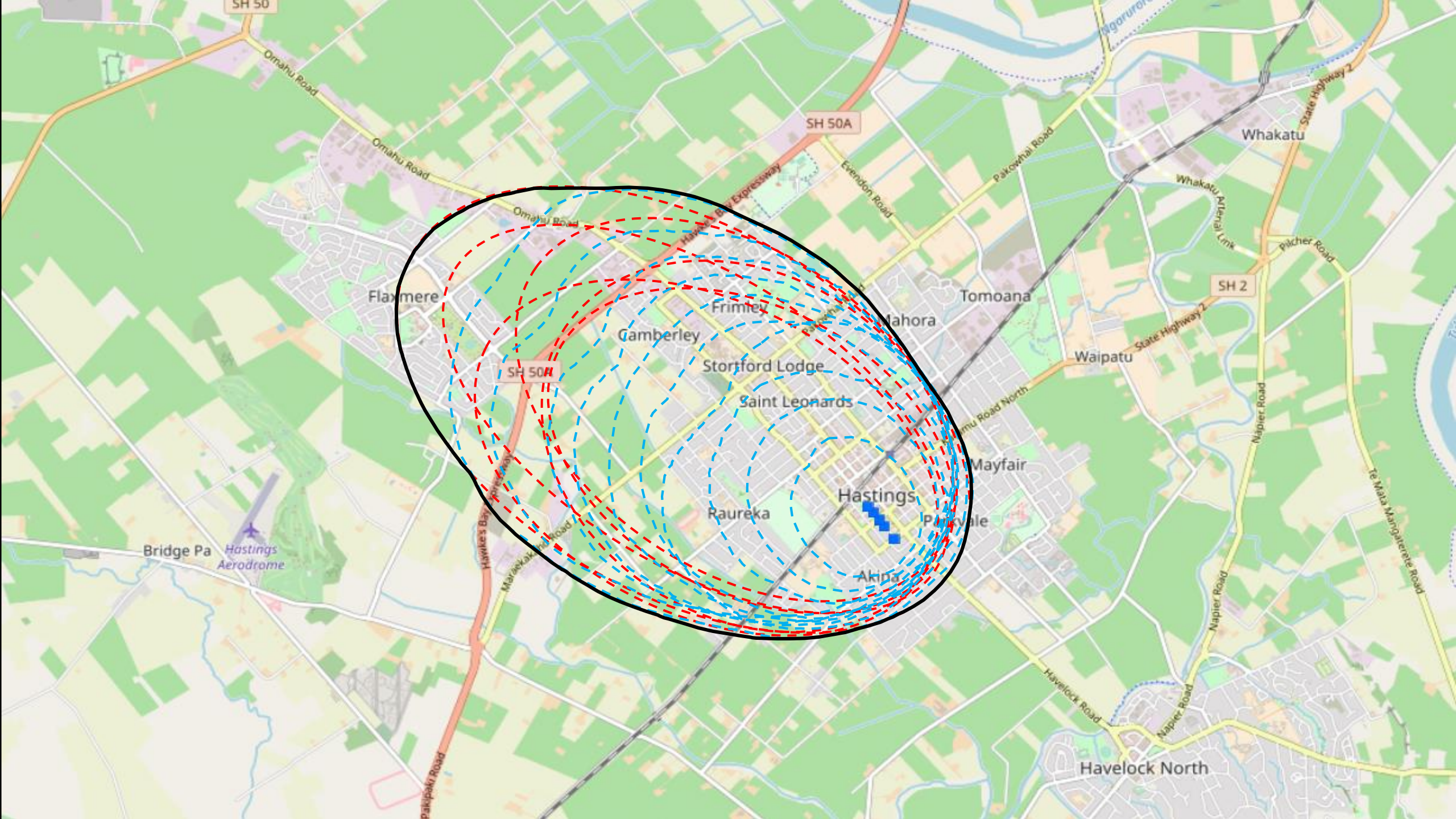


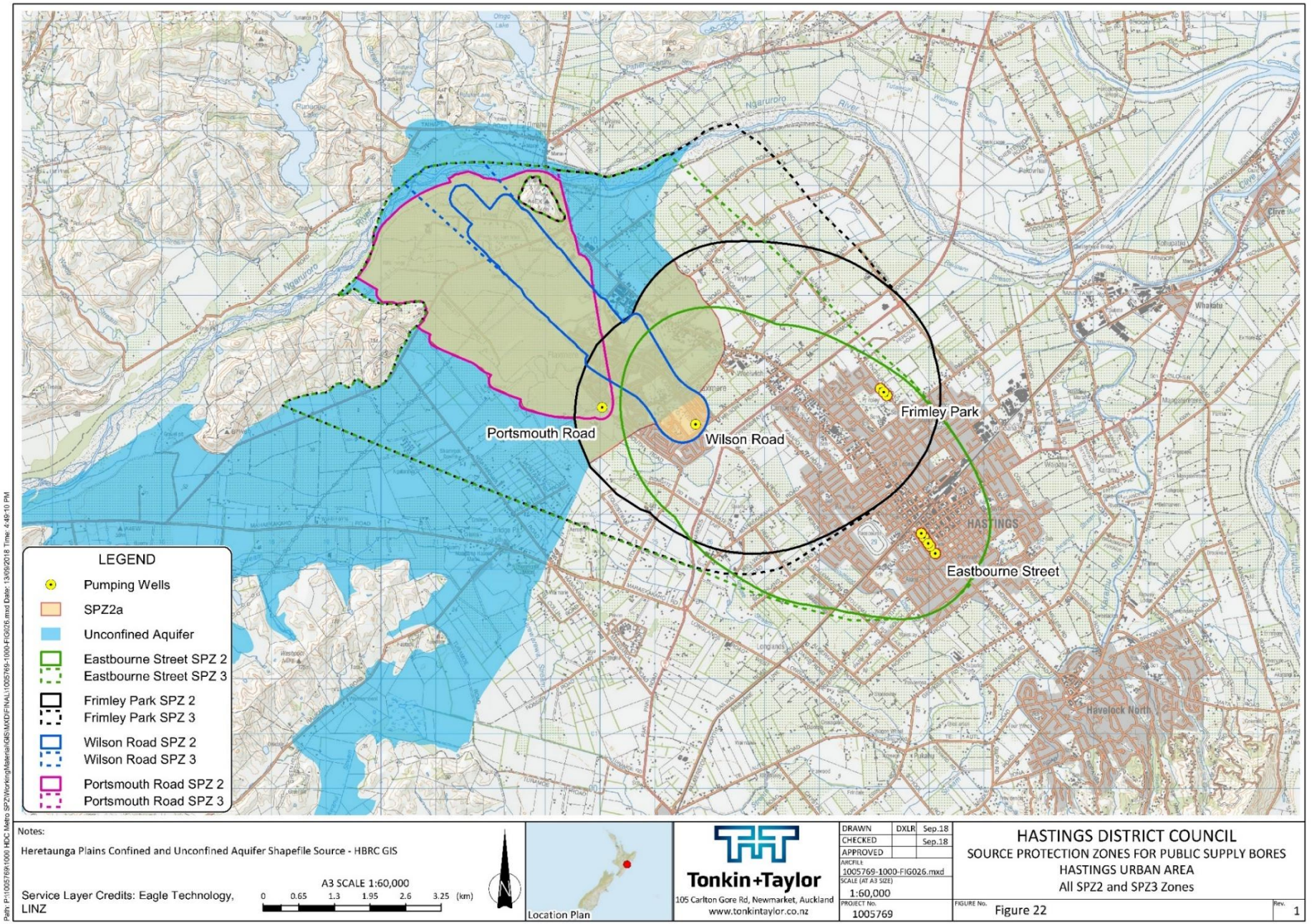



# HDC Source protection zones

- SPZs were defined for four Hastings metropolitan water supply bore fields
- Developed using USEPA WhAEM software
- SPZs determine future management areas for each of the bore fields, including:
    - Eastbourne Street
    - Wilson Road
    - Portsmouth Road
    - Frimley Park




SH 50
Omahu Road
SH 50A
Evendon Road
Pakowhai Road
Whakatu
State Highway 2
Whakatu Arterial Link
Pitcher Road
SH 2
Flaxmere
Frimley
Tomoana
Mahora
Gamberley
Stortford Lodge
Saint Leonards
Waipatu
SH 50A
Mayfair
Hastings
Raureka
Parkvale
Akina
Bridge Pa
Hastings Aerodrome
Hawkes Bay Expressway
Maraekakaho Road
Napier Road
Havelock Road
Havelock North
Te Mata Mangaterere Road
Pakipaki Road




Notes:

Heretaunga Plains Confined and Unconfined Aquifer Shapefile Source - HBRC GIS

Service Layer Credits: Eagle Technology, LINZ

A3 SCALE 1:60,000

0 0.65 1.3 1.95 2.6 3.25 (km)

Location Plan

Tonkin+Taylor
105 Carlton Gore Rd, Newmarket, Auckland
www.tonkintaylor.co.nz

| | | |
|---|---|---|
| DRAWN | DXLR | Sep.18 |
| CHECKED | | Sep.18 |
| APPROVED | | |
| ARCFILE | 1005769-1000-FIG026.mxd | |
| SCALE (AT A3 SIZE) | 1:60,000 | |
| PROJECT No. | 1005769 | |

HASTINGS DISTRICT COUNCIL
SOURCE PROTECTION ZONES FOR PUBLIC SUPPLY BORES
HASTINGS URBAN AREA
All SPZ2 and SPZ3 Zones

FIGURE No. Figure 22 Rev. 1

Path: P:\1005769\1000 HDC Metro SPZ\Working\Material\GIS\MXD\FINAL\1005769-1000-FIG026.mxd Date: 13/09/2018 Time: 4:49:10 PM

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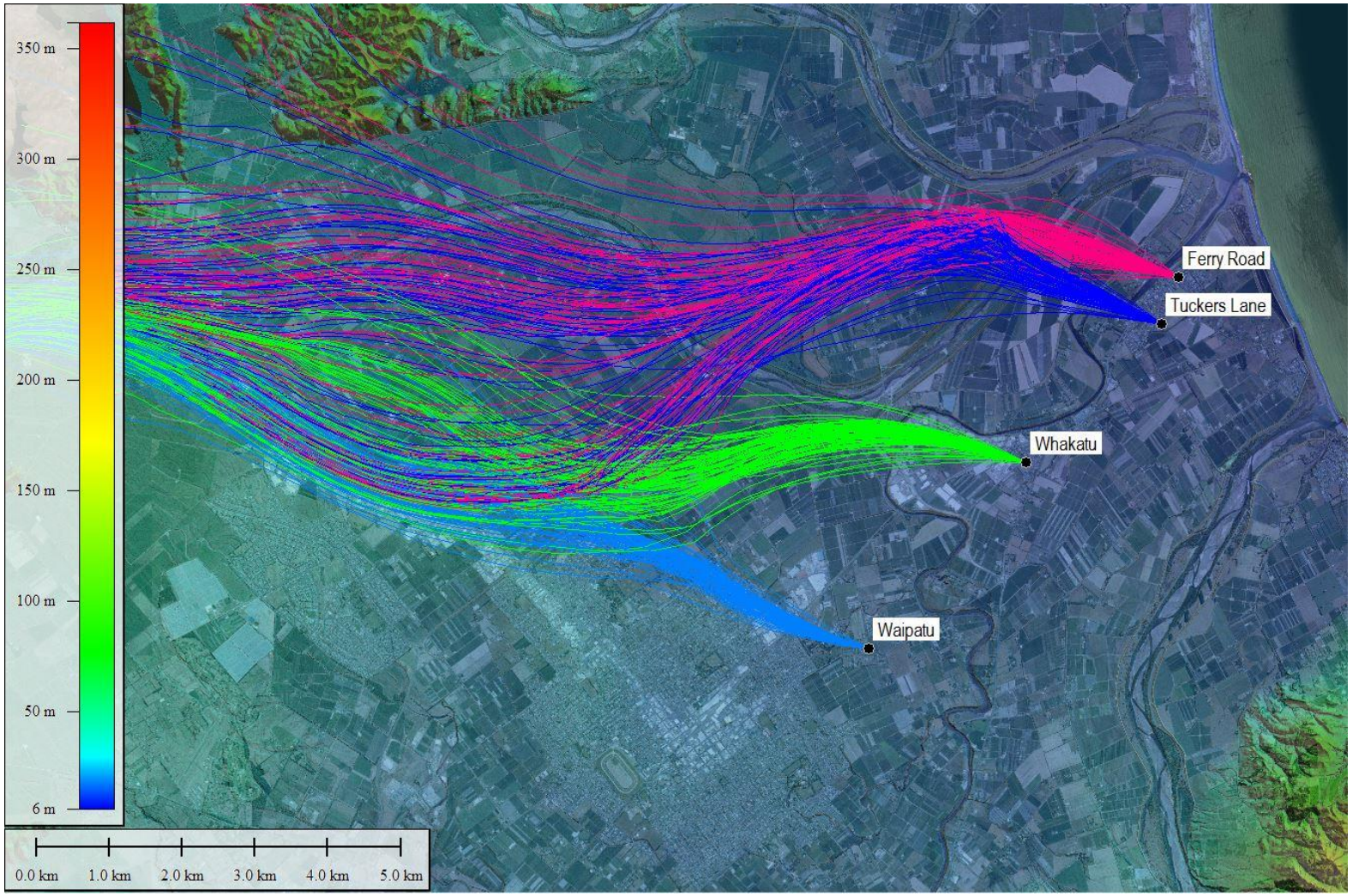
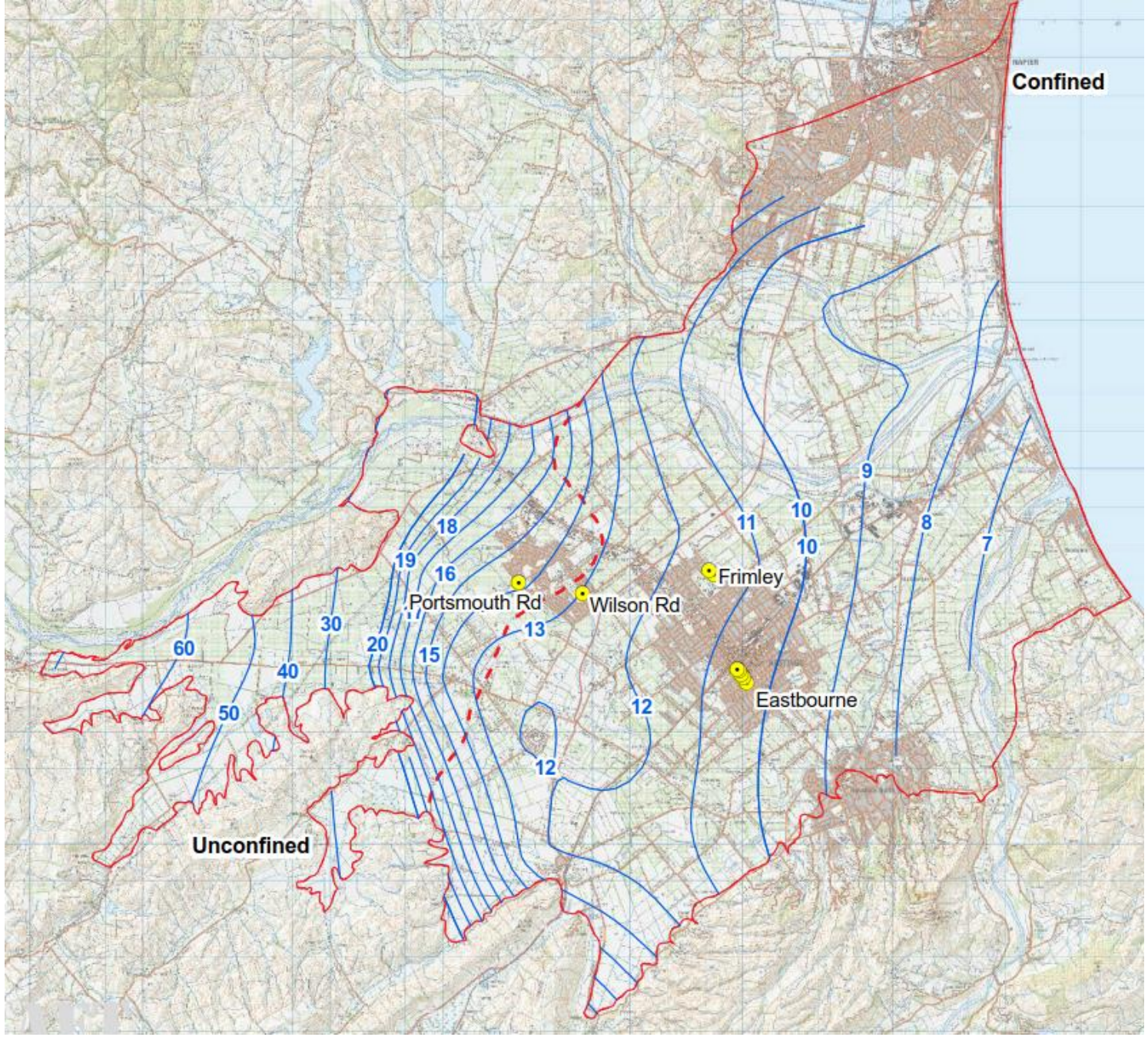
# Groundwater models




- Analytical Element Models (AEM)
- AnAqSim: Analytic Element Modelling Software for Multi-Aquifer, Transient Flow
- Well Head Analytic Element Model (WhAEM)
- GNS SPZ models
- Numeric models based on Modflow/Modpath/MT3D
- Point source assessment e.g. PFAS from firefighting facility

# Potential contaminant sources

- Active and abandoned wastewater infrastructure (microbiological)
- Onsite wastewater disposal/treatment (microbiological)
- Former gasworks sites (hydrocarbons/ heavy metals)
- Dry-cleaning (chlorinated solvents)
- Heavy industry (various)
- Bulk storage of chemicals
- Dairy feed lots or intensive calf rearing (protozoa)
- Emerging contaminants of concern (e.g. PFAS, endocrine disruptors)

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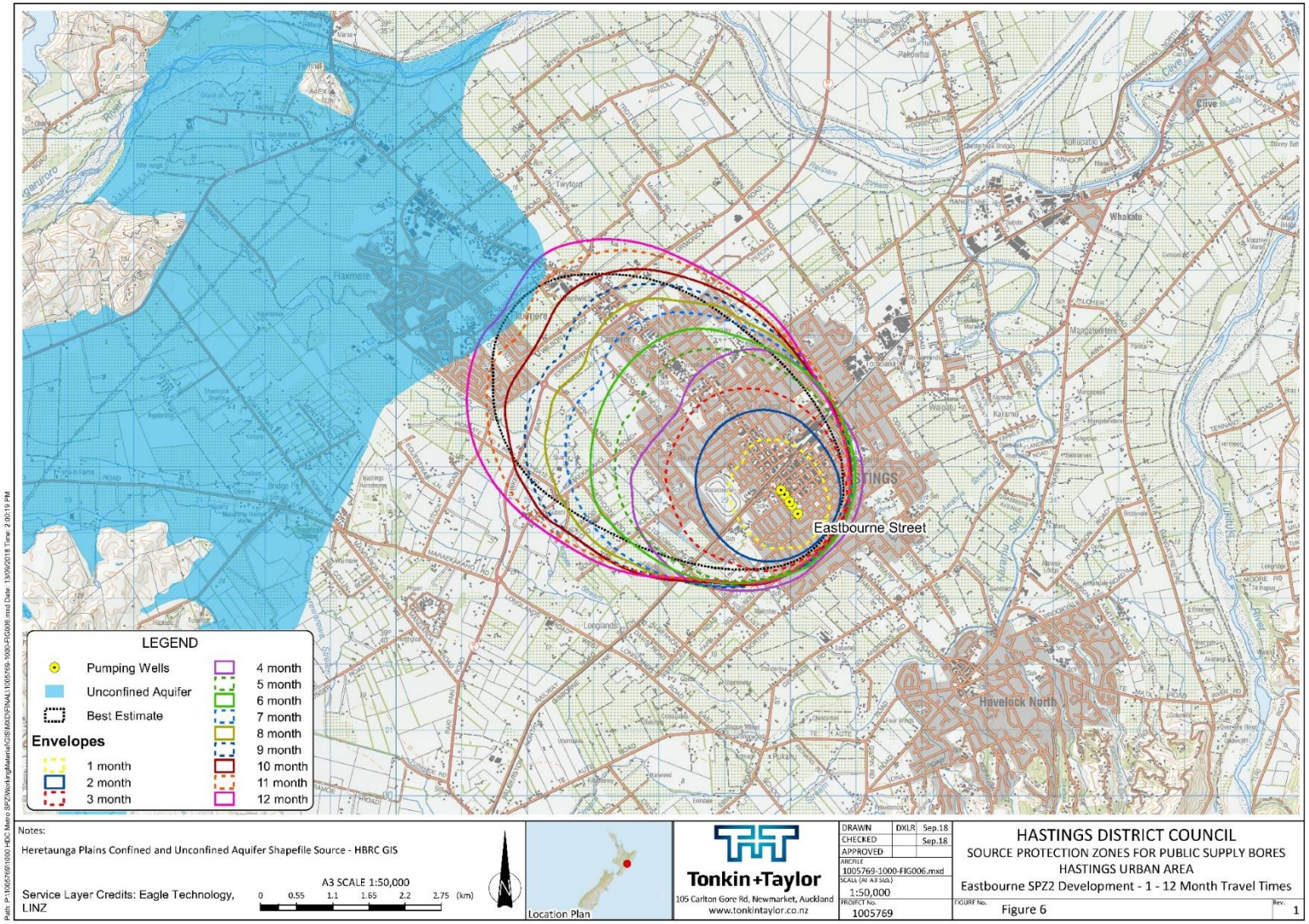
# Average summer groundwater level contours (February 2012 - 2015

LEGEND

- Pumping Wells
- Piezometric contours m RL (Feb 2012-15 Avg Data)
- Heretaunga Aquifer System

# Sensitivity analysis - SPZ2 zones

- Analysis captures the range of groundwater flow regimes that develop over relatively short periods of time (1 – 12 months)
- Final SPZ2 encompasses the range of groundwater flow regimes that develop inside a 1 year groundwater travel time
- Analysis includes hydraulic parameters (Kh, Kv, effective porosity etc.)

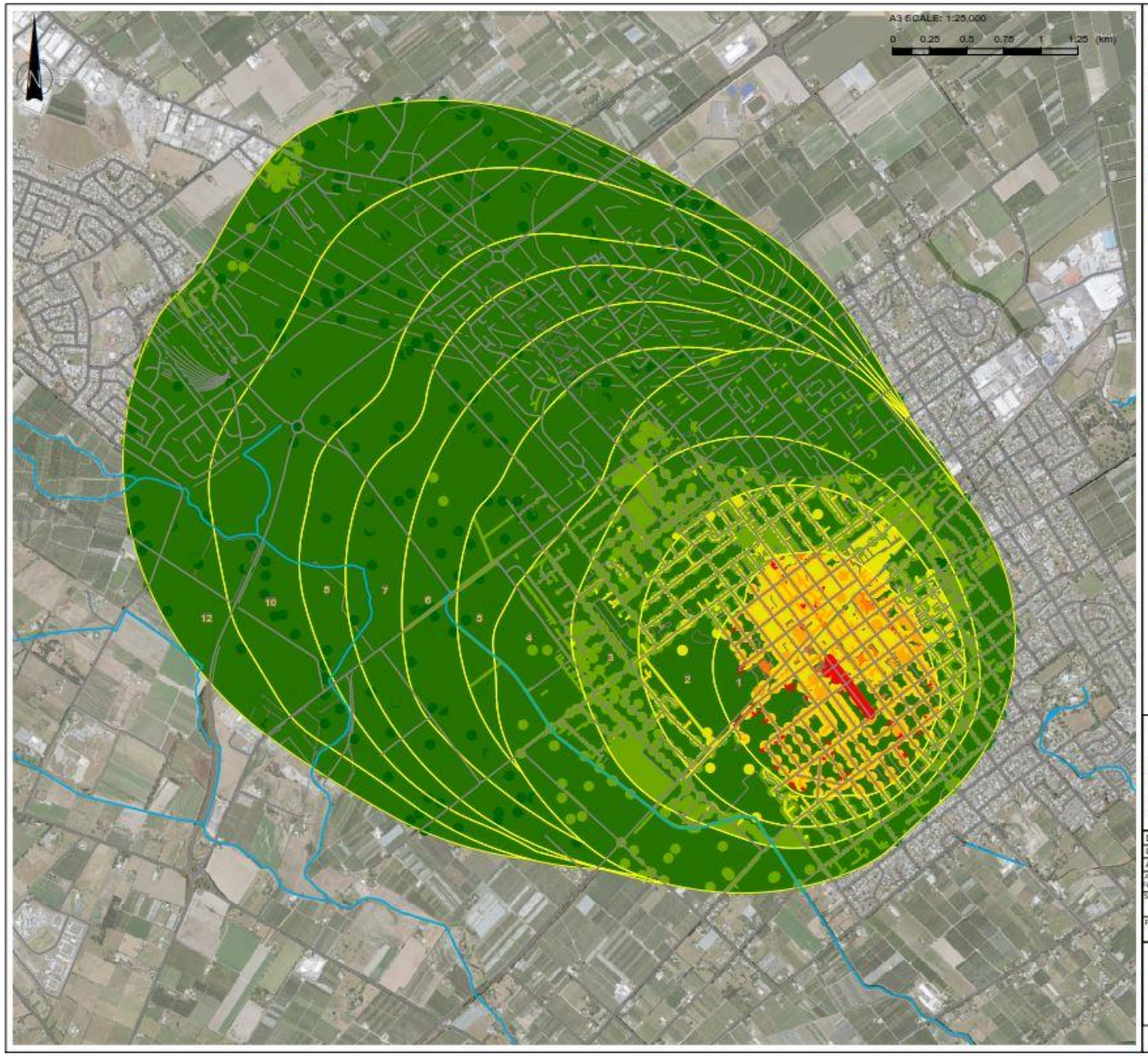


# Non-microbial contaminants

Non-microbiological contaminants for each bore field for following sources:

- Arsenic from orchard and timber treatment sites,
- Boron and PCP from timber treatment sites,
- BTEX from petrol stations,
- TCE, PCE from dry cleaners and workshop sites.

- Organic contaminants: contaminant migration in groundwater, biodegradation and dispersion.
- Levels would be below DWSNZ for plumes originating outside the SPZ, except for TCE (factor of 8 above DWS)
- Suitable for evaluation of emerging contaminants of concern e.g. PFAS




**LEGEND**

**Combined Potential Contamination Risk**

- Very Low
- Very High
- Rivers
- Road Centrelines
- Proximity Zones

Notes:

Map data courtesy of Hastings District Council and Hawkes Bay Regional Council. Basemap sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence

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| DRAWN | ANTH | Sep.18 |
| CHECKED | | |
| APPROVED | | |

ARCFILE: Fig1_CombinedRisk_IndicativeGraphic_v2.mxd

SCALE (AT A3 SIZE): 1:25,000

PROJECT No.: 1005770.1000

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105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

Catchment Sanitary Investigation:
Eastbourne Bore Field Risk Mapping
Combined Risk

Sheet:

Figure 1

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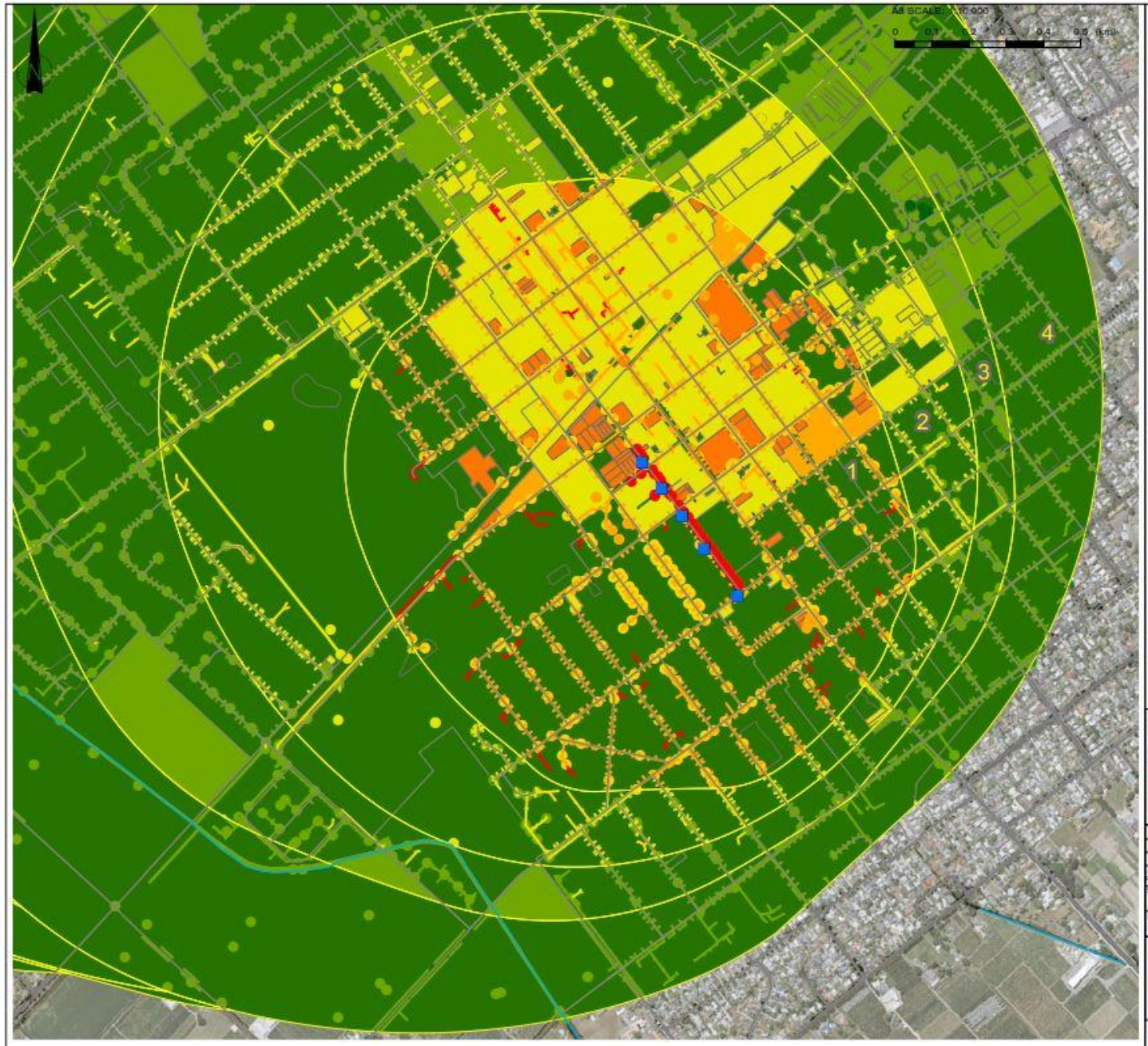


**LEGEND**

**Combined Potential Contamination Risk**

- Very Low
- Very High
- Boreholes - Operational
- Rivers
- Road Centrelines
- Proximity Zones

Notes:

Map data courtesy of Hastings District Council and Hawkes Bay Regional Council. Basemap sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence

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| DRAWN | ANTH | Sep.18 |
| CHECKED | | |
| APPROVED | | |

ARCFILE
Fig2_CombinedRisk_IndicativeGraphic_Detail_v2

SCALE (AT A3 SIZE)
1:10,000

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1005770.1000

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Catchment Sanitary Investigation:
Eastbourne Bore Field Risk Mapping
Combined Risk

Sheet:

Figure 2

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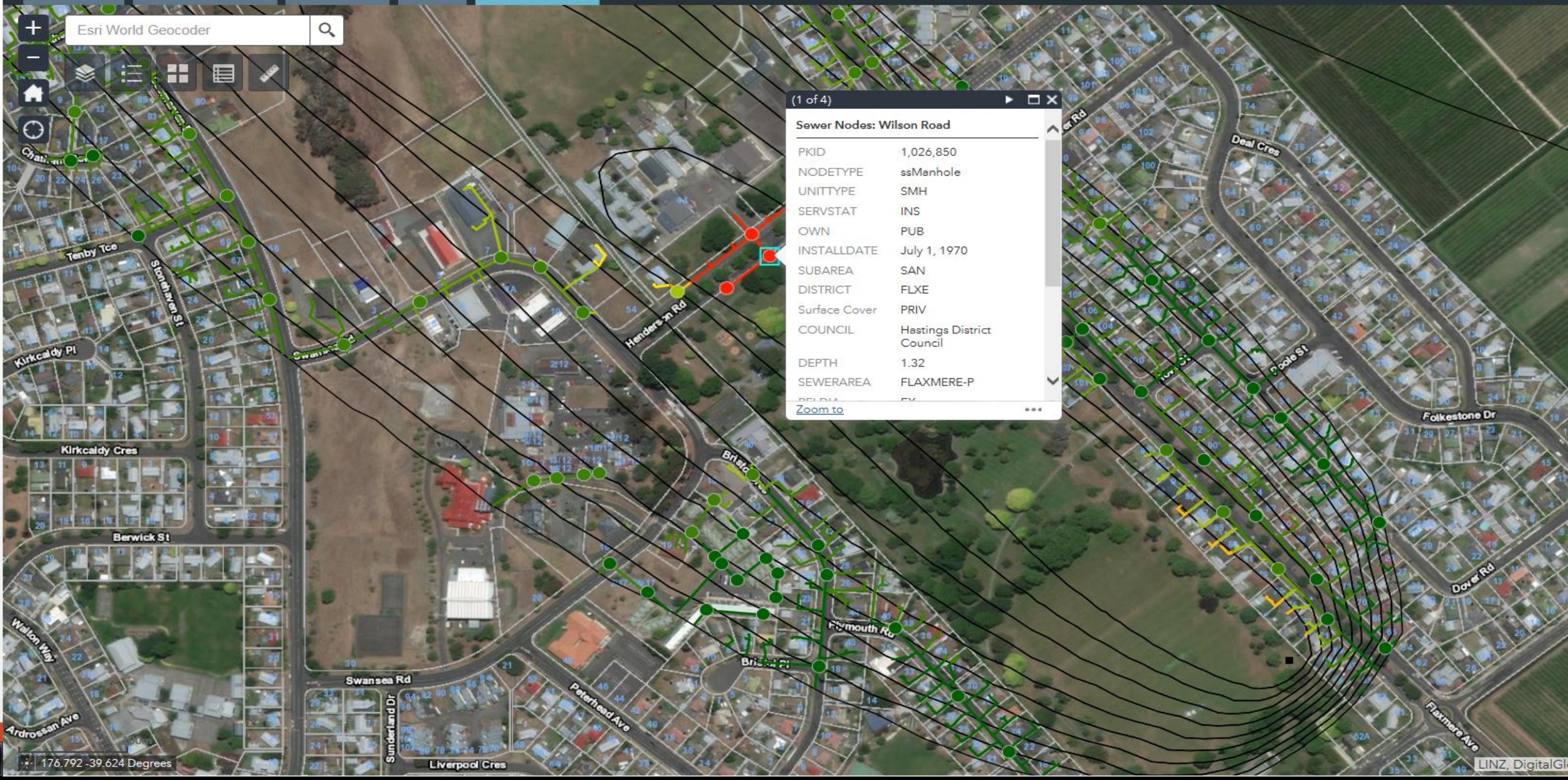
Portsmouth Rd
SH 50
Ngatarawa Rd
Turbet St
Northlee Pl
Flaxmere Ave
Peary Cres
Kingsley Dr
Lander St
Palgrave Ave
Weddell St
Diaz Dr
Baker St
Scott Dr
Ramsey Cres
Bangor St
1
2
3
4
5
6
7
8
9
10
-39.607 Degrees


Layer List
Operational Layers
Resource Consents
Well Permits
Boreholes - Operational
Boreholes - Abandoned
Sewer Nodes
Sewer Mains
Sewer Service Lines
Water Mains - Abandoned
Weddell St
Diaz Dr
Baker St
Scott Dr
Diaz Pl
Burton Pl
Burton Cres
Stanley St
Livingstone Rd
Cabot Pl
Walton Pl
Tenby Tce
Stonehaven St
Kirkcaldy Pl
Kirkcaldy Cres
Berwick St
Chatham Rd
Portsmouth Rd
Walton Way
Ardrossan Ave
Swansea Rd
Liverpool Cres
Caernarvon Dr
Peterhead Ave
Birkenhead Cres
Whitby Cres
Henderson Rd
Folkestone Dr
Dover Rd
Wilson Rd
Lorne Cres
Ayr St
Dundee Dr
Crail Ave
200m

# HDC Catchment Sanitary Investigations

Eastbourne | Frimley Lyndhurst | Portsmouth | Wilson | All Catchments



# 3 Waters Reform in NZ


New Zealand's looming 'three waters' crisis

Pattrick Smellie · 05:00, Nov 22 2018



MARTIN DE RUYTER/STUFF


Timaru District Council water supplies need upgrading

MATTHEW LITTLEWOOD
Last updated 15:34, April 6 2018

Stephen Barker/Stuff

Time is running out for Timaru district residents to have their say on a council proposal to meter water supplies.

## Key factors:

- Response to Havelock N
- Lack of investment in aging infrastructure
- More stringent health & environmental standards
- Replace/renew existing 3 Waters assets **$14 billion**
- Funding challenges
- Water industry rationalisation (aggregation models)
- New regulatory body

Tonkin+Taylor

FEBRUARY 28, 2019
*UPDATED FEBRUARY 28, 2019*

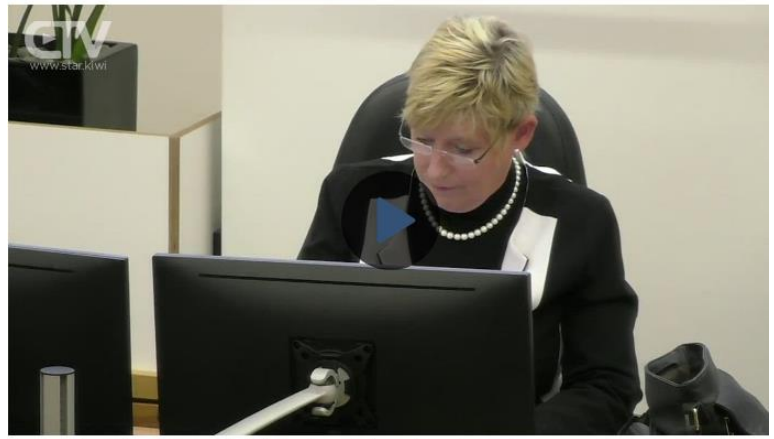

David Williams
David Williams is Newsroom's South Island correspondent and investigative writer.

NEWS

**Councils plan a huge hike in spending, debt**

***A financial check on councils reveals a huge hike in planned capital spending and debt. David Williams reports.***

**Fixing Christchurch City's drinking water comes with multi-million dollar price tag**




The multi-million dollar cost of fixing the city's well heads has been revealed.

A city council report has shown two options to regain water secure status. The preferred will cost $21.5 million.

# Application to the Pacific Islands

- Protect public health and drinking water sources
- Effective monitoring and assessment of overall risks to the water supply
- Prioritise management/mitigation
- Assess contaminating activity controls to manage public health risk
- Applicable to surface water and groundwater sources
- Atoll islands with freshwater lenses used for drinking water

# Thank you!

# Questions?


## Tony Cussins, Tonkin + Taylor International Ltd

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