

A Comprehensive Hydrological Model for the Canterbury Region

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on leave from the University of Texas at Austin

This is a Keynote Presentation for the Workshop “Towards a Water Data Infrastructure for New Zealand” held at the University of Canterbury, April 10-11, 2018

Dr Maidment’s visit to the Waterways Centre is supported by an Erskine Fellowship from the University of Canterbury. The help of Jenny Webster-Brown, Julie Clark, and Suellen Knopick of the Waterways Centre for Freshwater Research is gratefully acknowledged. Data support and guidance from Environment Canterbury and the Horizons Regional Council is also gratefully acknowledged.

Plans require good science & data

- Water quantity
- Water quality
- Land use
- Presented according to:
 - Current state
 - Future scenarios
- The environment needs to be monitored, trends established & outcomes defined



Plans are not infinite – 5 & 10 year intervals

- Plans must be assessed on a 5 & 10 yearly cycle
- There is an expectation that data and science models can explain improvements and indicate further actions required
- How do we secure systematic, credible answers for the next generation?



Re-conceptualising Canterbury's water



- **Goal:** Combining technology, data science and modelling for improved decision-making
- **Key targets:** reduced planning costs, increased certainty and enhanced credibility

A real-time, hydrologically connected (3D) model for Canterbury

Model **surface water** – quantity and quality

Model **groundwater** – flow paths, connectivity and change over time; also include GW quality

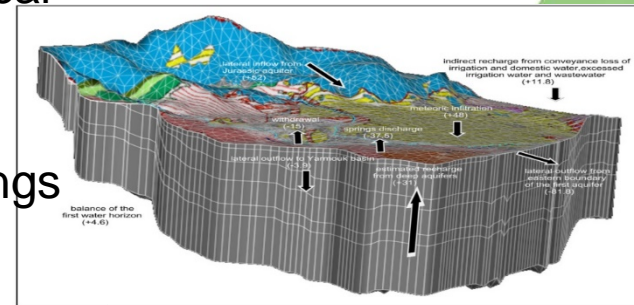
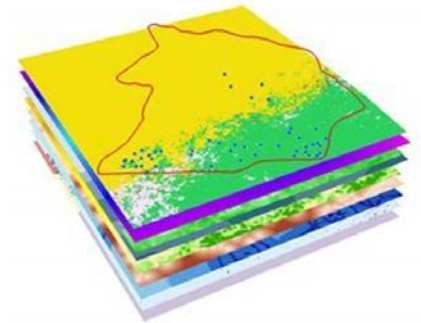
Have the ability to **backcast** – based on prior data to show quarterly, seasonal and annual changes over time

Have the ability to show **real-time** data– what is the state today? – based on current hydrological and meteorological information

Have the ability to **forecast** – scenarios & options, warnings

Have the ability to connect w/ non-science data (e.g., consents, water metering) and inform adaptive **management** conditions

Incorporate Mātauranga **Māori** indicators



A Comprehensive Hydrological Model for the Canterbury Region

- What do we have now?
- What is needed?
- How do we get there?

A real-time, hydrologically connected (3D) model for Canterbury

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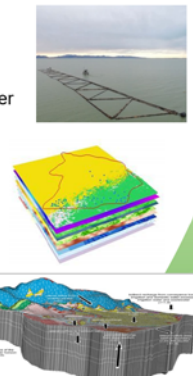
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Environment Canterbury Regional Council
Kaumihēra Taiao ki Wairarapa

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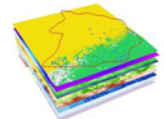
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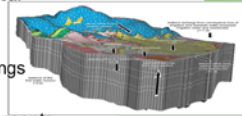


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Incorporate **Matauranga Maori** indicators

Environment Canterbury Regional Council (ECan) Available Data

University of Canterbury
28 Feb 2018

Fouad Alkhaier
Senior hydrogeologist



Types of available data (ECan)

- Precipitation
- Groundwater level
- Stream and river flows

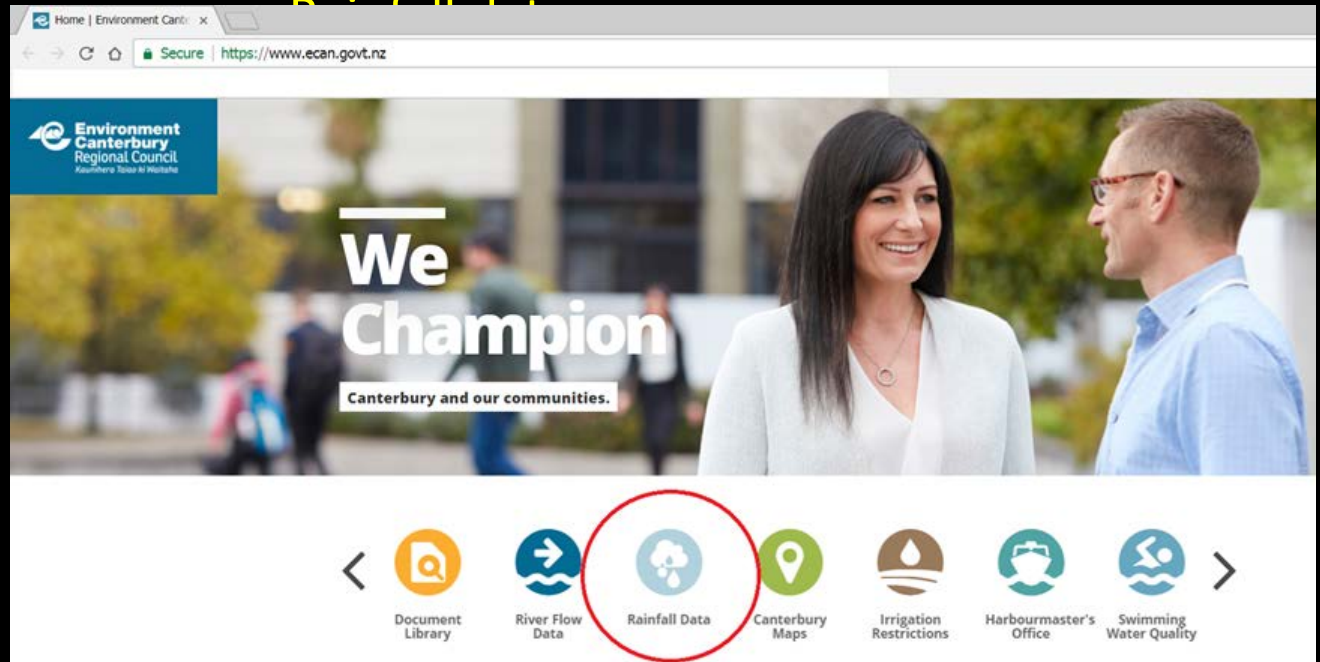
Other sources of data (NIWA)

- Real weather stations data
- Virtual climate stations (VCS)

Precipitation



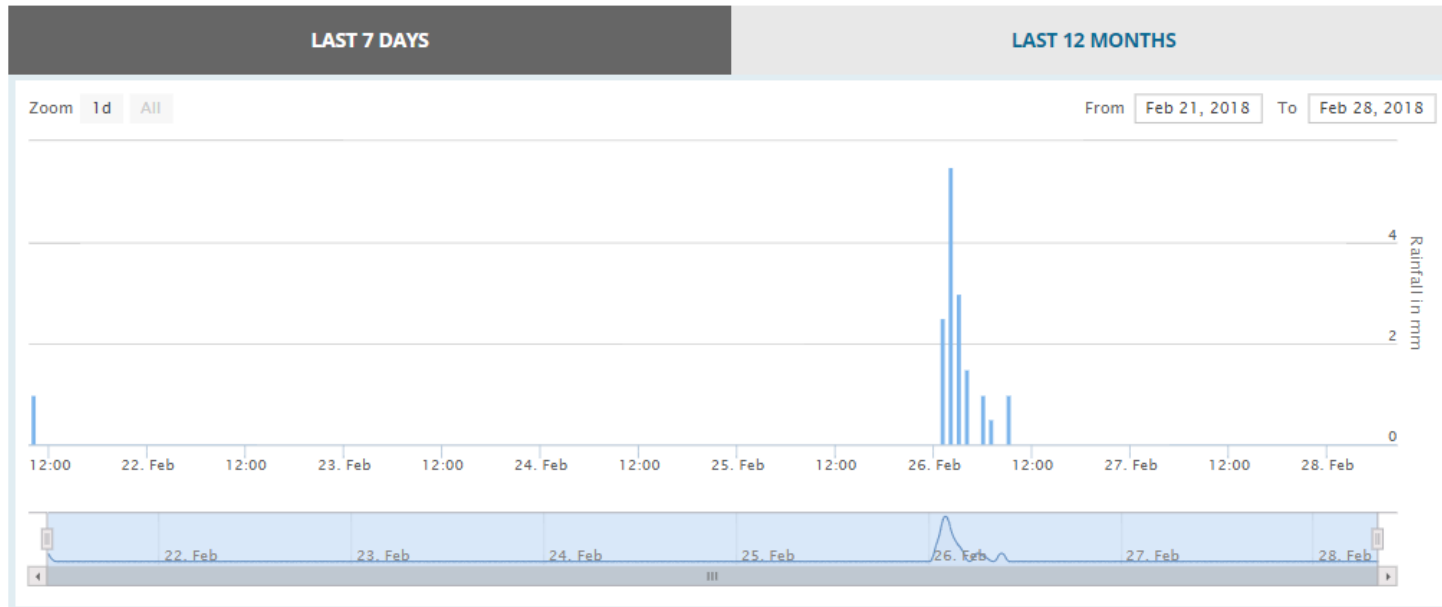
<https://www.ecan.govt.nz/>



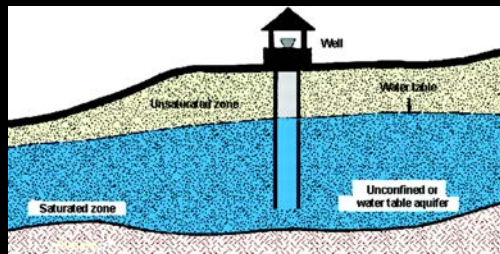
Rainfall for Ridgens Rd

LAST SAMPLE (NZD STD TIME)	LAST HOUR	RAIN TODAY	-1 DAY	-2 DAY	-3 DAY	-4 DAY	-5 DAY	-6 DAY	-7 DAY	TOTAL RAINFALL
2018-02-28T08:05:00+13:00	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	18.0	33.0

Rainfall 16mm from Wed 21 Feb 2018 to Wed 28 Feb 2018

[Back to Listing](#)[Download data](#)

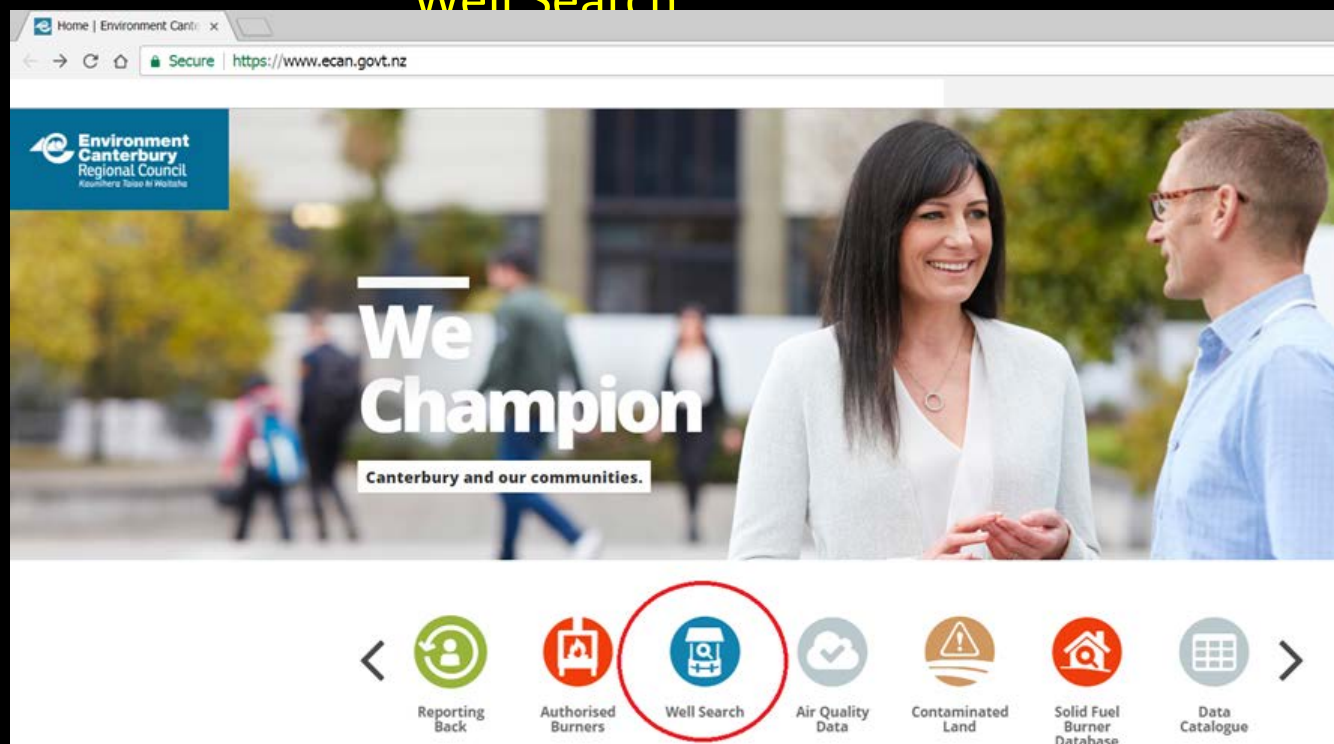
Groundwater level



<https://www.ecan.govt.nz>

/

Well Search



Water Level Monitoring Network

All Wells

Legend

Current CRC Monitoring Well



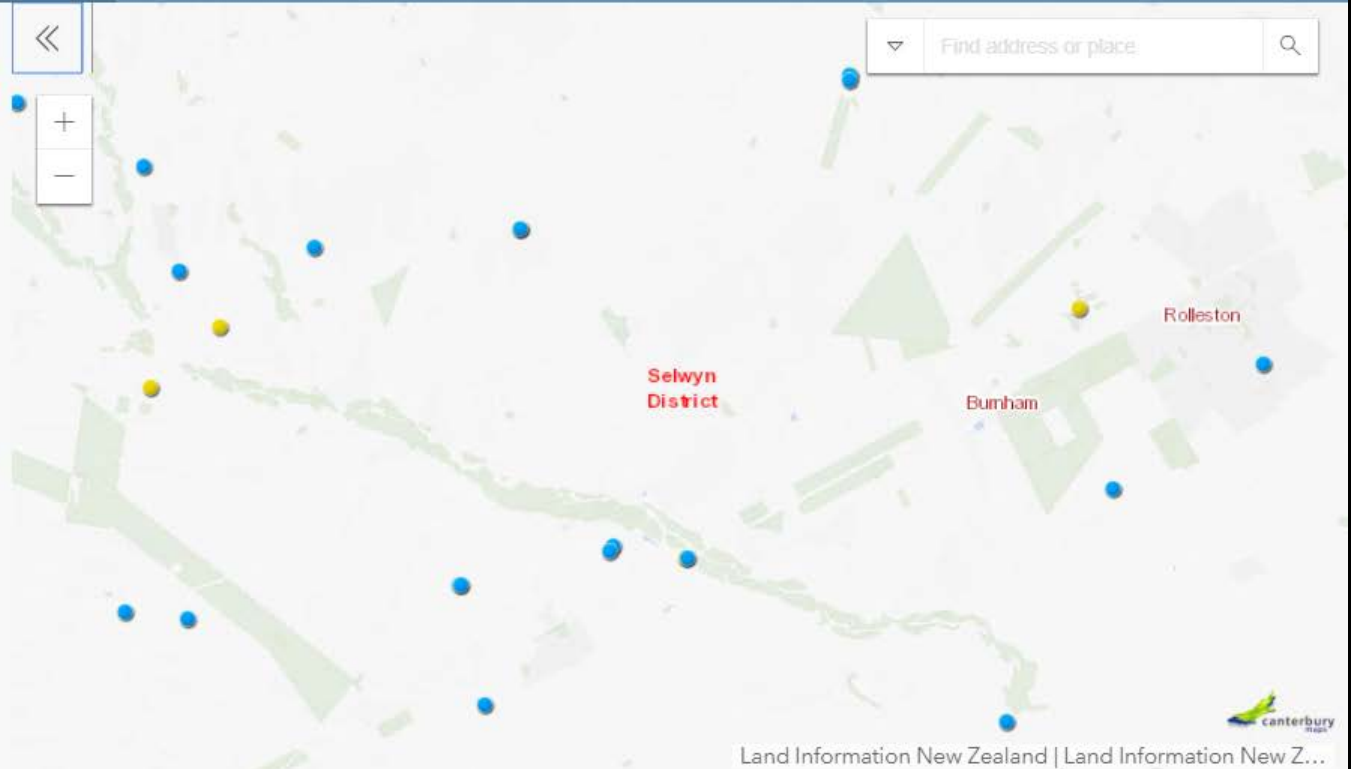
Former CRC Monitoring Well



Current CCC Monitoring Well



Find address or place



Water Level Monitoring Network

All Wells

Legend

Current CRC Monitoring Well



Former CRC Monitoring Well



Current CCC Monitoring Well



Current CRC Monitoring Well

L36/0063

[Go to Well card details](#)

Zoom to



Find address or place



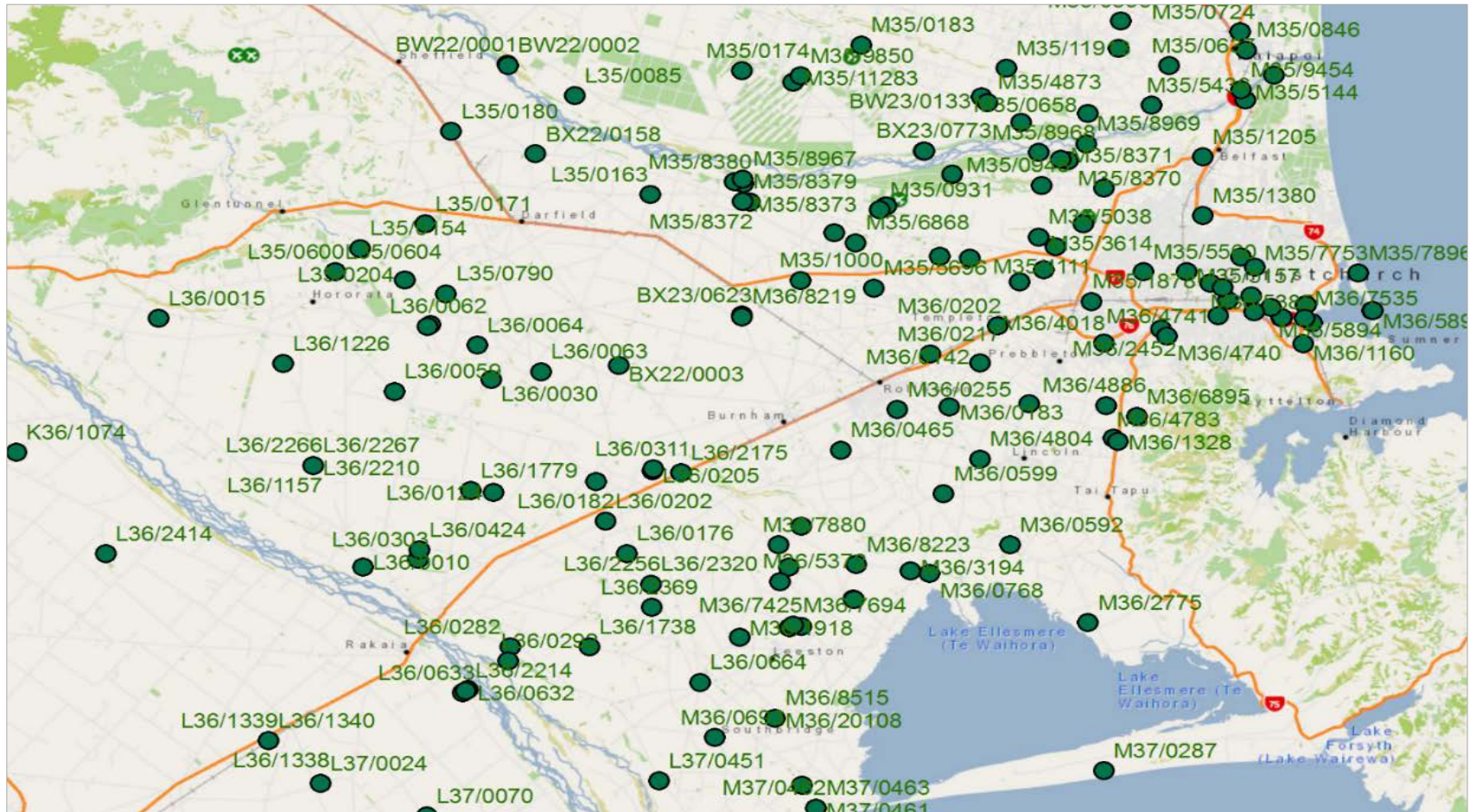
Rolleston

Bunham



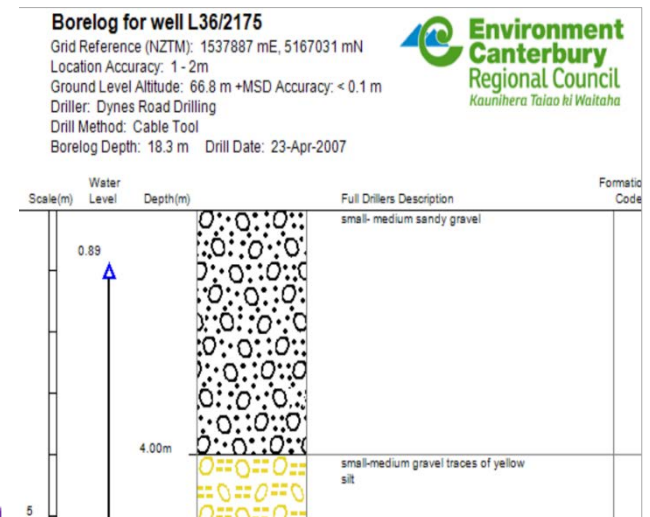
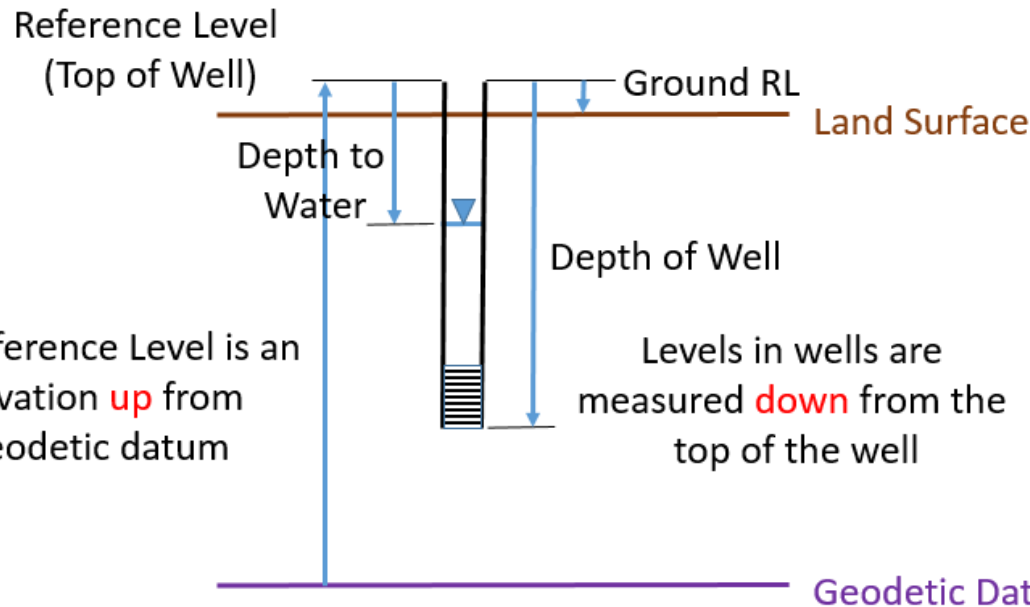
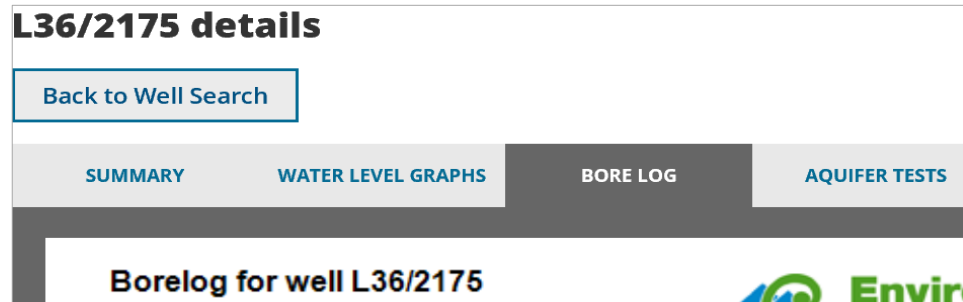
Land Information New Zealand | Land Information New Z...

Observation wells



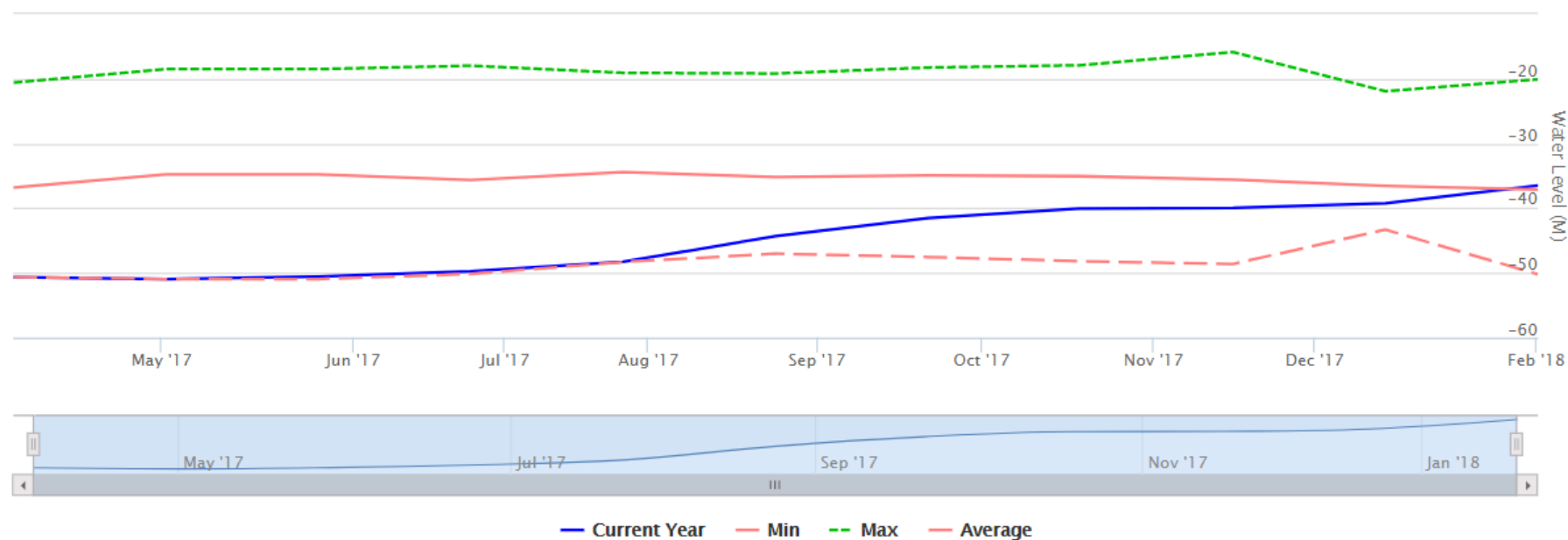
Borehole Descriptions

<https://www.ecan.govt.nz/data/well-search/>



[SUMMARY](#)[WATER LEVEL GRAPHS](#)[BORE LOG](#)[AQUIFER TESTS](#)[LOCATION MAP](#)

Water Level Plot for L36/0063 (Relative to Ground Level)



Full Record for L36/0063 (Relative to Measuring Point)

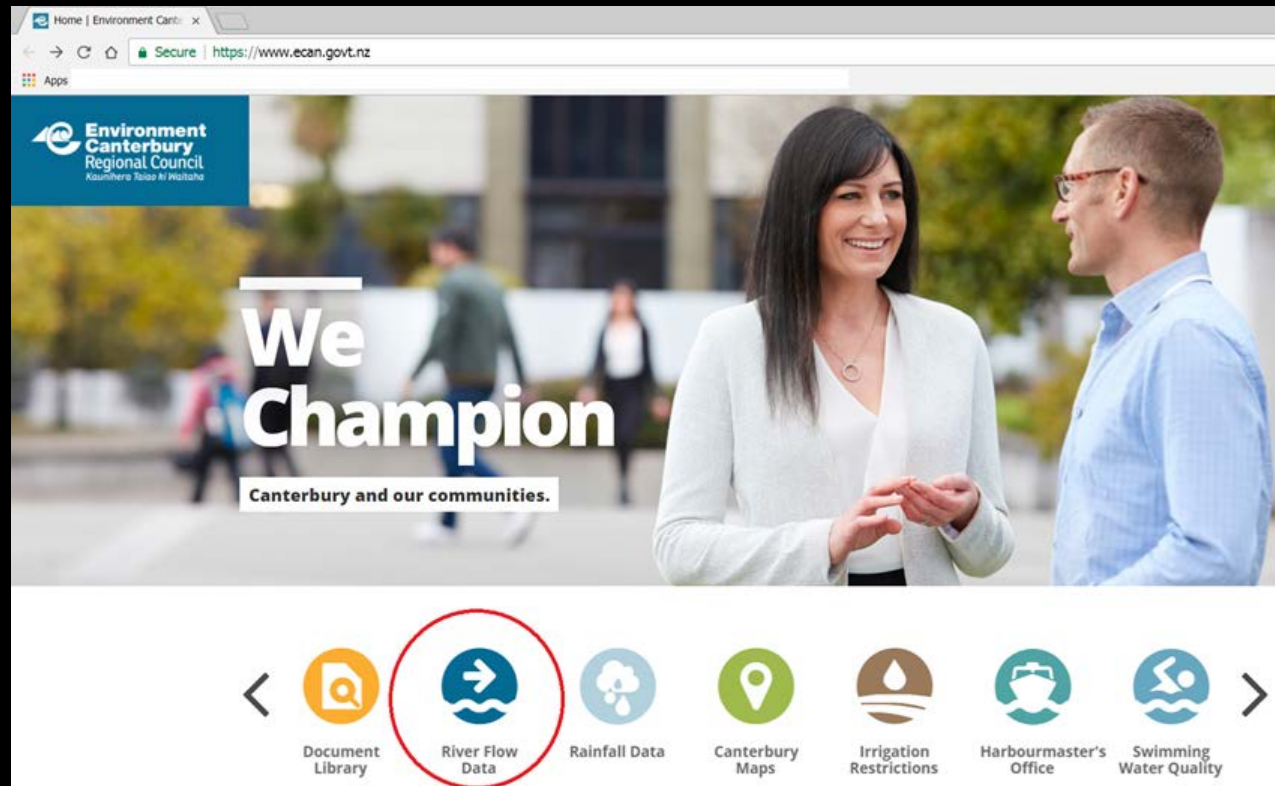
[Download Water Level Data](#)

Stream and river flows



<https://www.ecan.govt.nz>

/



NORTHERN REGION

NORTHERN REGION

NORTHERN REGION



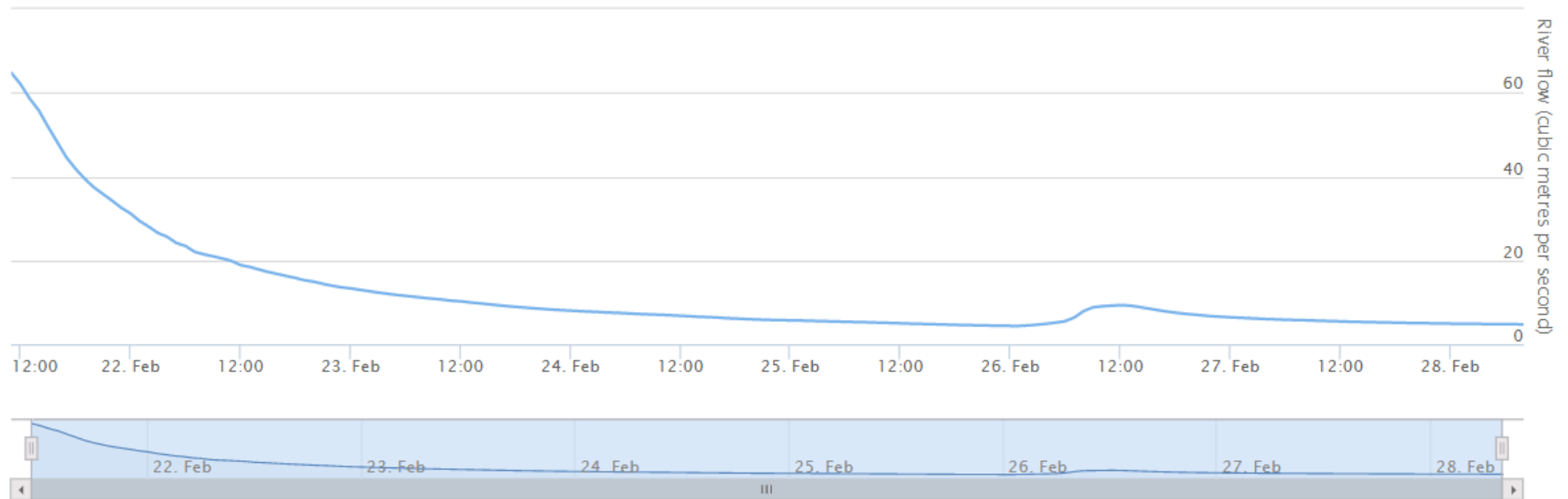
River flow (cubic metres per second)

LAST 7 DAYS

LAST 30 DAYS

Zoom 1d 1w 1m All

From Feb 21, 2018 To Feb 28, 2018

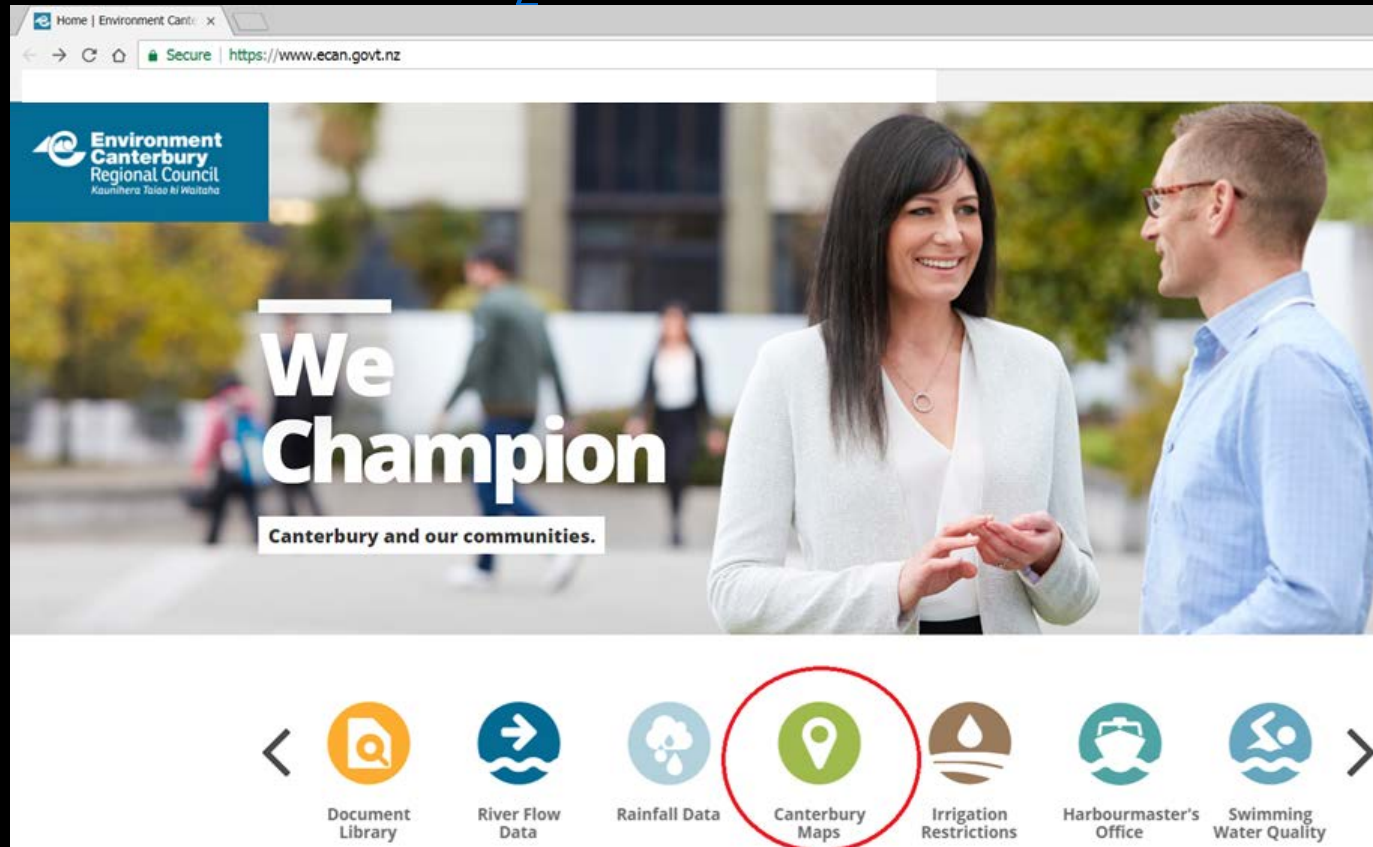


[Back to Listing](#)

[Download data](#)

Canterbury Maps

<https://www.ecan.govt.nz>





Canterbury Historic Imagery



Environmental Reporting Canterbury Water Management Zones

LAND ZONING

N/A - Rural & Unmapped

Green Zone, N/A - Rural & Unmapped

Land classified as green means that homes are suitable for repair and rebuild.

CERA - My Land Zone



Explore your region



Newsletter

Subscribe



Map Viewer



Go Mobile



Open Data



What's new?

Tip of the Week:

Find out more about the functionality of the draw tool!

Draw

Hide drawings

Add a drawing

Select drawing mode



Recreation & Attractions



Transport & navigation



Water



Zoning & boundaries



Council Services

Search

Water

Category

District

Ashburton

Christchurch

Hurunui

Kaikoura

Mackenzie

Selwyn

Timaru

Waimakariri

Waimate

Waitaki

Potable Water Schemes

Water schemes managed by Hurunui District Council

Tools for Water Consultants

A series of spatial data layers to assist water consultants in the Canterbury region

Water Services

Water supply, storm and waste networks in Canterbury.

Groundwater

Features and information relating to Groundwater quantity, quality and supply in the Canterbury Region.

Hinds Managed Aquifer Recharge Pilot Project

Read about the story behind the Hinds/Hekeao Managed Aquifer Recharge (MAR) Pilot

Environmental Reporting Canterbury Water Ma

This web app allows the user to see environmental monitoring results in the Canterbury region

Recreational Water Quality

This map will give you an indication whether a swimming spot is generally suitable for swimming, based on risk of faecal contamination and wa

Water Quality and Monitoring

Water Quality and Monitoring Sites throughout the Canterbury Region.

Piezometric Contours

View piezometric contours, depth to groundwater lines, wells and groundwater flow directions by survey name.

Rivers Lakes and Catchments

Rivers Lakes and Catchments in the Canterbury Region.

Other sources for data (NIWA)

<https://cliflo.niwa.co.nz/>

The National Climate Database

The National Climate Database

NIWA
Taihoro Nukurangi

[help](#) | [home](#) | [subscription](#) | [query](#) | [General Help](#) | [Home](#) | [Subscription Info](#) | [Query Help](#)

Database Query

[Save Settings](#) | [Preview](#) | [Send Query](#) | [?](#)

[logout](#)

Your subscription details: username= public

1. Datatype

[?](#) select datatype(s) [last used datatype\(s\)](#) [Manage](#) [?](#) [Remove All Datatypes](#)

Selected datatype(s): Specify options: Remove datatype:

You need to select a datatype before proceeding further:

- A datatype is the "kind" of data you require e.g. max/min temperature - you currently have no datatypes choosen.
- Choose a datatype using the "select datatype(s)" button above to bring up a popup window (ensure popup windows are not blocked for this site).
- After choosing your datatype, it will be placed here.
- See this [help link](#) for a datatype definition [?](#)

2. Location

[?](#) choose station(s) [?](#) (based on "updated" datatypes above) [last used station\(s\)](#) [Manage](#) [?](#)

Station agent number(s): 3925

3. Date/time

[?](#) [last used date](#) [Manage](#) [?](#)

Start date (yyyy mm dd hh): 2018 02 25 00

End date (yyyy mm dd hh): 2018 02 28 00

4. Format

[?](#) [last used format](#) [Manage](#) [?](#)

Date/Time standard for output:
NZST is NZ Standard Time
UTC is Universal Coordinated Time

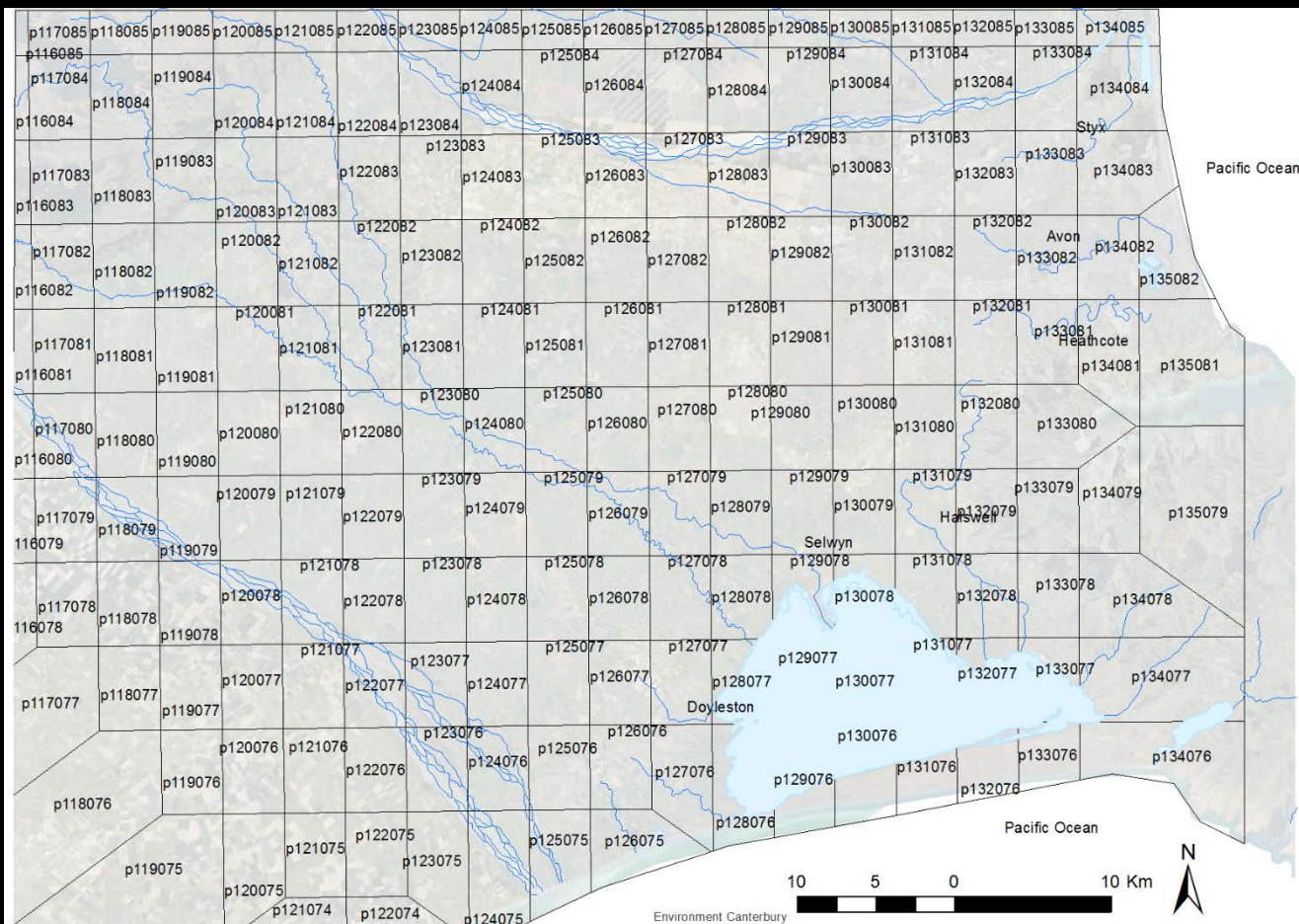
Date/time format for output: Default (yyyymmdd.hhmm) [?](#)

Split date into date and time columns:
☐ No (single date column)
☐ Yes (separate date and time columns) [?](#)

File download option: HTML Table [?](#)

Station Identifier: Agent Number [?](#)

Virtual Climate Stations (VCS) Network



NZ's Digital River Network

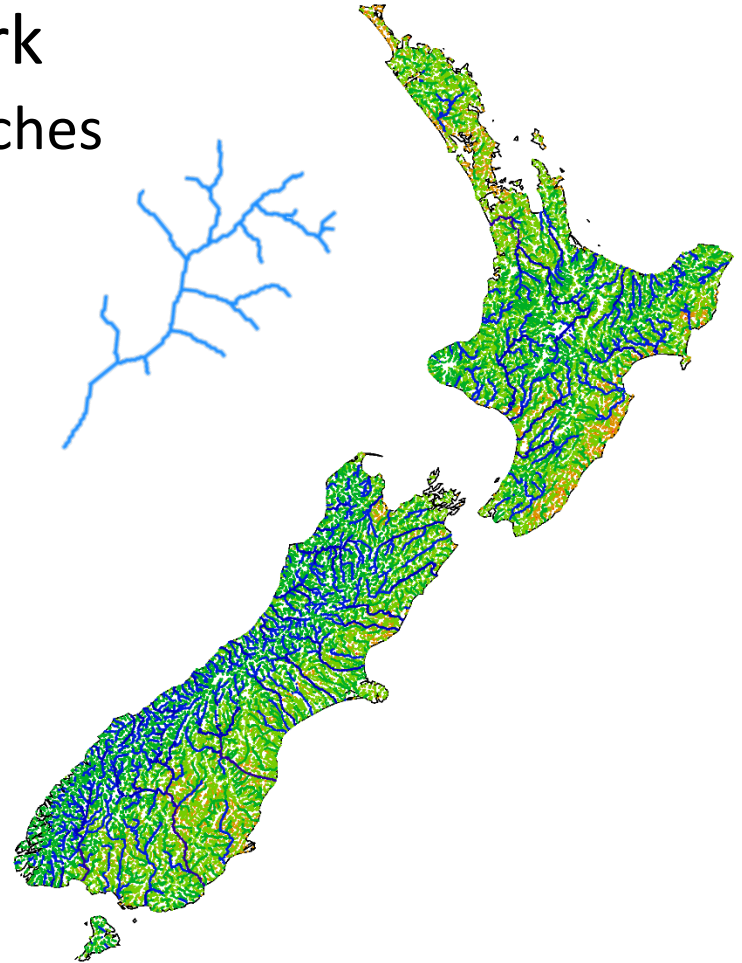
Dr Amy Whitehead

NIWA Christchurch

NZ's Digital River Network

What is it?

- Dendritic stream network
 - > 576,000 individual reaches
 - 425,000 km of river



NZ's Digital River Network

How was it made?

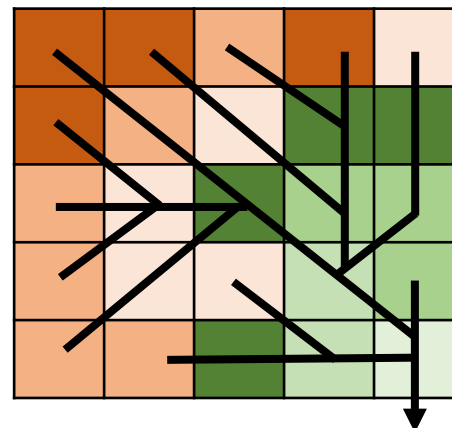
78	72	69	71	58
74	67	56	49	46
69	53	44	38	37
69	58	55	22	31
68	61	47	21	16

Digital elevation model

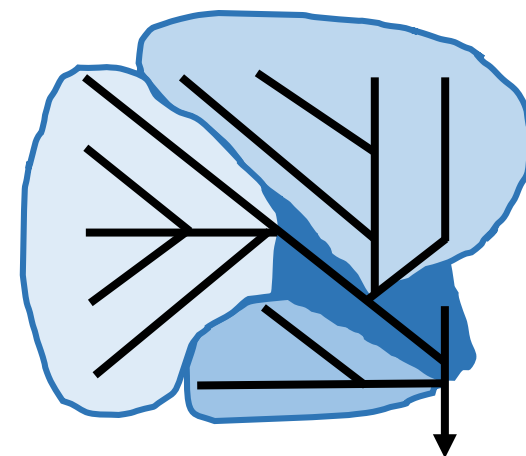


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↘	↘	↘	↓	↓
→	→	↘	↙	↙
↗	↗	↘	↘	↓
↗	→	→	→	↓

Flow direction



Stream network

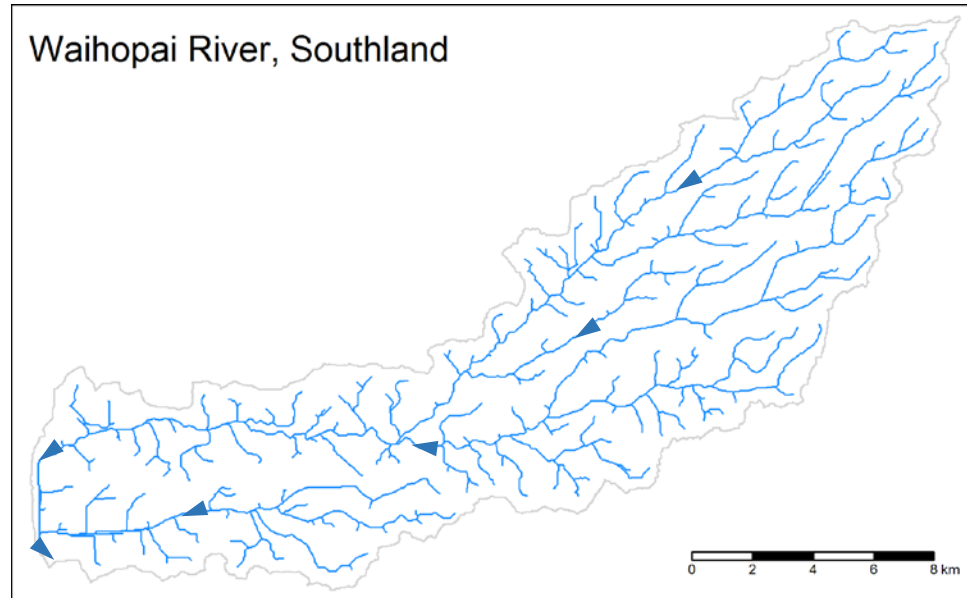


Watersheds & catchments

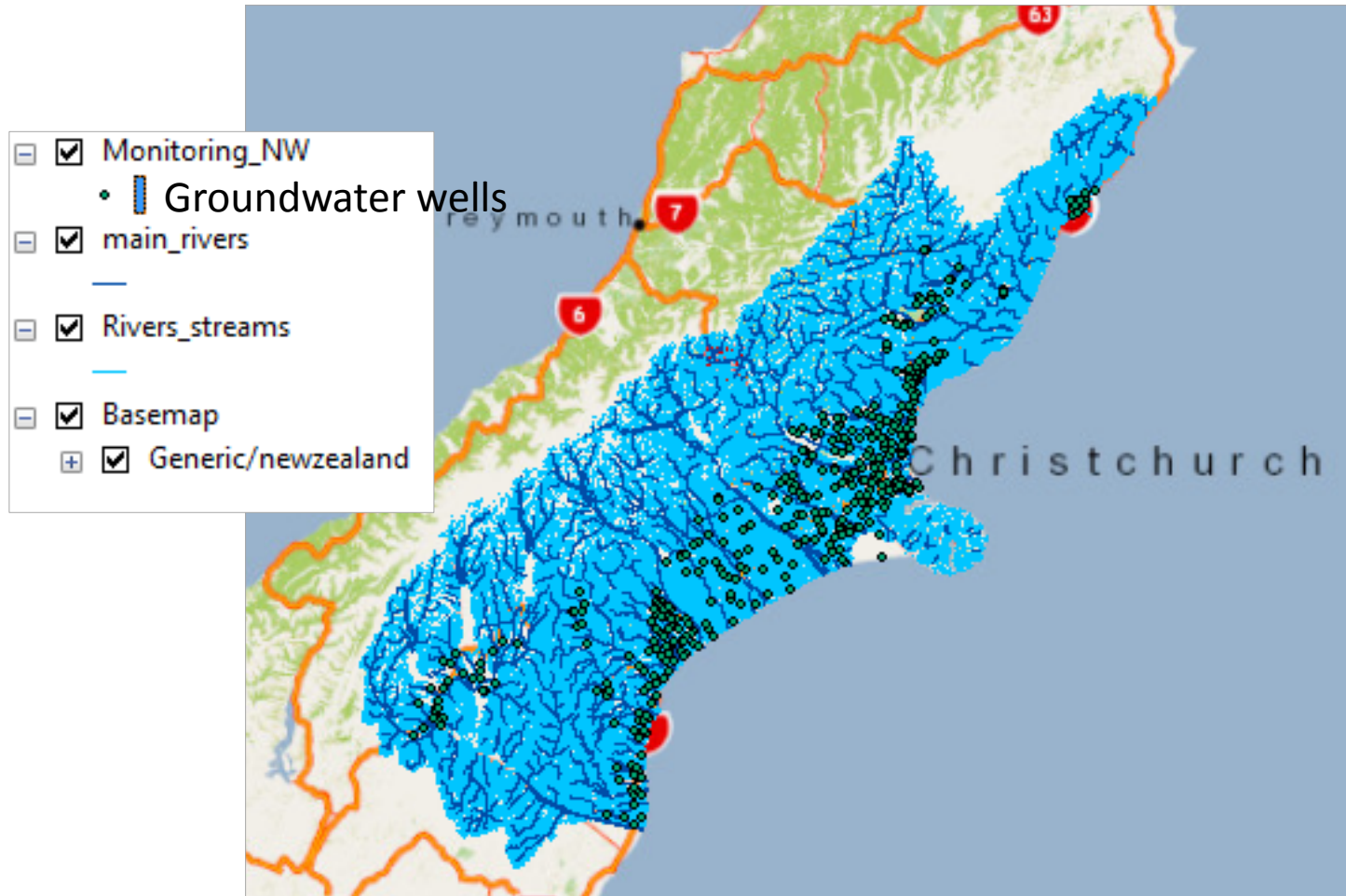
NZ's Digital River Network

How was it made?

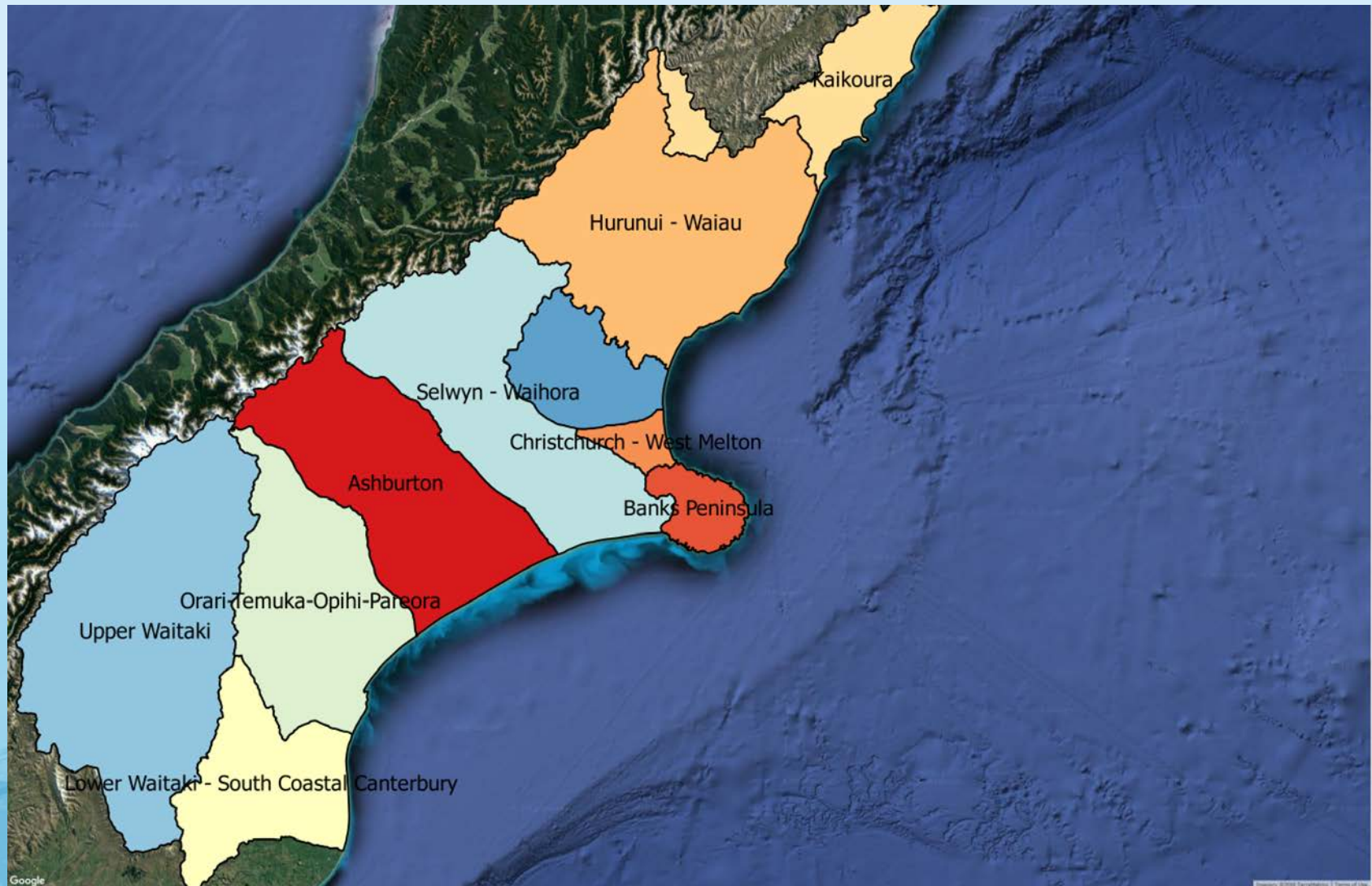
- 30m digital elevation model
- Calculated local and upstream variables for each reach
 - Elevation
 - Slope
 - Rainfall
 - Geology
 - Landcover



Canterbury Streams and Groundwater Monitoring



Planning Zones with Flow Models



Potentially Irrigable Areas of New Zealand

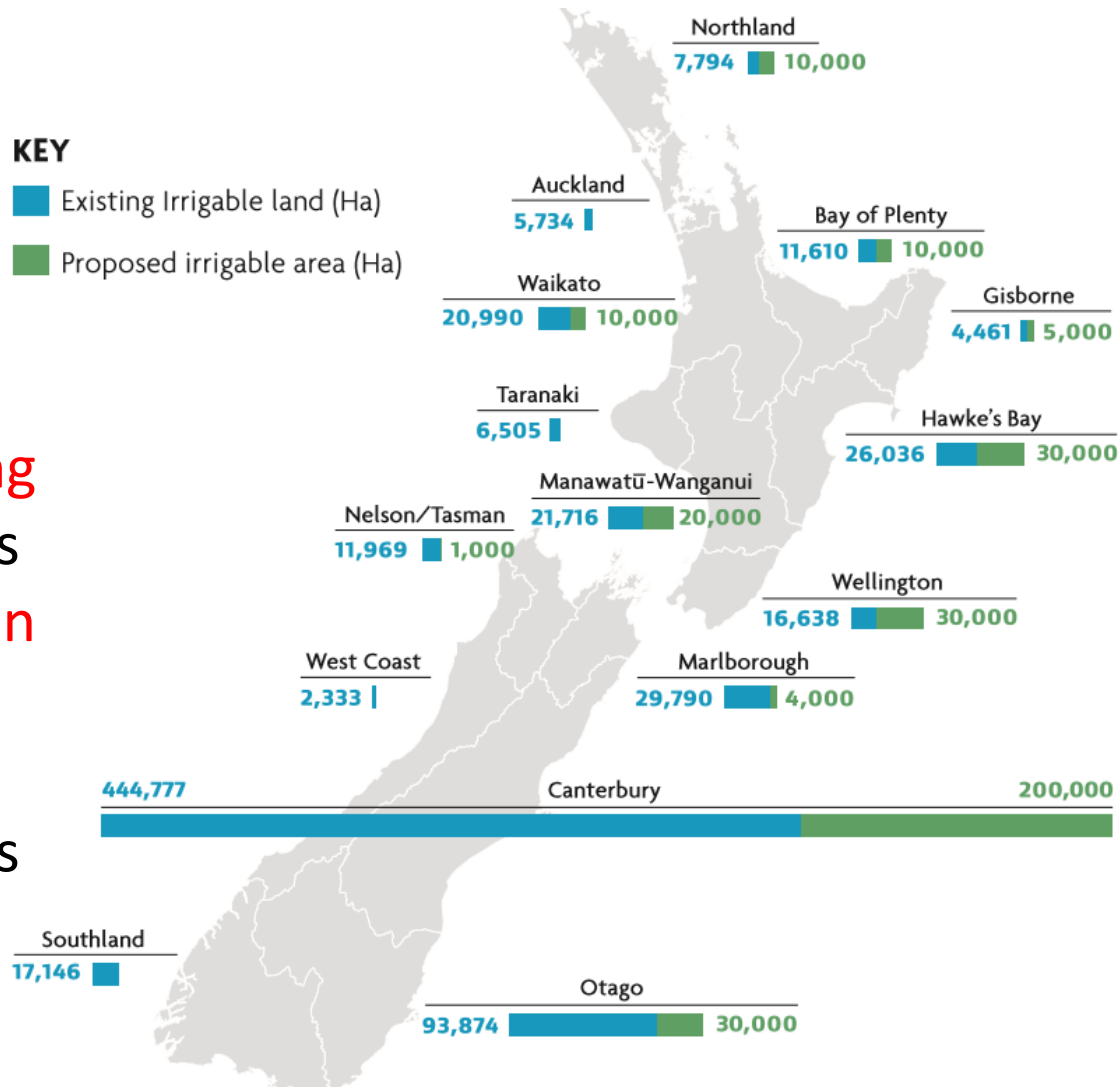


Source of Data: Andrew Dark, Aqualinc

Existing and Proposed Irrigable Areas

KEY

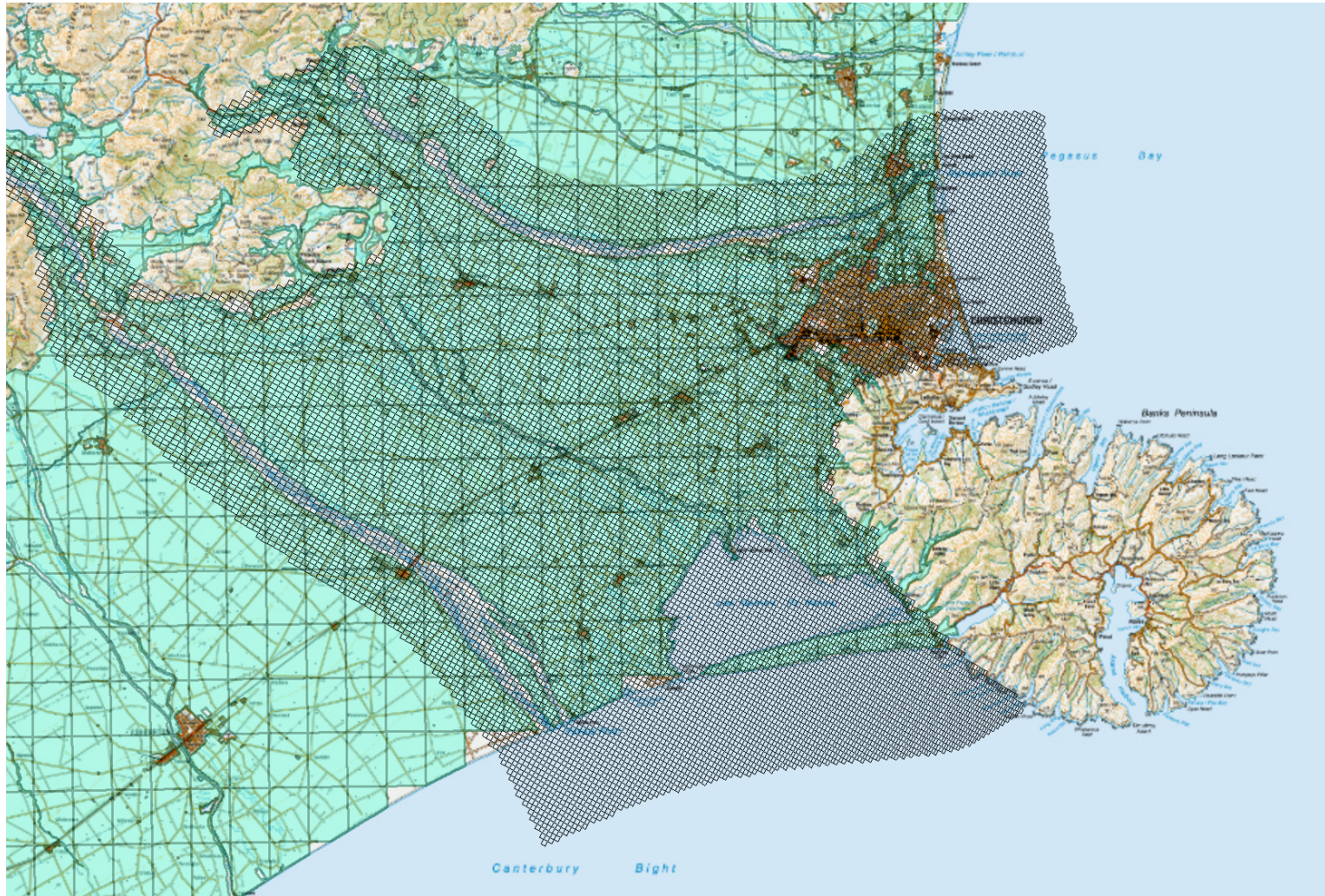
- Existing Irrigable land (Ha)
- Proposed irrigable area (Ha)



Half of existing
irrigable areas
and more than
half of
proposed
irrigable areas
are in
Canterbury

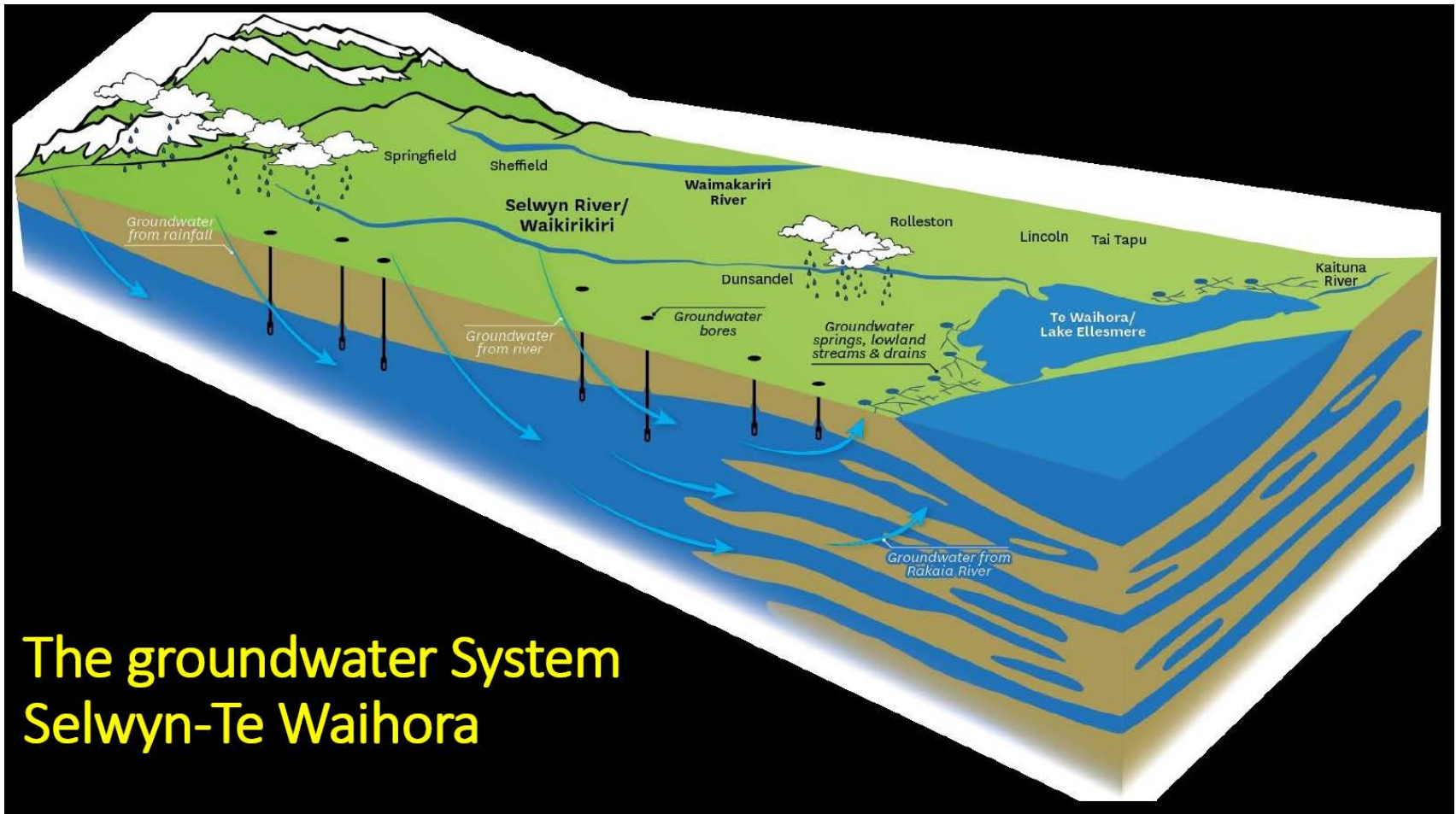
Source: Irrigation New Zealand

Selwyn Modflow Groundwater Model



Source of Data: Julian Weir, Aqualinc

Selwyn Groundwater System

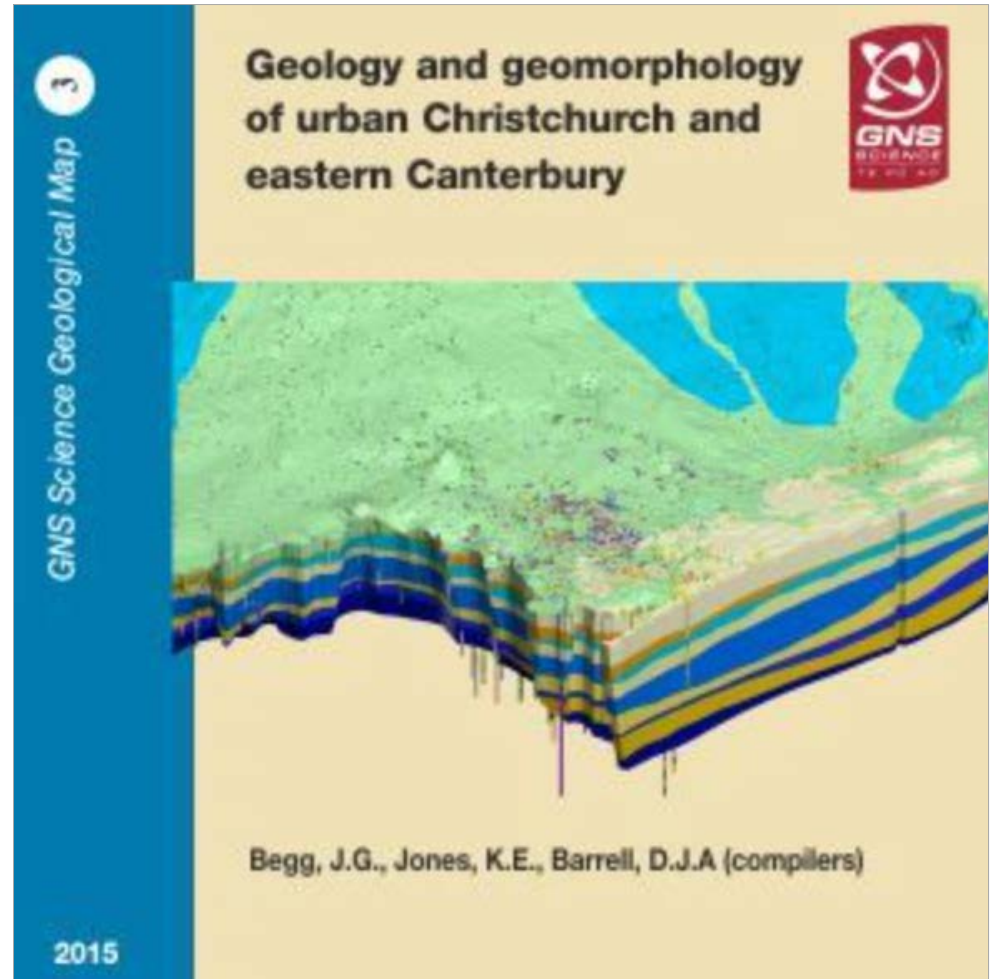


Geological and Nuclear Sciences Data

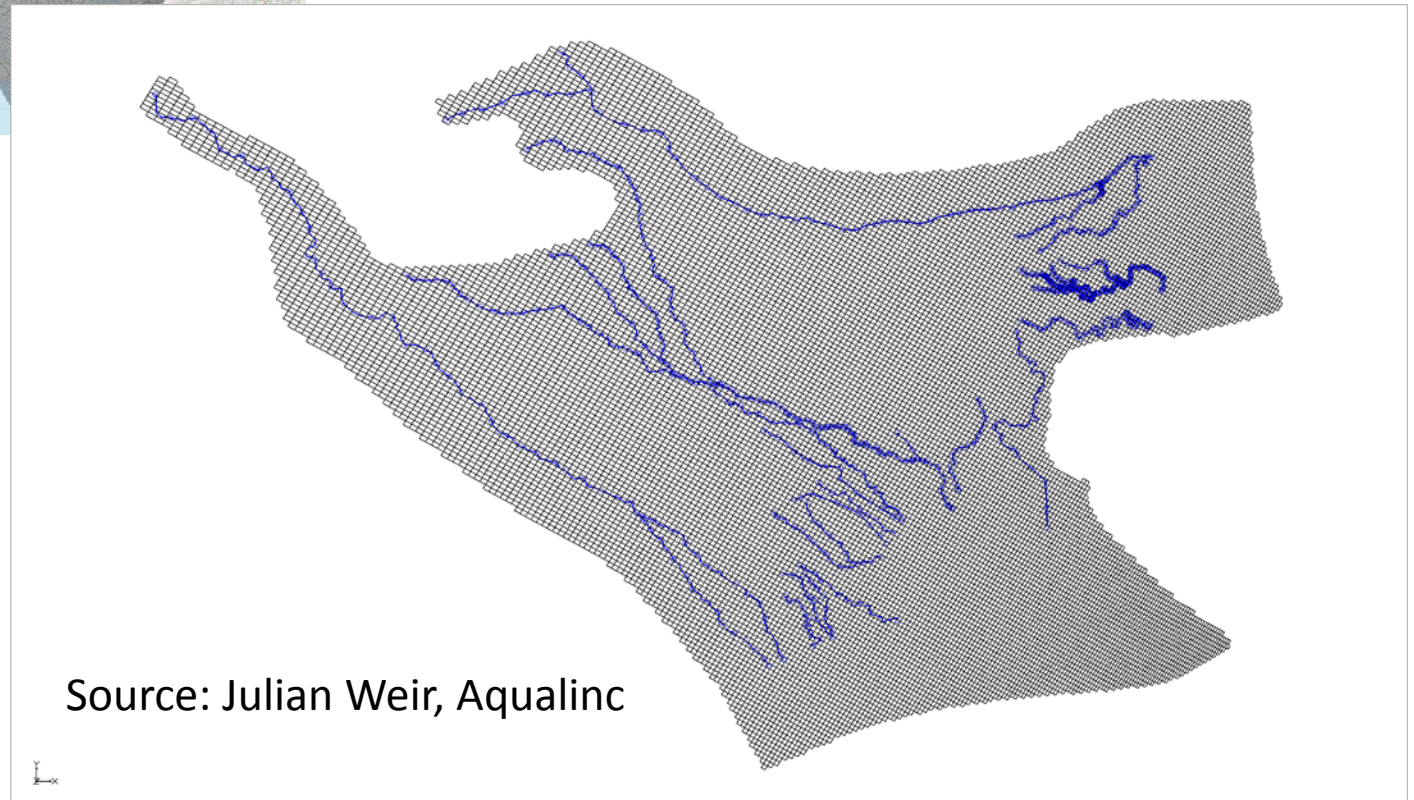
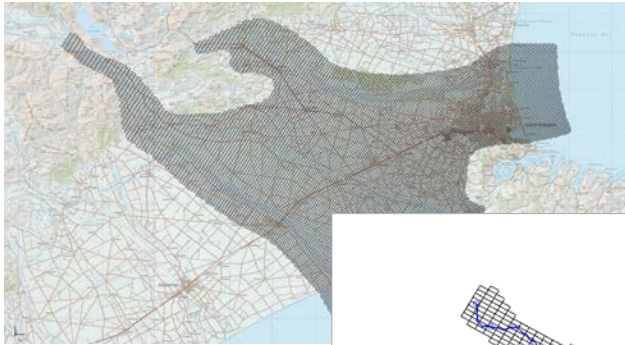


Can be purchased and sent by mail

GEOLOGY AND GEOMORPHOLOGY OF
URBAN CHRISTCHURCH AND EASTERN
CANTERBURY : DIGITAL VECTOR DATA
2015

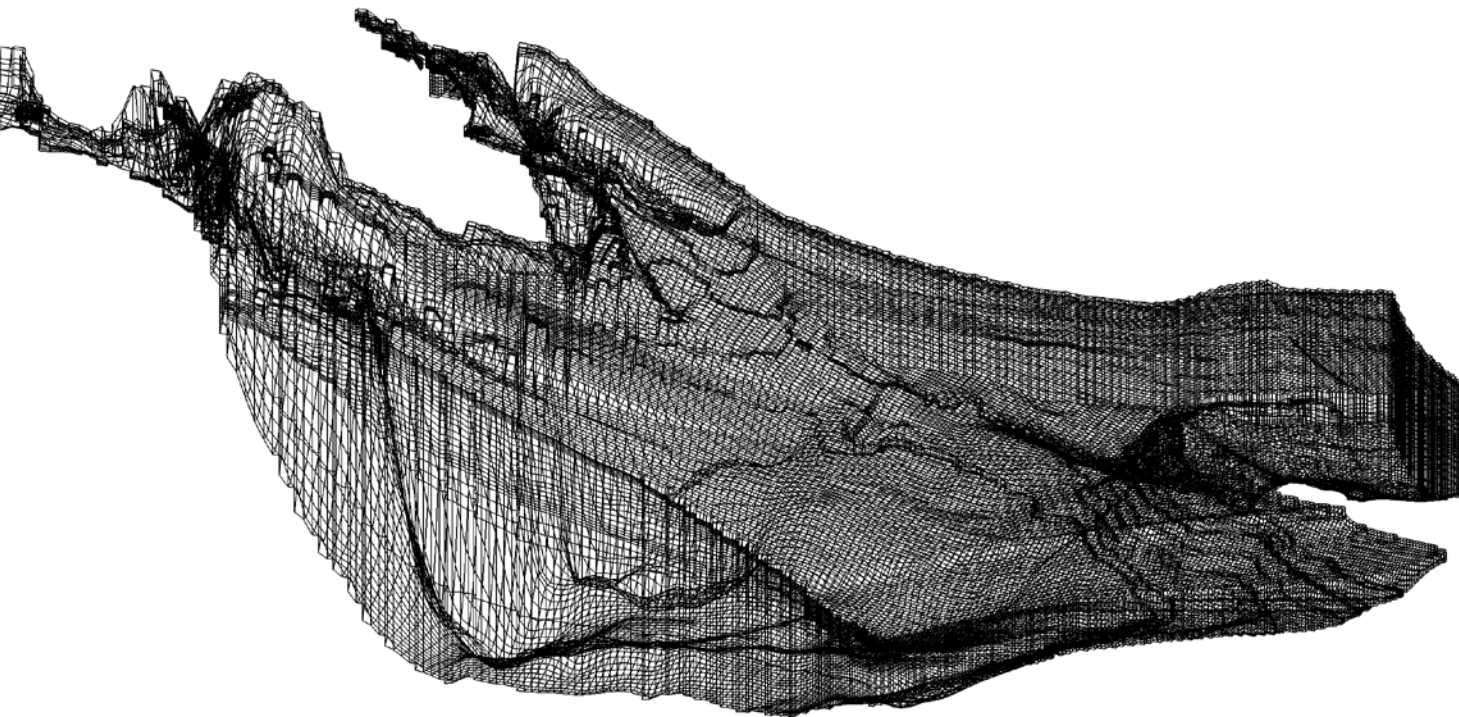


Rivers in Selwyn Groundwater Model



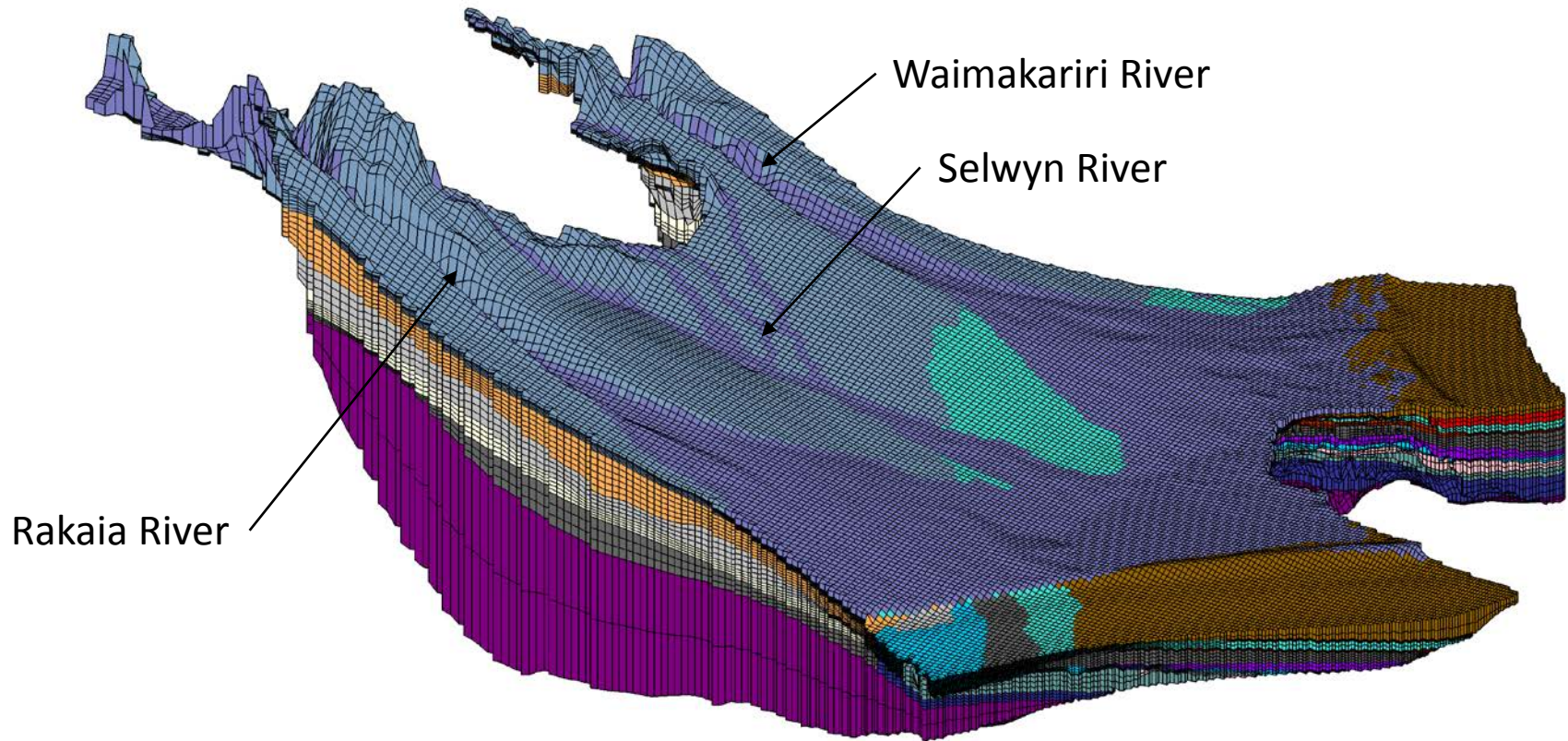
Source: Julian Weir, Aqualinc

3D Model of Selwyn Groundwater



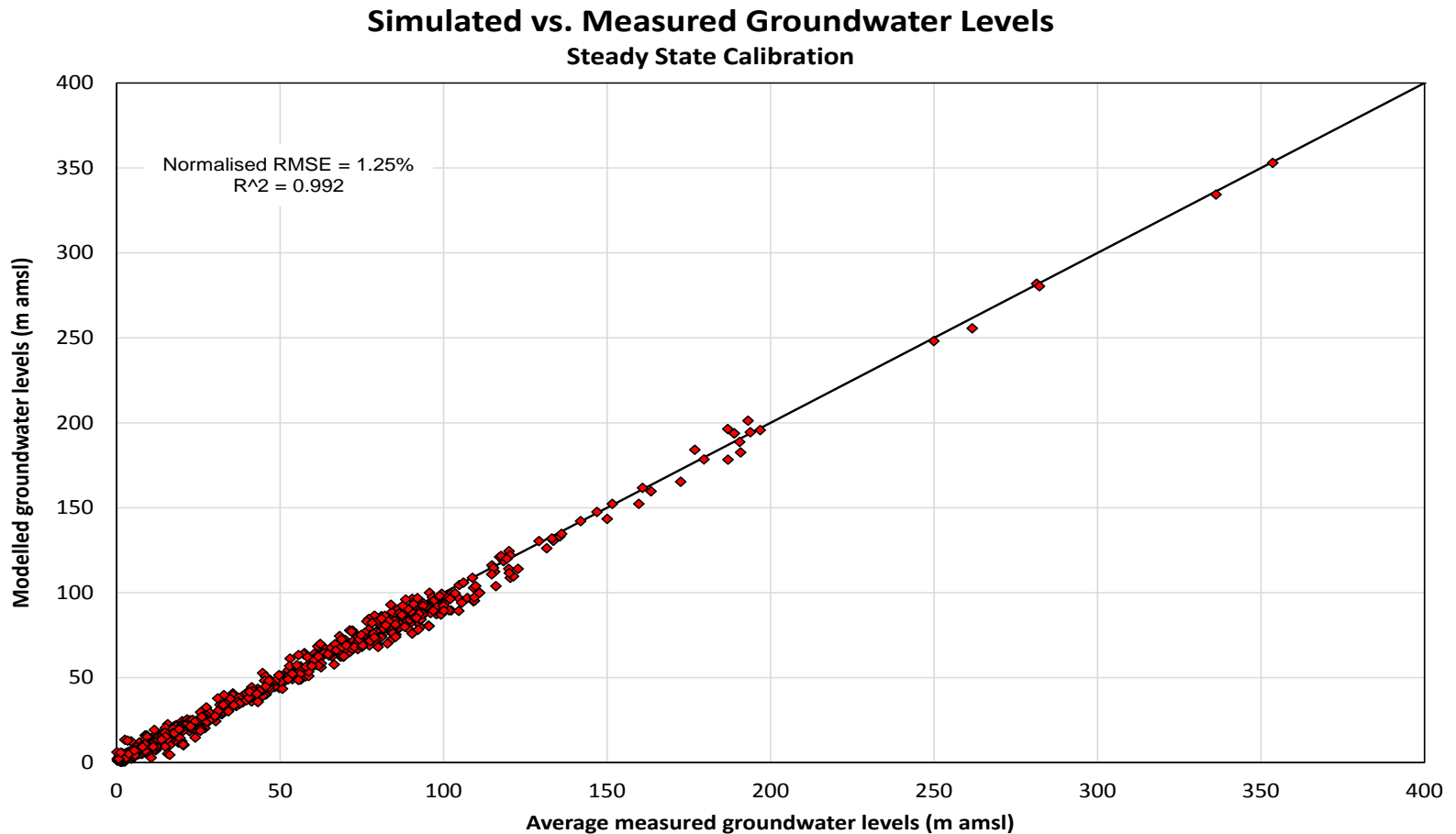
Source: Julian Weir, Aqualinc

Selwyn Hydrogeological Strata



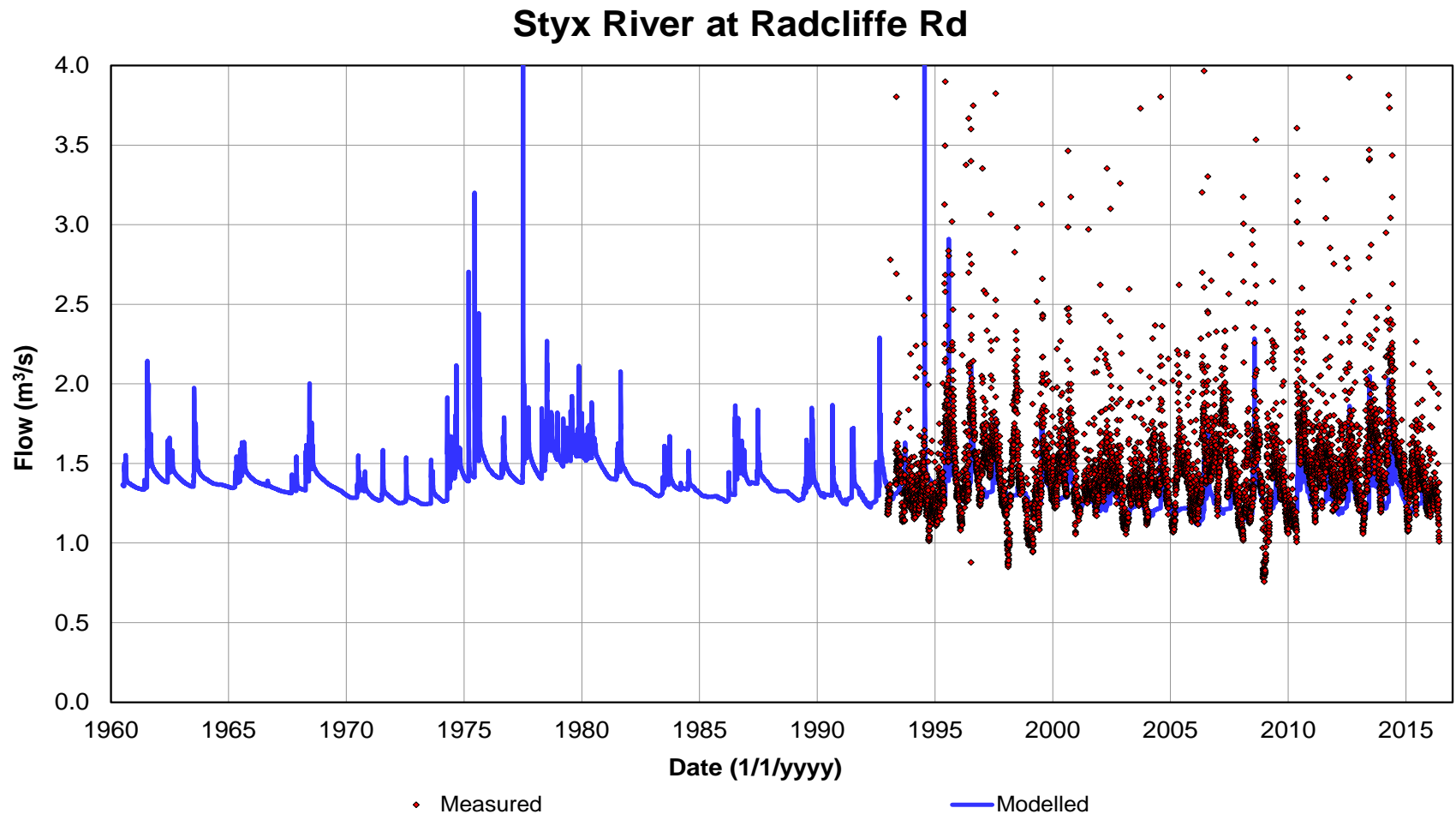
Source: Julian Weir, Aqualinc

Groundwater Level Calibration



Source: Julian Weir, Aqualinc

Surface Water Calibration



Source: Julian Weir, Aqualinc

A Comprehensive Hydrological Model for the Canterbury Region

- *What do we have now?*
 - Canterbury is “data rich”
 - Lots of *observations data*
 - Good *web sites* for individual data locations
 - Good *digital river network*
 - Impressive *groundwater modeling* for planning zones

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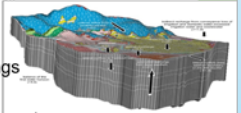
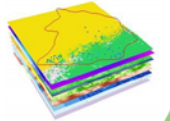
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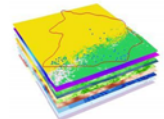
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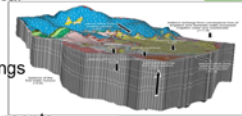


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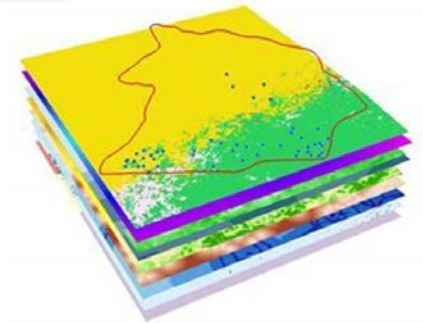
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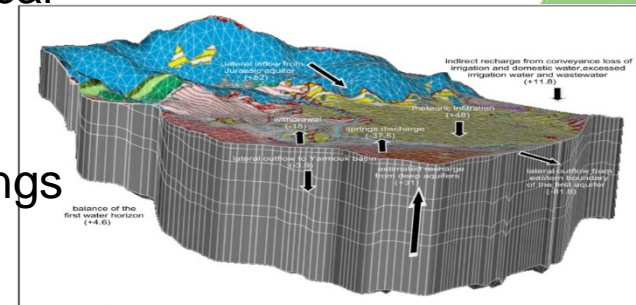


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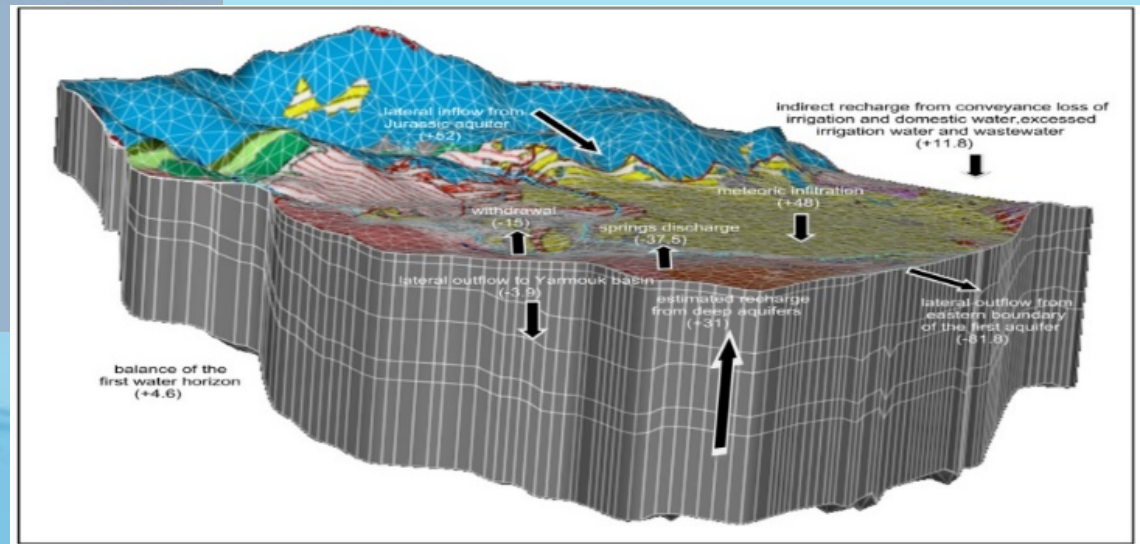
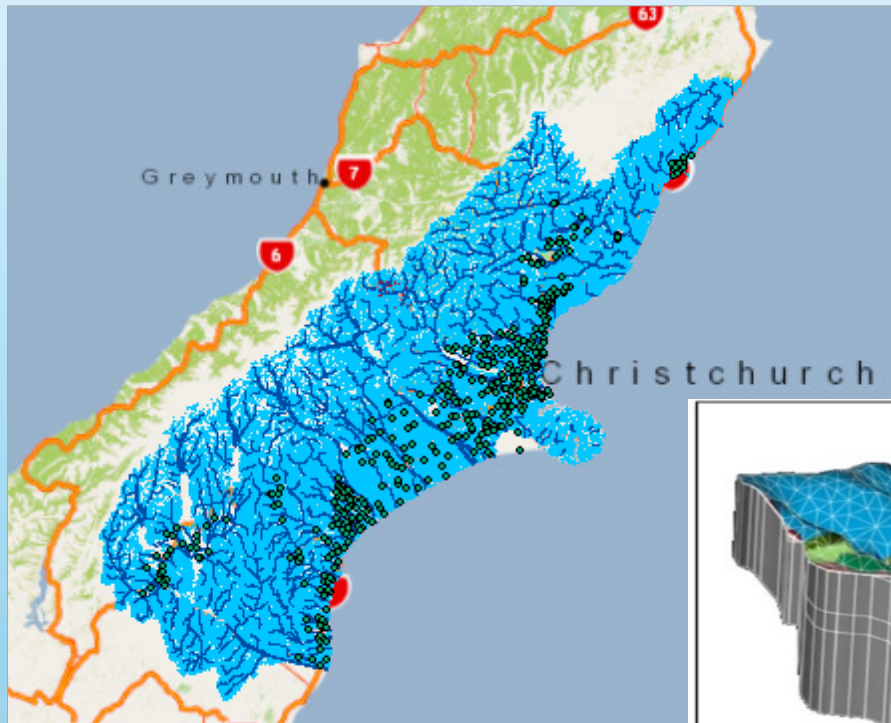
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Surface Water and Groundwater, Quantity and Quality, in 3D for all of Canterbury



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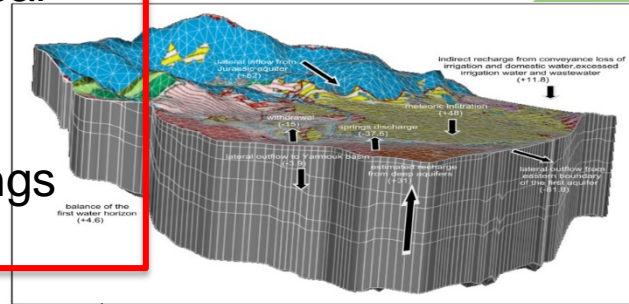
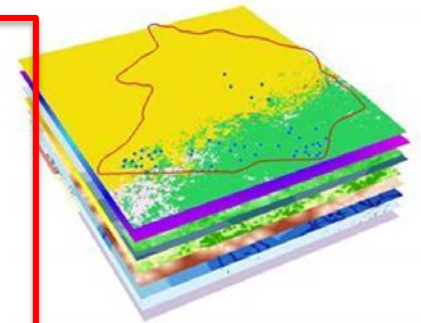
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Incorporate Mātauranga **Māori** indicators



Situational Awareness

Perspective

Foresight



Slide :Rob Vertessy

Past Present Future

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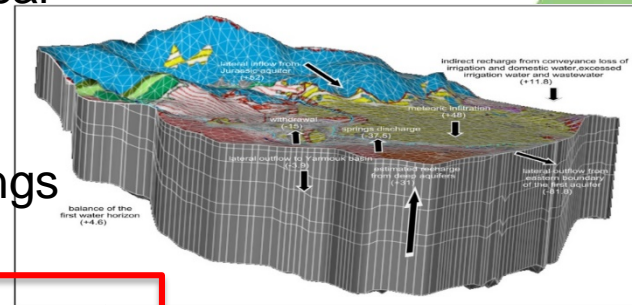
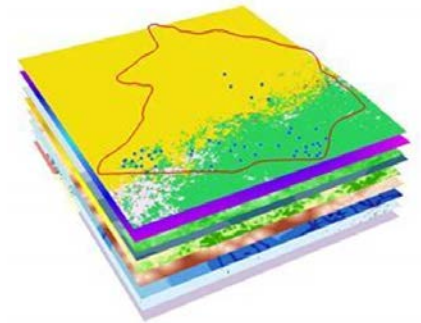
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Incorporate Maturanga **Maori** indicators

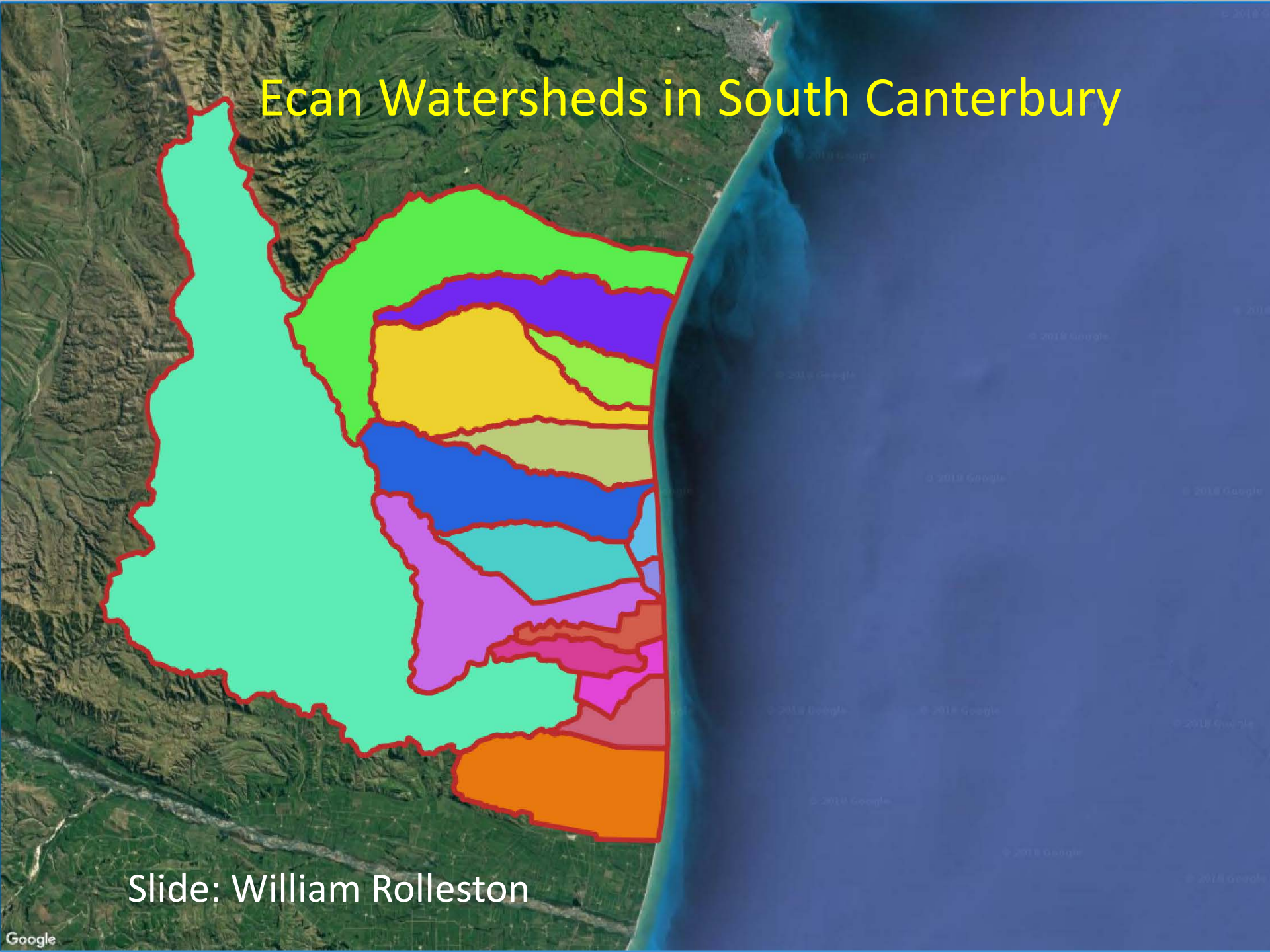


Blue Cliffs Station

Presented by William Rolleston
28 March 2018

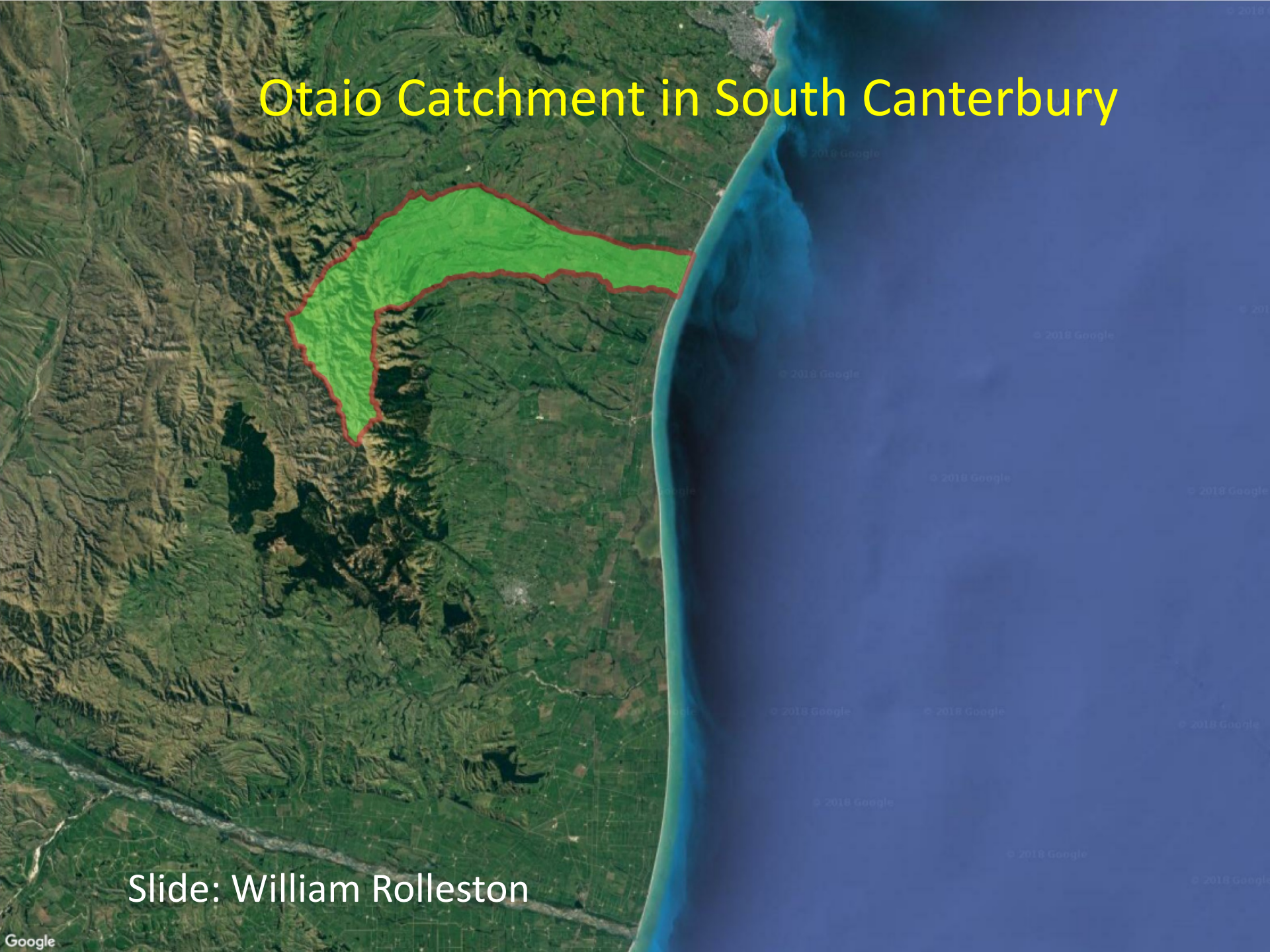


Ecan Watersheds in South Canterbury



Slide: William Rolleston

Otaio Catchment in South Canterbury



Slide: William Rolleston

Blue Cliffs Station (5000 ha)

Slide: William Rolleston

Possible Riparian Zones on Blue Cliffs

45 Hectares

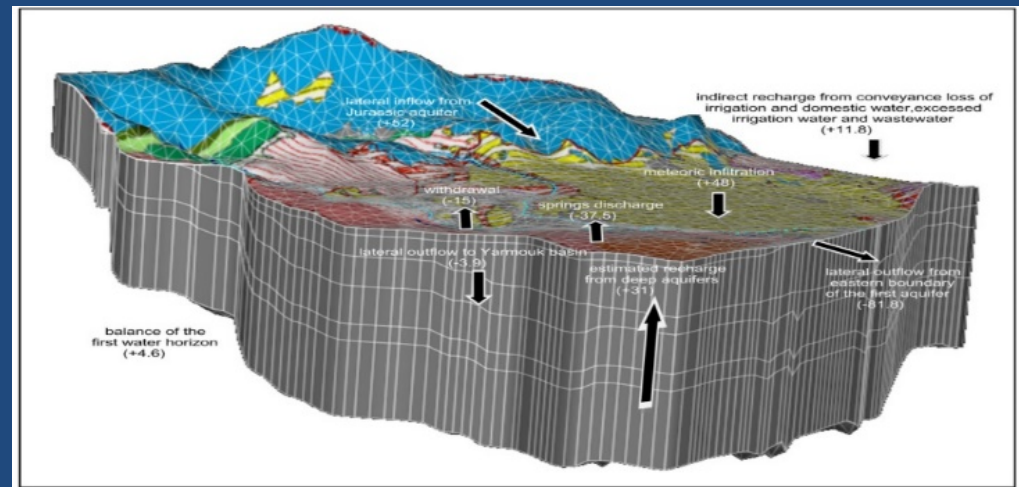
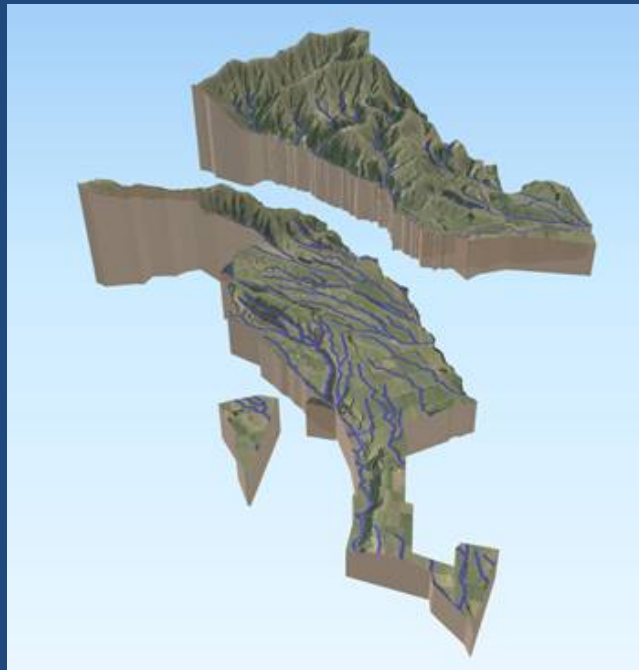
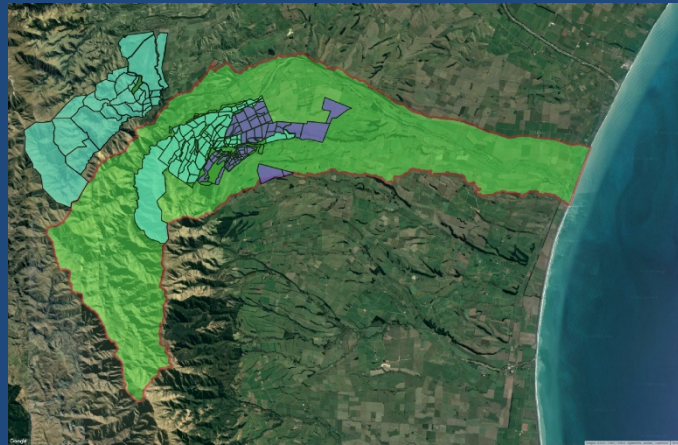
49 Hectares

27 Hectares

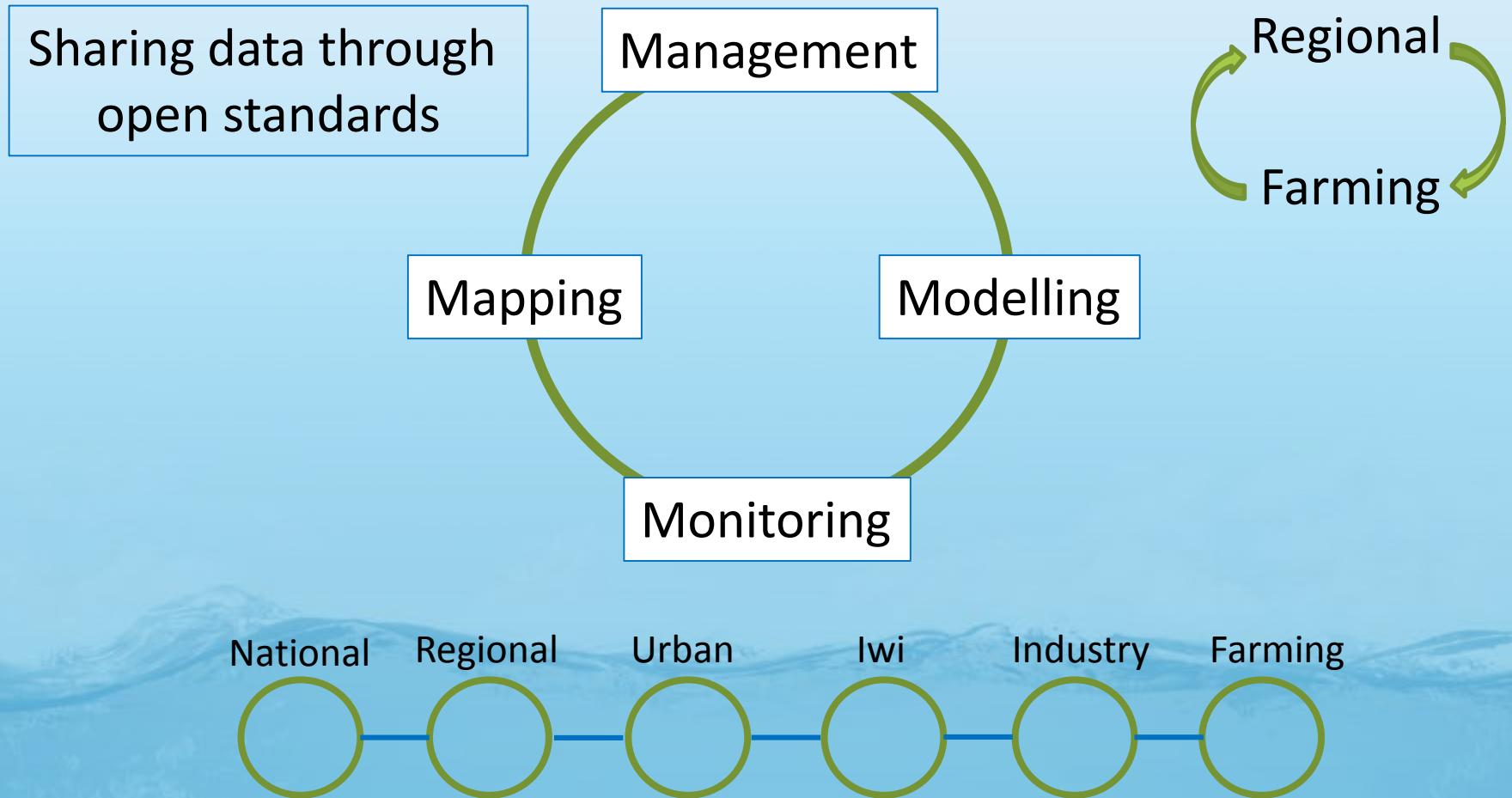
Slide: William Rolleston

Hydrology and Groundwater of Blue Cliffs Modelled in 3D

Make regional modelling meaningful at farm scale



Water Data Canterbury



A Comprehensive Hydrological Model for the Canterbury Region

- *What do we have now?*
- *What is needed?*
- *How do we get there?*

A real-time, hydrologically connected (3D) model for Canterbury

Model **surface water** – quantity and quality

Model **groundwater** – flow paths, connectivity and change over time; also include GW quality

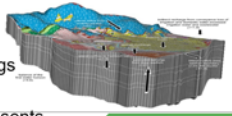
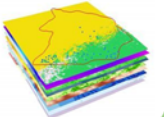

Have the ability to **backcast** – based on prior data to show quarterly, seasonal and annual changes over time

Have the ability to show **real-time** data – what is the state today? – based on current hydrological and meteorological information

Have the ability to **forecast** – scenarios & options, warnings

Have the ability to connect w/ non-science data (e.g., consents, water metering) and inform adaptive **management** conditions

Incorporate **Matauranga Maori** indicators



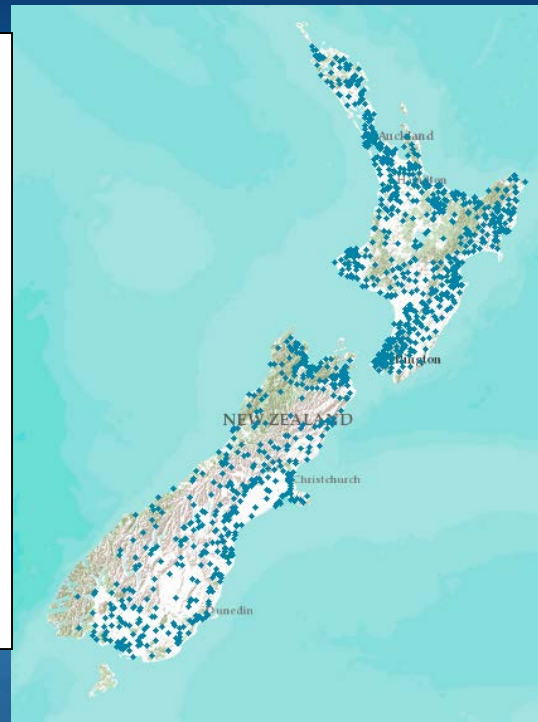
Environment Canterbury Regional Council
Kaumihēra Taiao ki Wairarapa

New Zealand Water Information System proposed in 2013



NIWA operates about 10% of 1300 hydrometric stations
Regional authorities operate about 90% of stations

- ◆ Auckland Council
- ◆ Bay of Plenty Regional Council
- ◆ Environment Canterbury
- ◆ Environment Southland
- ◆ Gisborne District Council
- ◆ Greater Wellington Regional Council
- ◆ Hawkes Bay Regional Council
- ◆ Horizons Regional Council
- ◆ Marlborough District Council
- ◆ **National Institute of Water and Atmospheric Research**
- ◆ North Shore City Council
- ◆ Northland Regional Council
- ◆ Otago Regional Council
- ◆ Taranaki Regional Council
- ◆ Tasman District Council
- ◆ Waikato Regional Council
- ◆ West Coast Regional Council



**New Zealand
Water Information System**

Develop a federated hydrological information infrastructure . . .
. . . linking nationally and regionally collected data

Current State of Play for NZ – all Done!

Local Government

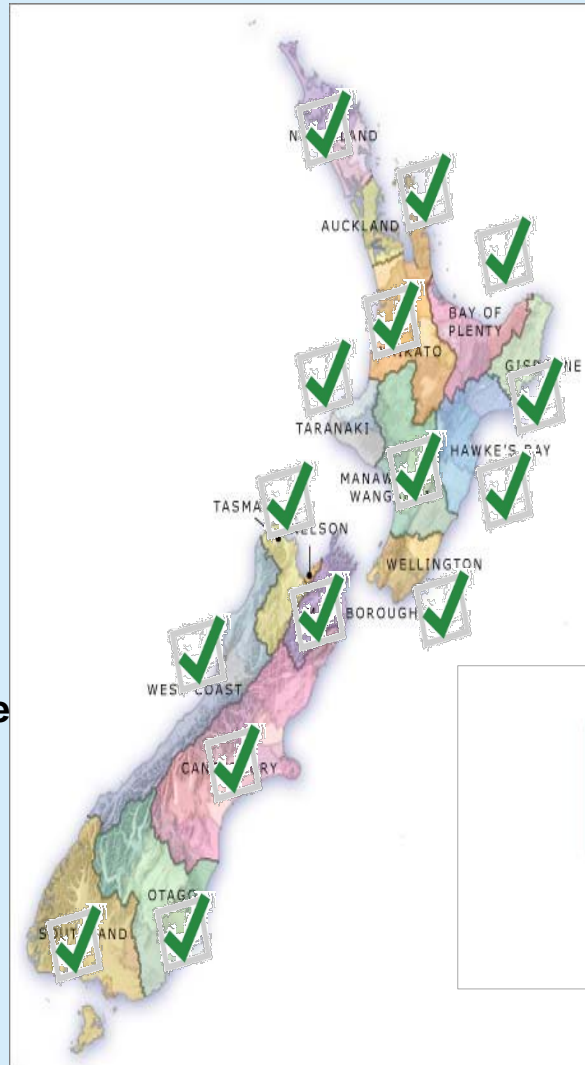


16

SOS2/WaterML2
now

SOS = Sensor Observation Service

Slide: Brent Watson, HRC



National - CRIs

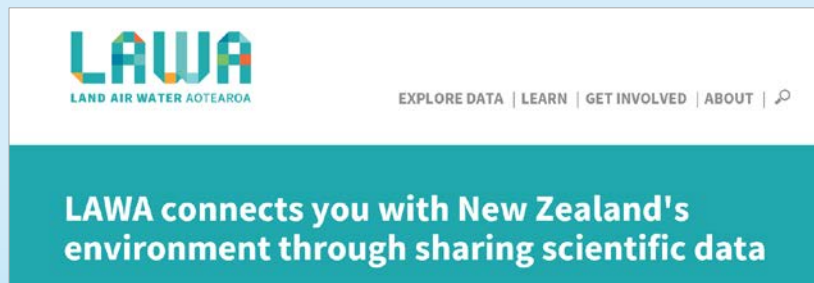


3

SOS2/WaterML2
now



Land Air Water Aotearoa (LAWA)



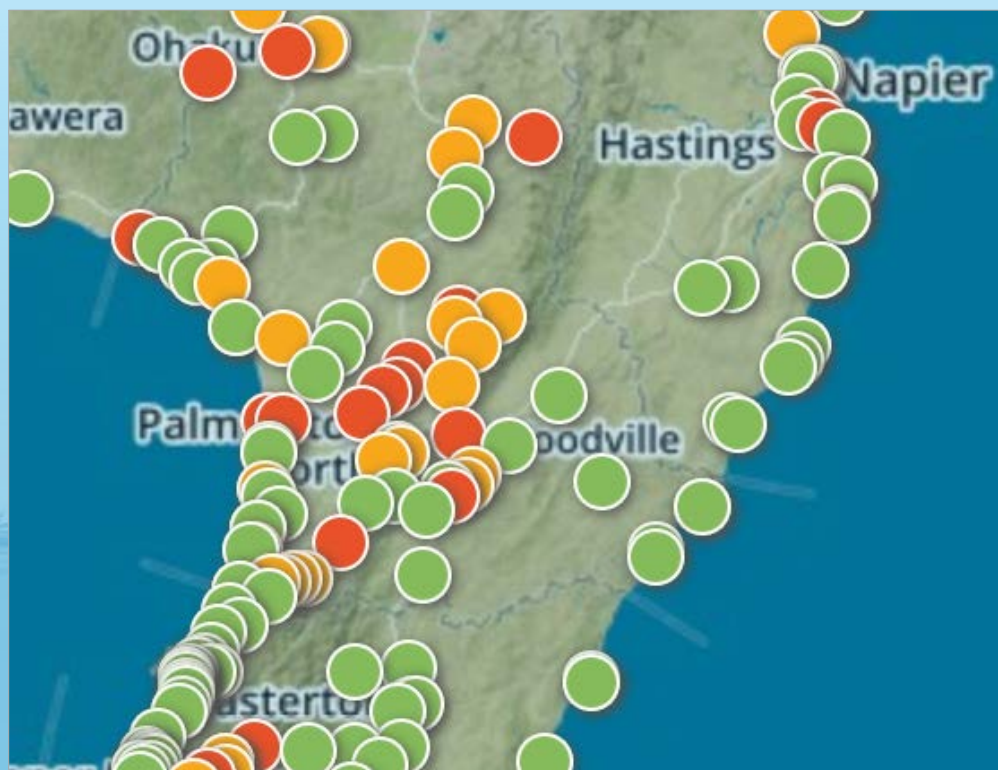
CAN I SWIM HERE?

We have many rivers, lakes & beaches to swim in. Find out the water quality at sites near you ►

Observations of Water Quality

Recreational water quality result

-  Suitable for swimming
-  Caution advised
-  Unsuitable for swimming
-  No data



Data Sharing using Open Standards in LAWA

- Each region maintains its own data
 - Data are accessed through “web services”
 - Common language for water: WaterML2
 - Open Geospatial Consortium standards
 - All information “looks the same” to user
-
- ***A tremendous technological achievement for New Zealand!!!***



Credit: LAEMG, especially Horizons Regional Council
Michael McCartney, Jeff Watson, Brent Watson, Sean Hodges
NIWA and Landcare

December '17 Technical and Planning Committee Meeting - Palmerston North, New Zealand

OGC TC/PC - December 3rd, 2017 - December 7th, 2017

[Read More...](#)



Core Observation Networks

Precipitation



Streamflow

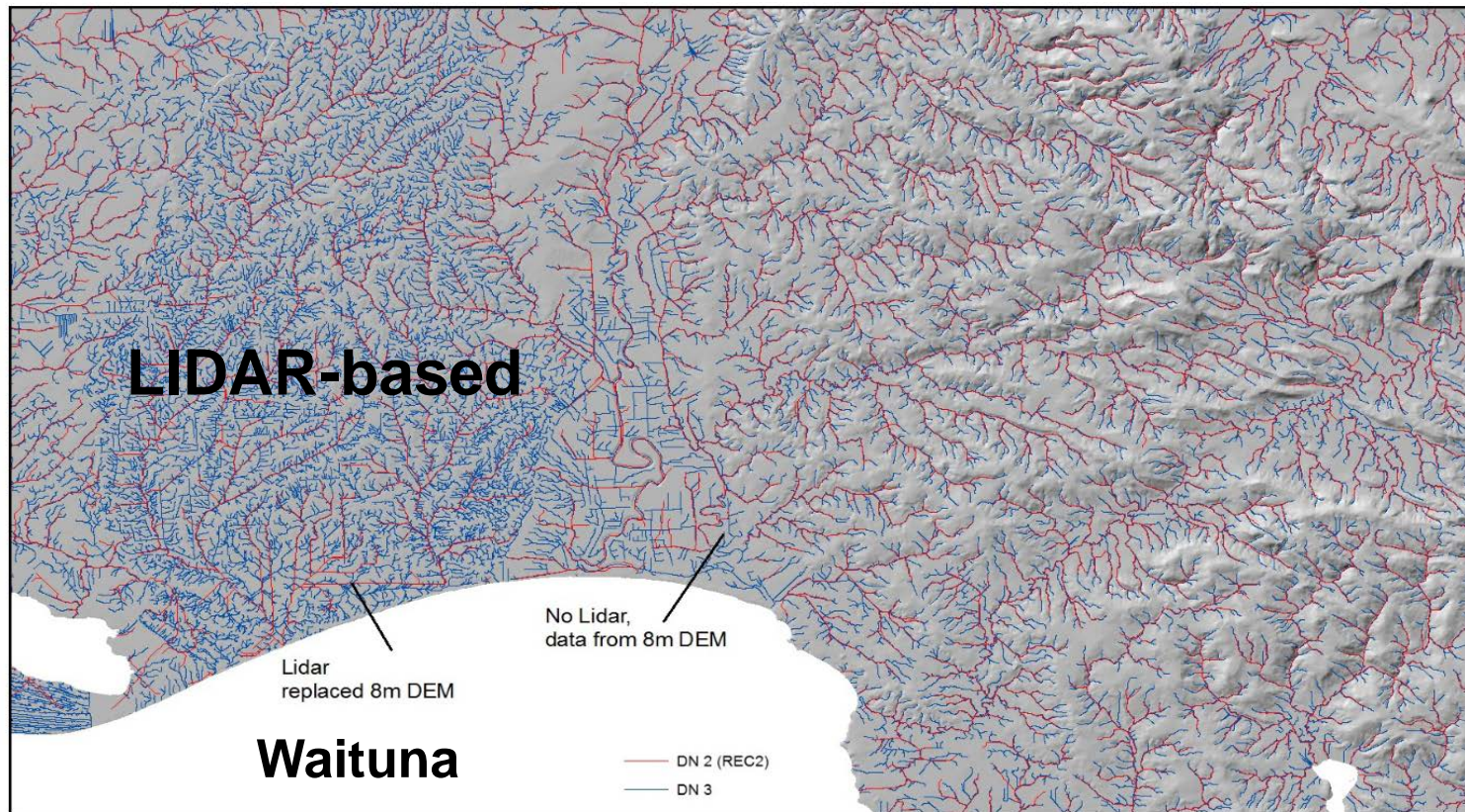


Groundwater



Digital River Network of New Zealand

Version 3 (DN3) -- NIWA, Christchurch



Improvements started in Southland, done for most of North Island by June 2017,
for all of North and South Islands by June 2018

The image shows the National Water Center building, a large, classical-style structure with a prominent pediment and columns. The name "NATIONAL WATER CENTER" is inscribed on the pediment. A group of people is gathered on the steps in front of the building.

NATIONAL WATER CENTER

This meeting led to an engagement between the academic community of the United States and the National Weather Service to help build the National Water Model

Inaugural Meeting – May, 2014

National Flood Interoperability Experiment

- Partnership between National Weather Service and the academic community
- Includes Summer Institutes for 105 graduate students from 49 universities at the National Water Center, June-July in 2015, 2016, 2017,

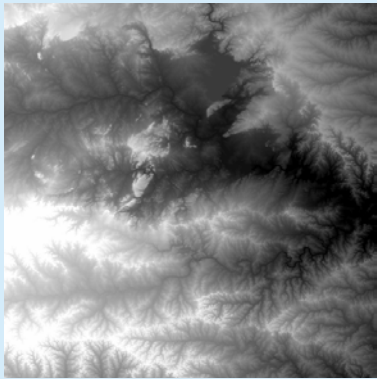


Centralized Water Model and Forecasting



NHDPlus Version 2.1

Foundation for a Geospatial Hydrologic Framework for the United States



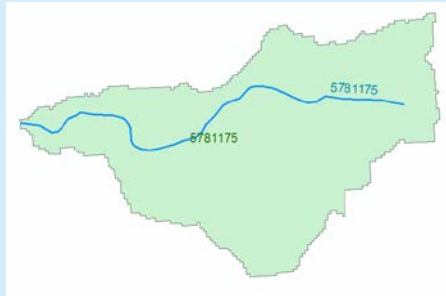
National Elevation Dataset

NHDPlus

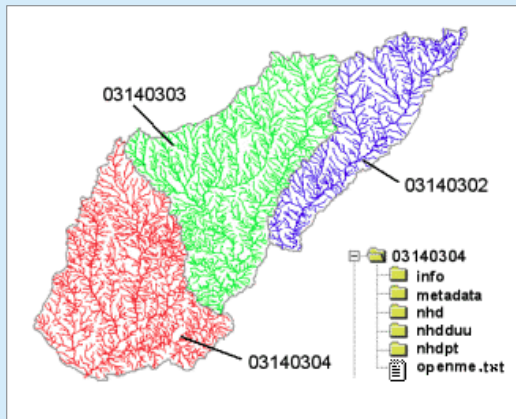
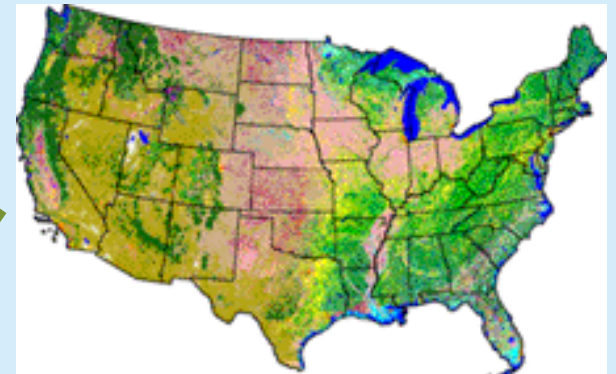
2.7 million reach catchments in US
average area 3 km²
reach length 2 km
Uniquely labelled



Watershed Boundary Dataset



National Land Cover Dataset



National Hydrography Dataset

Stampede



1.2 million gallon cooling tank



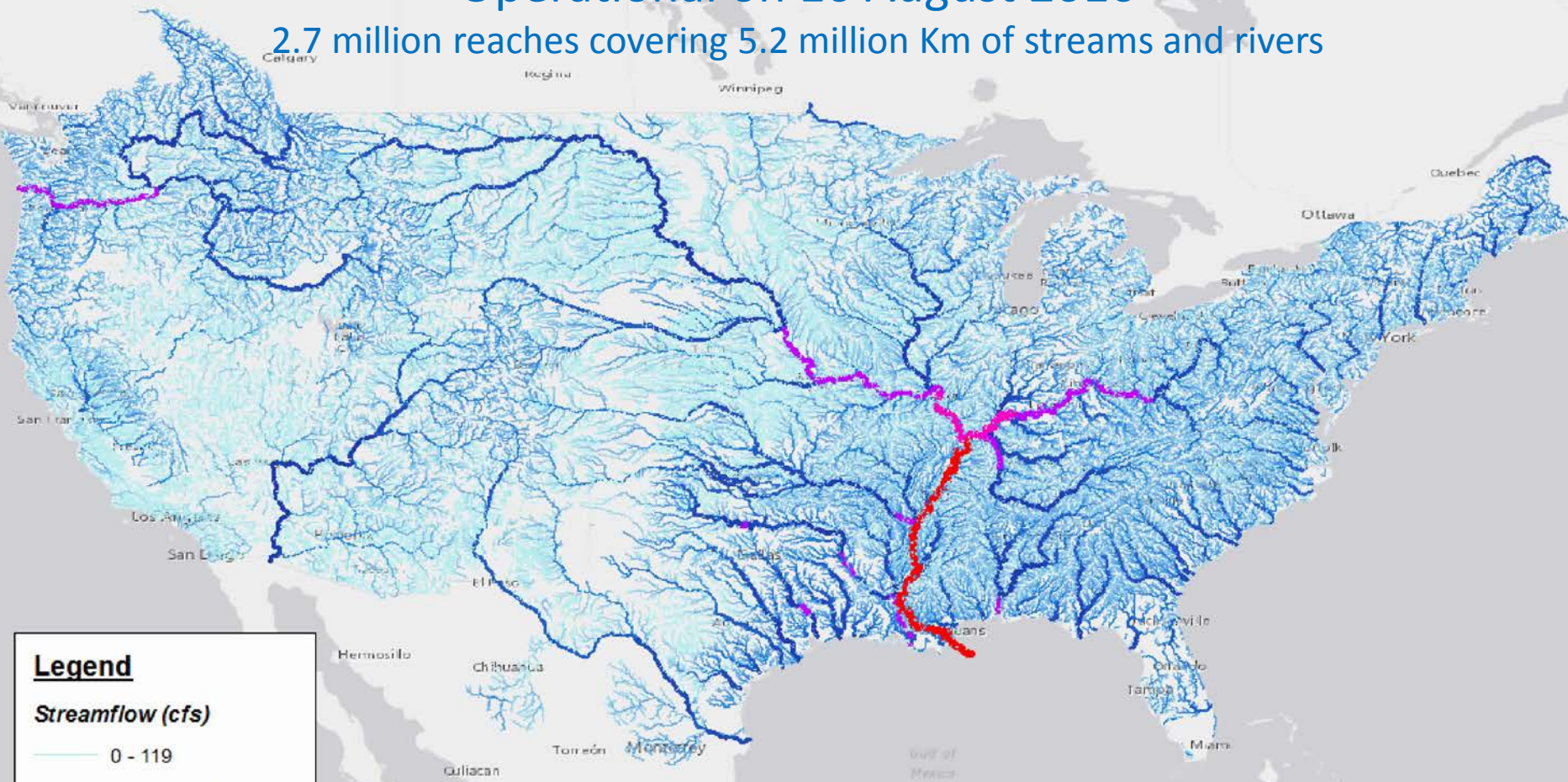
500,000 processors operating in parallel



National Water Model

Operational on 16 August 2016

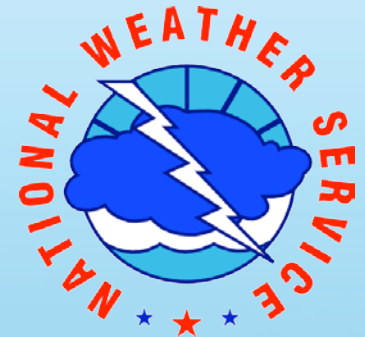
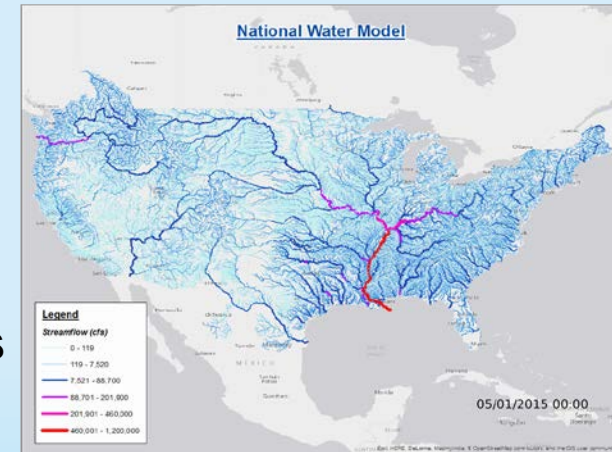
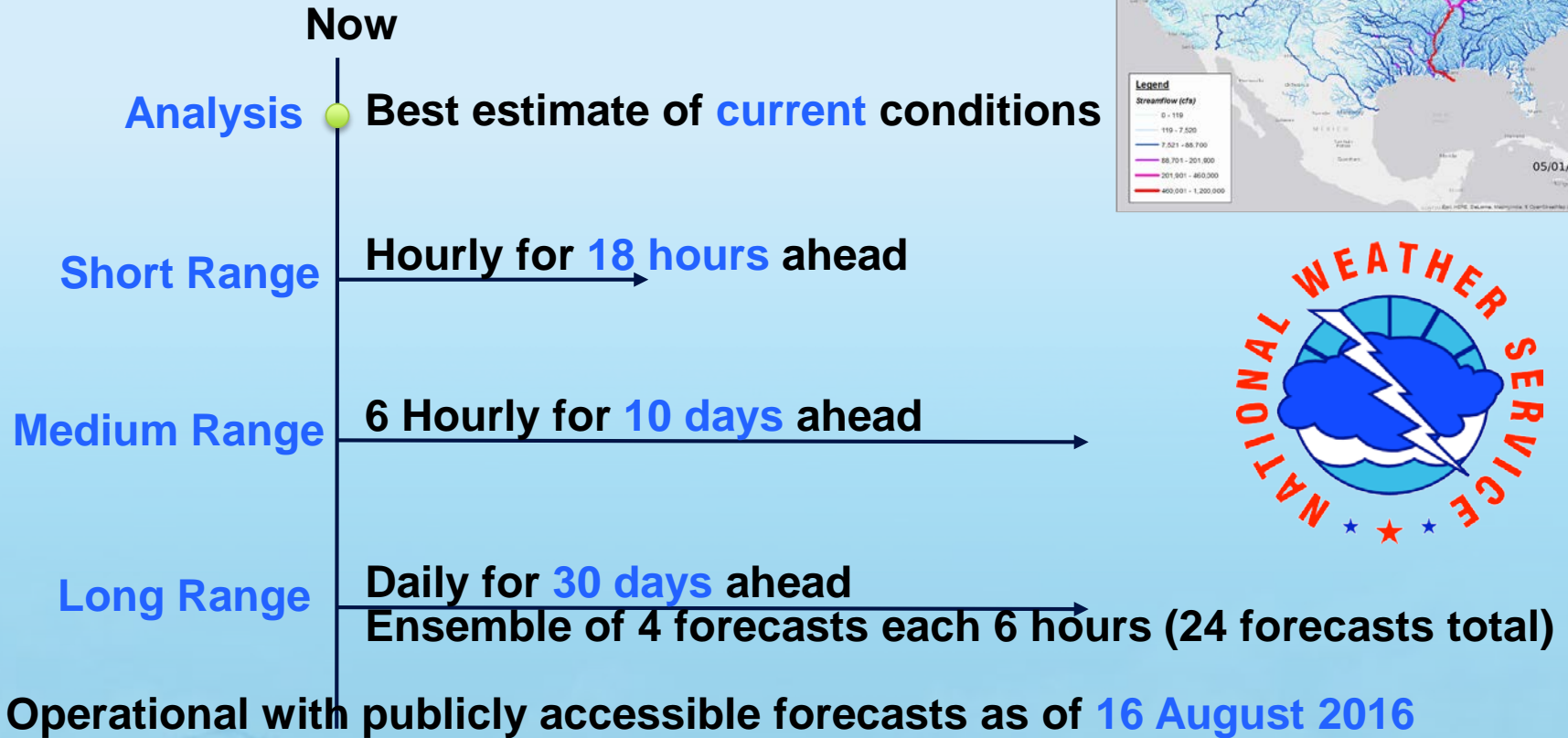
2.7 million reaches covering 5.2 million Km of streams and rivers



National Water Center
Tuscaloosa, AL

05/01/2015 00:00

National Water Forecasting



Name	Last modified	Size
Parent Directory		-
nwm.t06z.medium range.channel rt.f003.conus.nc.gz	12-Jul-2016 12:09	33M
nwm.t06z.medium range.channel rt.f006.conus.nc.gz	12-Jul-2016 12:09	33M
nwm.t06z.medium range.channel rt.f009.conus.nc.gz	12-Jul-2016 12:09	33M

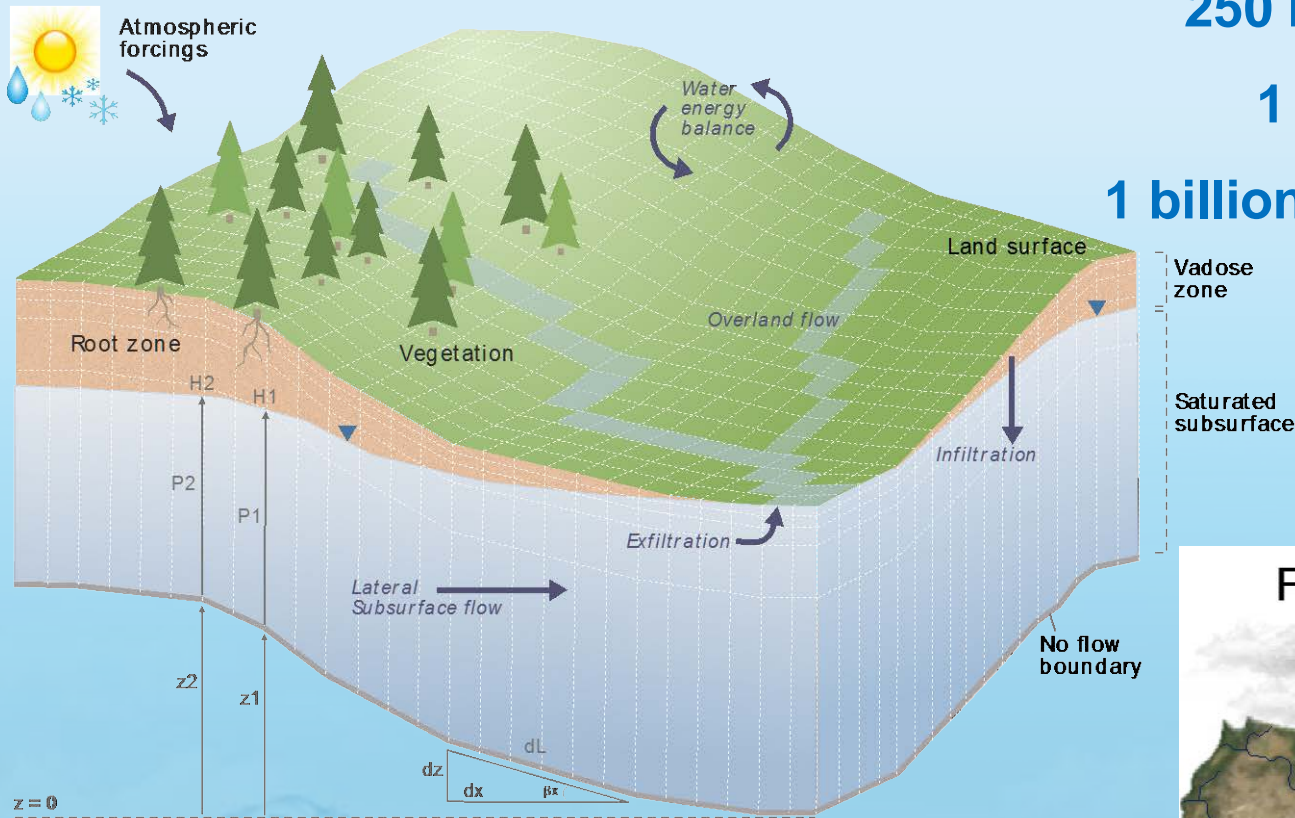
<ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/nwm/prod/>

Groundwater Model for Continental US

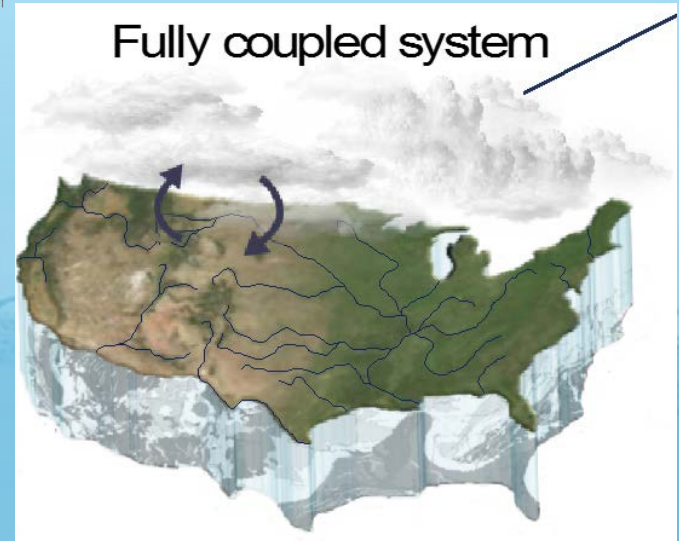
250 m cells horizontal

1 km total depth

1 billion computational cells

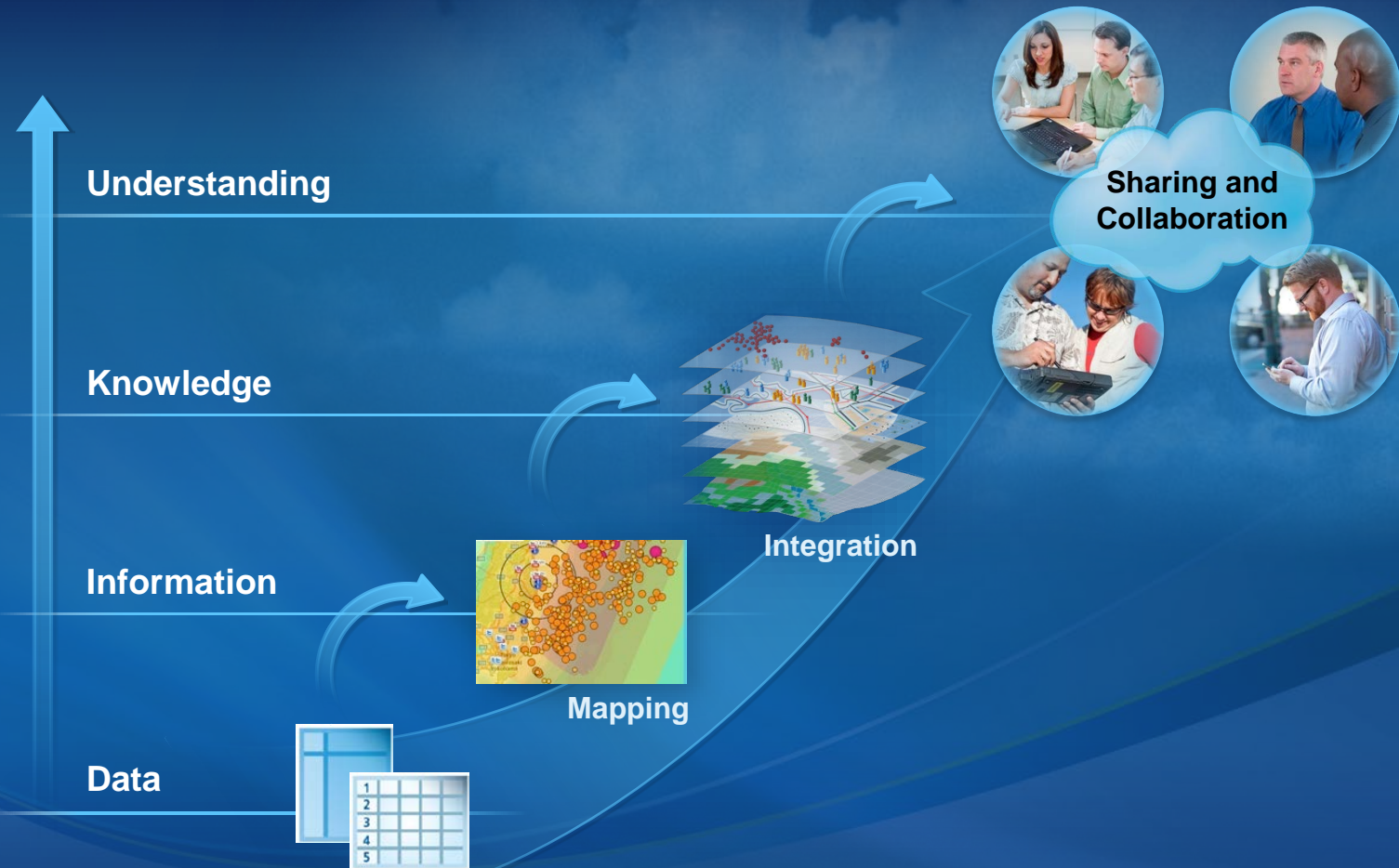


Fully coupled system



Source: Reed Maxwell
Colorado School of Mines

Geospatial Systems Are Helping Us Understand



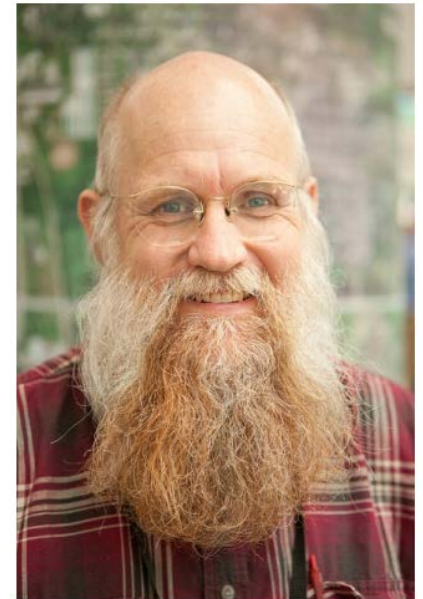
... Helping Us Make Better Decisions

Geographic Data Models

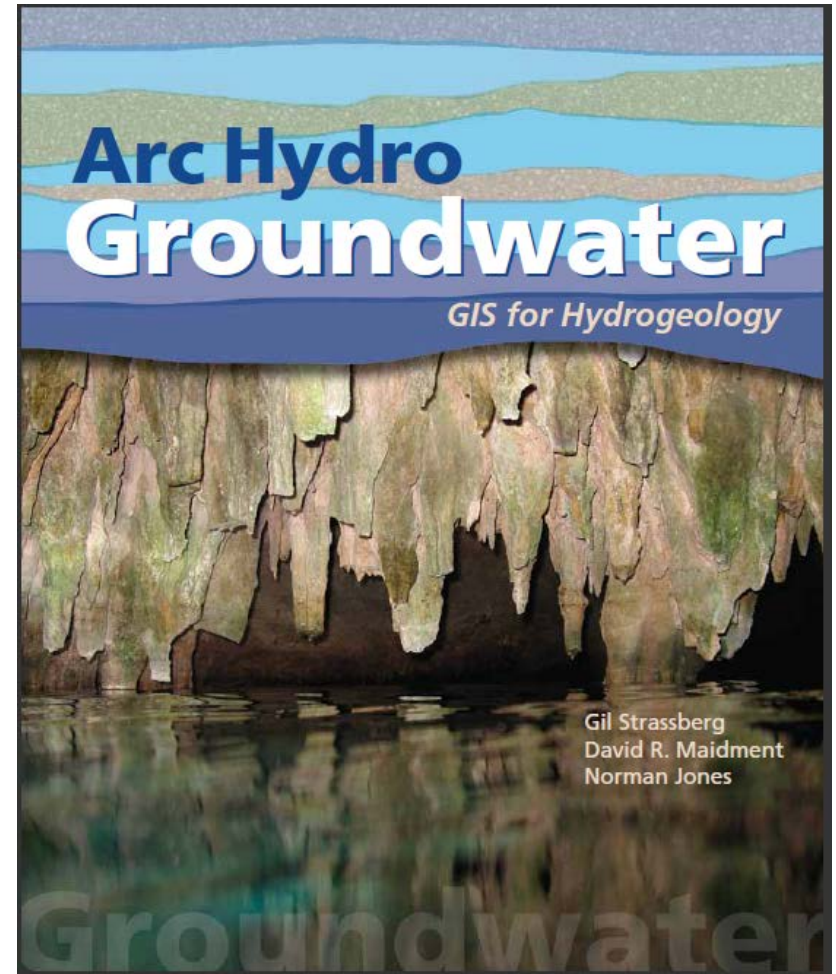
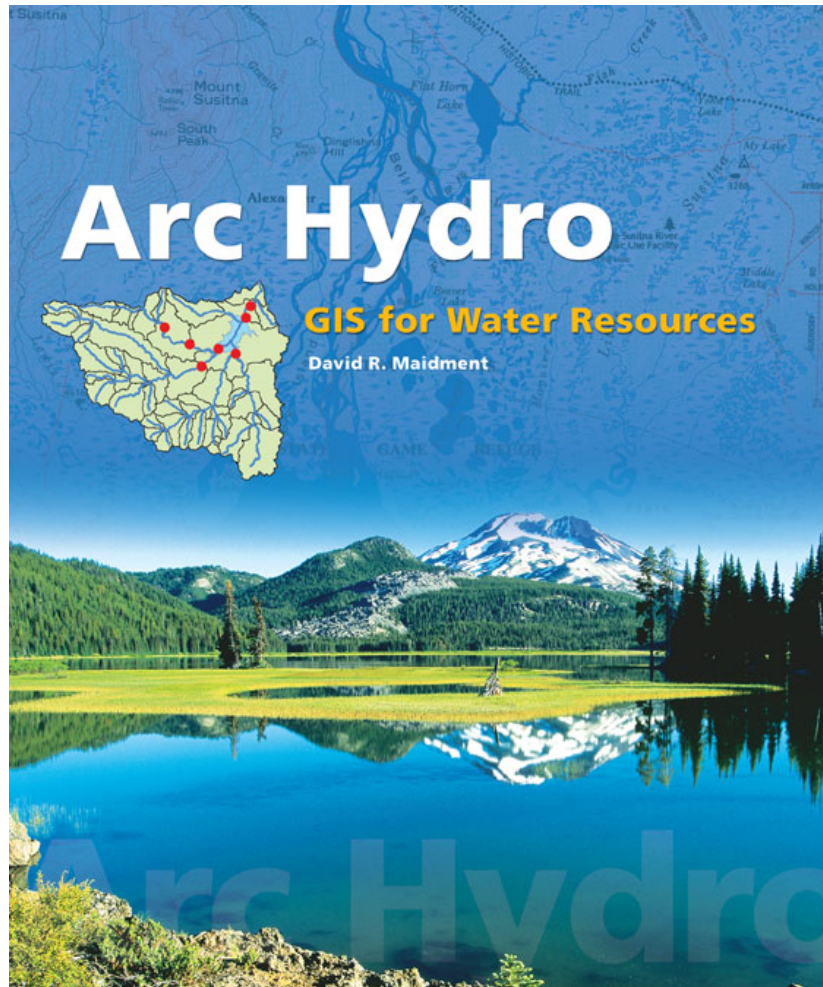
“All geographic information systems are built using **formal models** that describe how things are located in space. **A formal model is an abstract and well-defined system of concepts.** A geographic data model defines the **vocabulary for describing and reasoning about the things that are located on the earth.** Geographic data models serve as the foundation on which all geographic information systems are built.”

Scott Morehouse, Preface to “Modeling our World”, First Edition. He was the chief software engineer at ESRI

Scott Morehouse

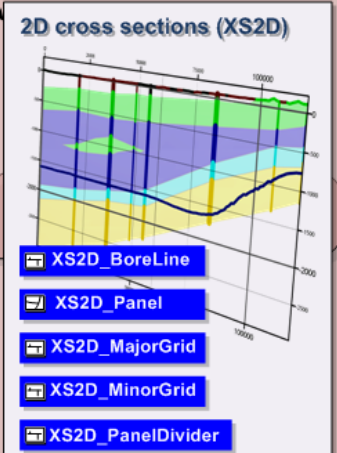
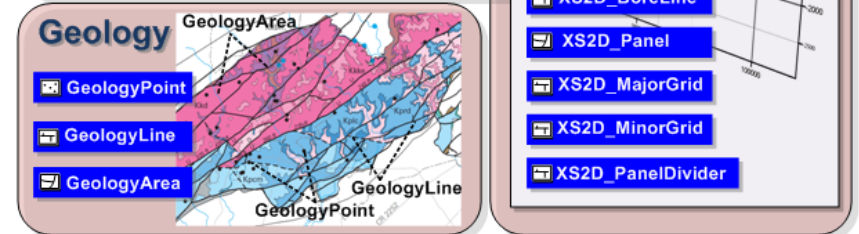
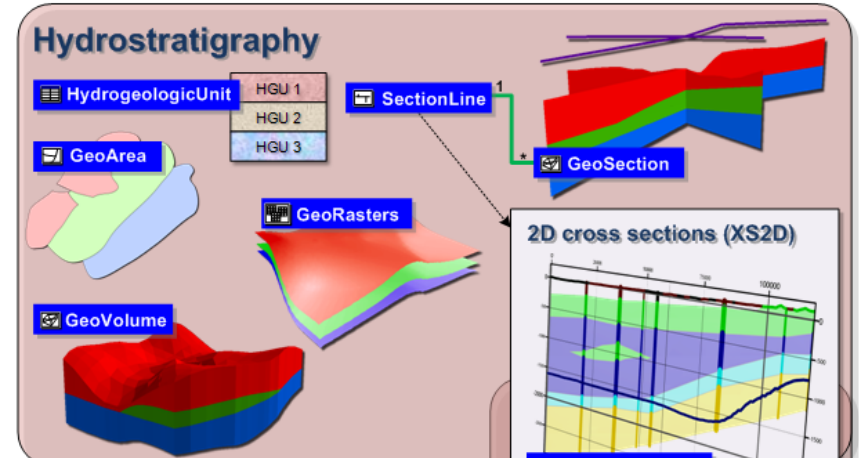
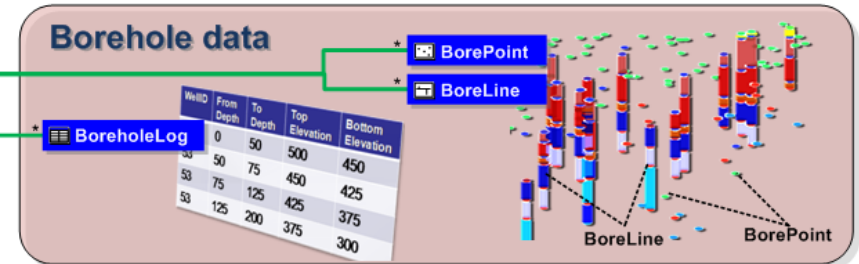
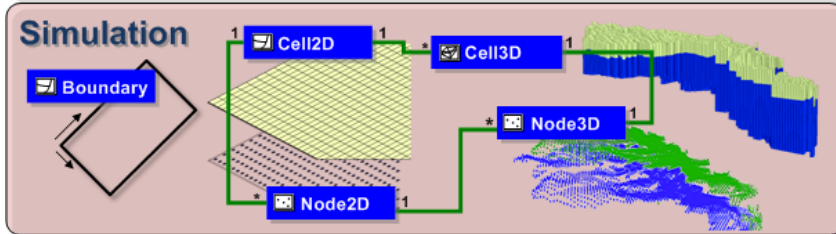
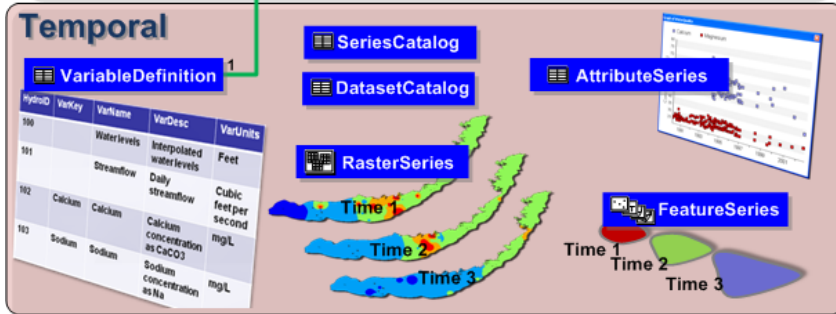
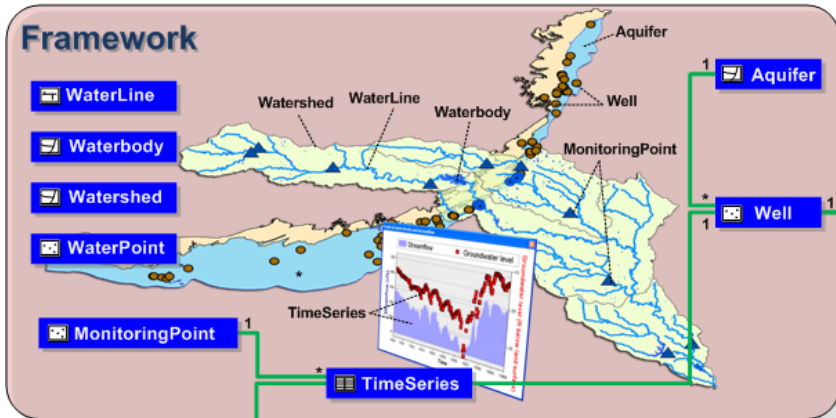


Geographic Information Models for Surface Water and Groundwater



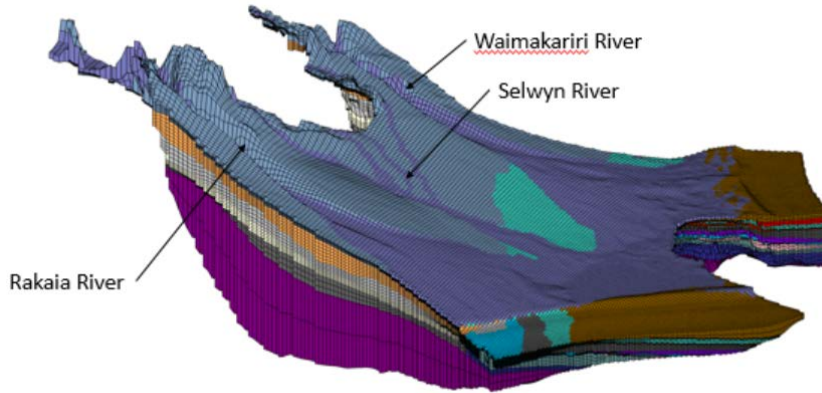
Arc Hydro Groundwater Data Model

Environment Canterbury has all these data



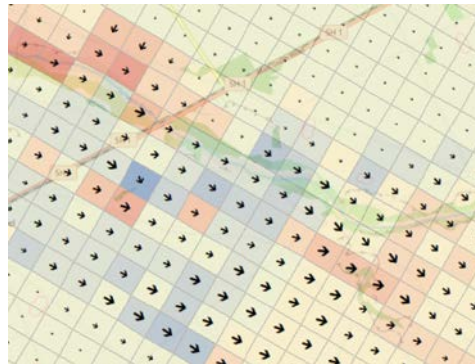
Aqualinc MODFLOW Model Grid, MODFLOW-NWT

Not yet in AH-GW ☹️



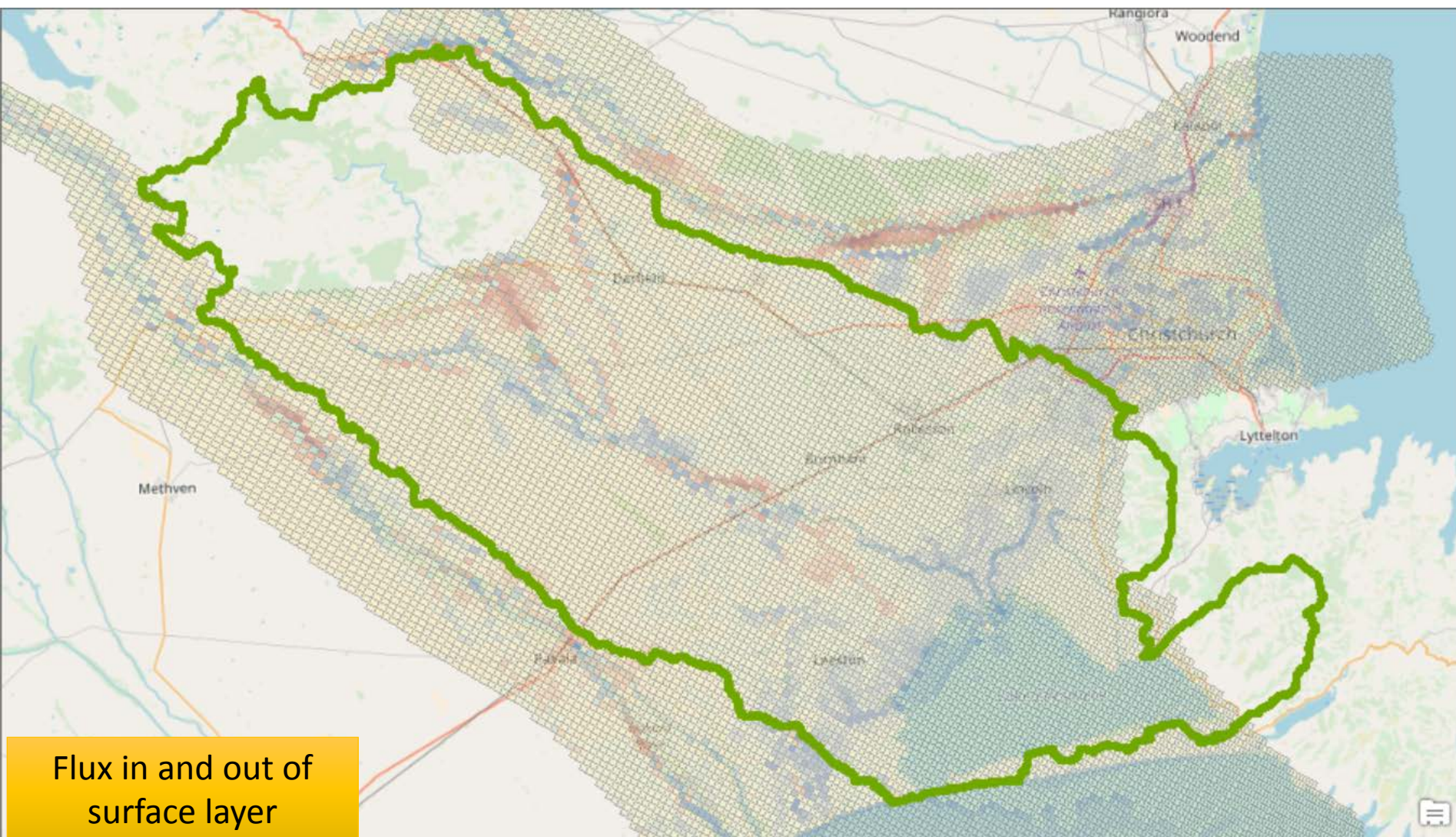
Source: Julian Weir, Aqualinc

flopy &
pyshp

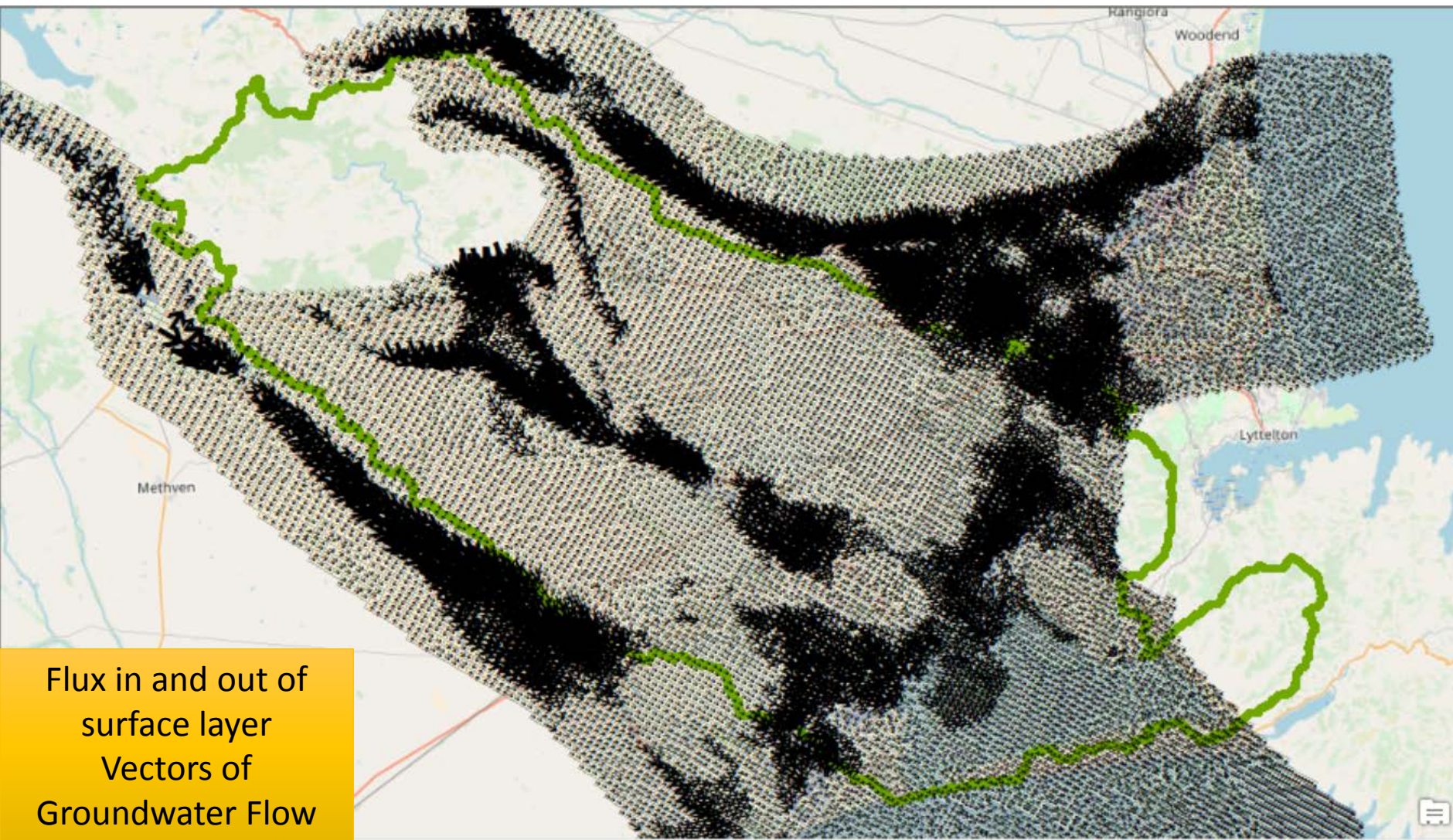


CellBudgetFile
Headfile
Grid Shapefile
->
Modflow Output
in ArcGIS

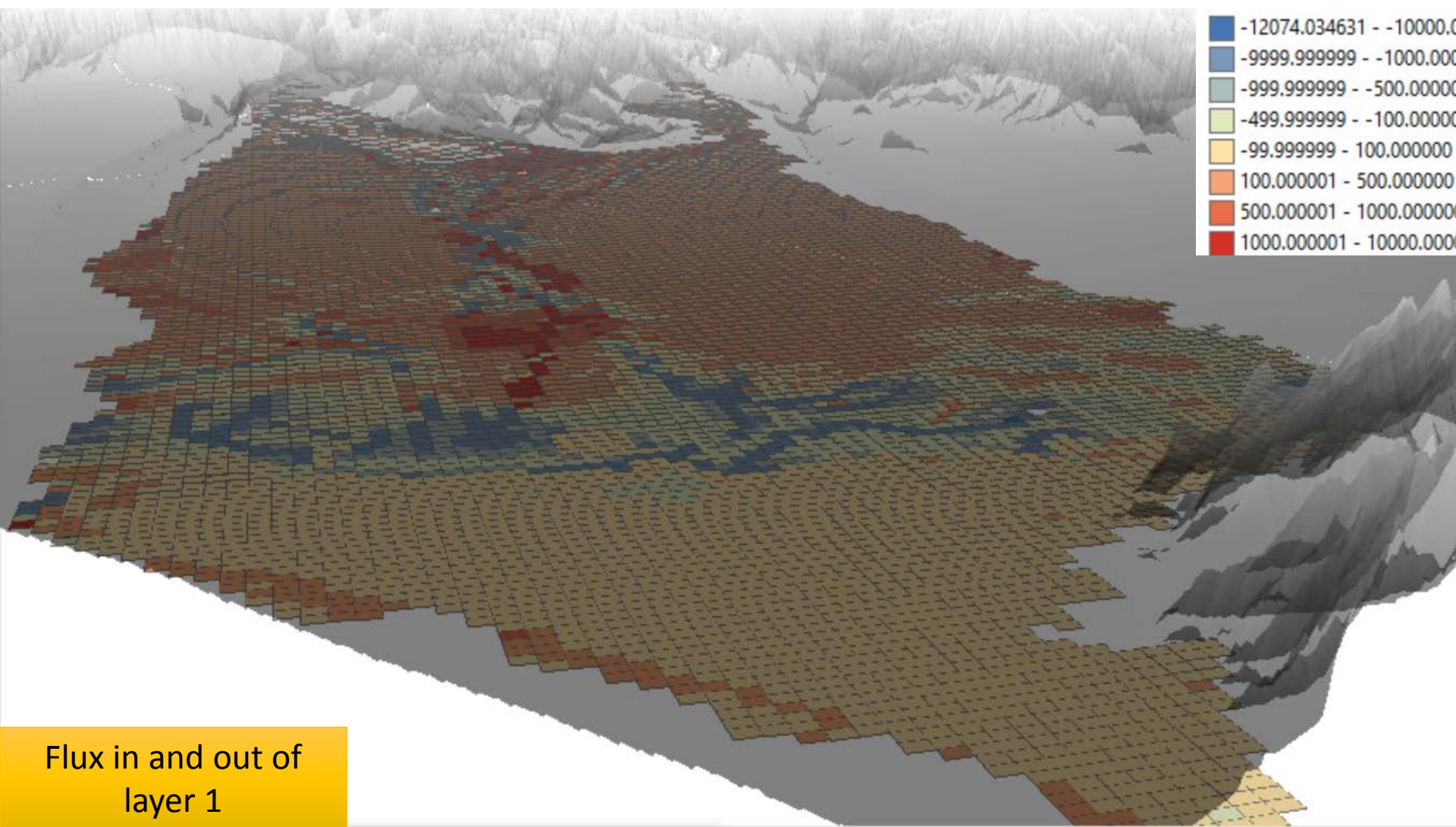
Slide: Justin Rogers



Slide: Justin Rogers



Slide: Justin Rogers

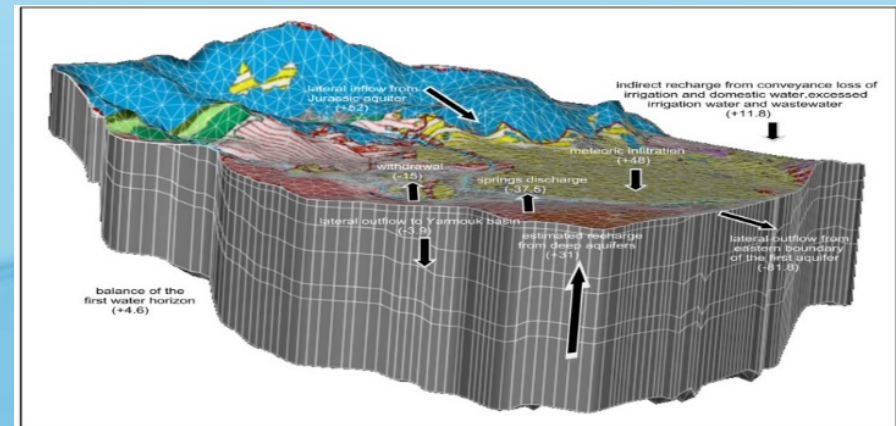


Slide: Justin Rogers

Surface Water and Groundwater, Quantity and Quality, in 3D, for all of Canterbury



Can this be done
.... yes, we can



It needs information models, services, and supercomputing