UNIQUE SOAKAGE DESIGN FOR THE THREE KINGS QUARRY

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Introduction

Three Kings Site is located in a unique and complex geological setting

Where is Three Kings?

Three Kings – John Kinder – circa 1875

Three Kings - 1905

Photo taken from Mt Eden

Three Kings 1920

More history?

http://temp.aucklandcouncil.govt.nz/EN/AboutCouncil/representativesbodies/LocalBoards/Puketapapalocalboard/Documents/threekingsheritagestudy2015.pdf

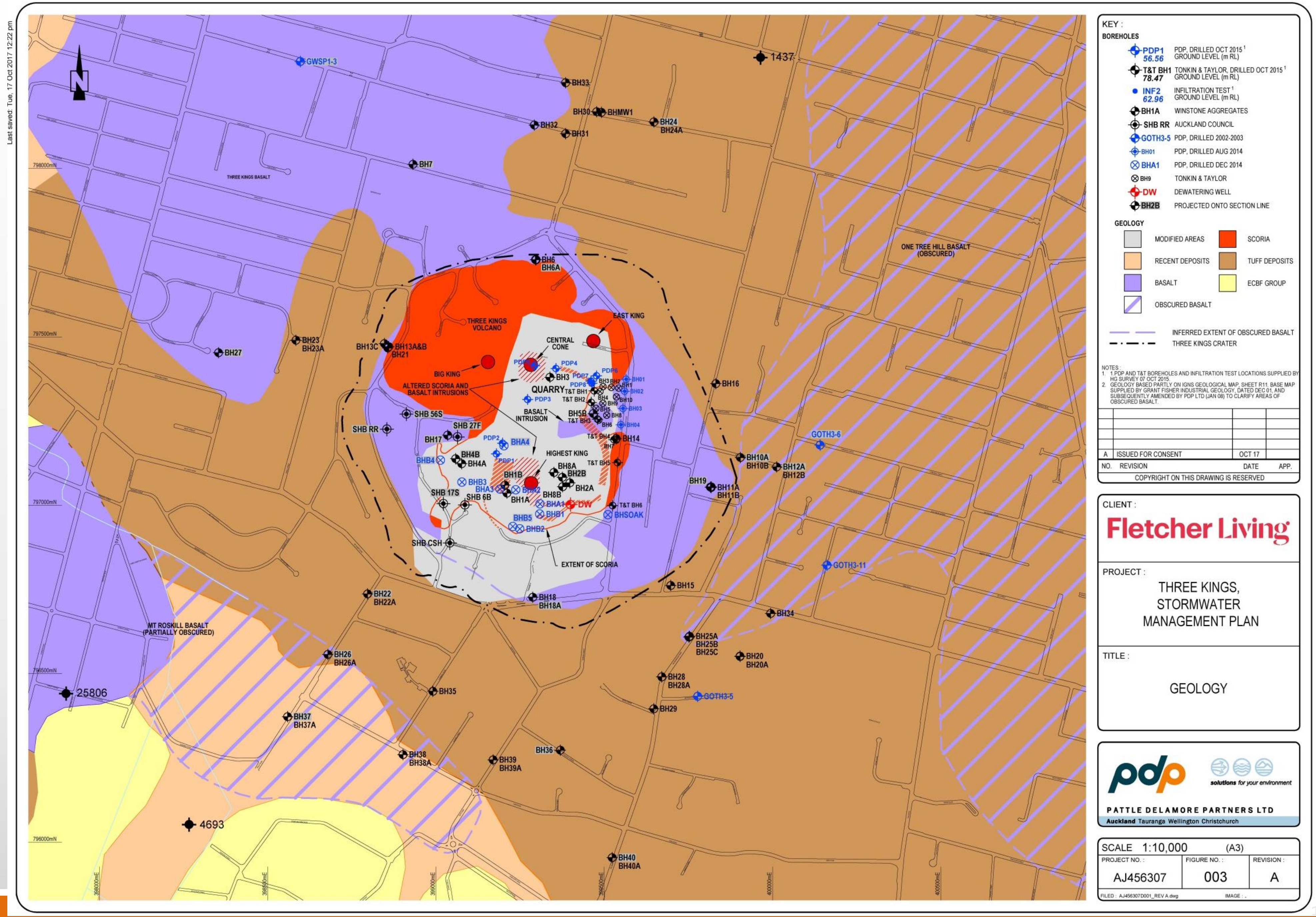
Geology

Not the stormwater stuff!

Kilauea

Kilauea

Geology

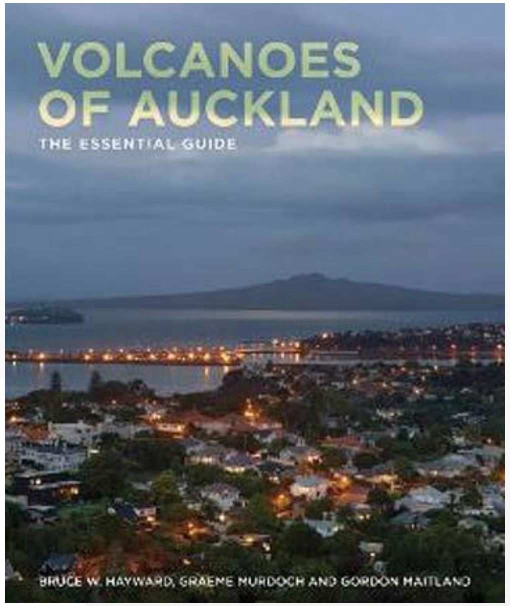


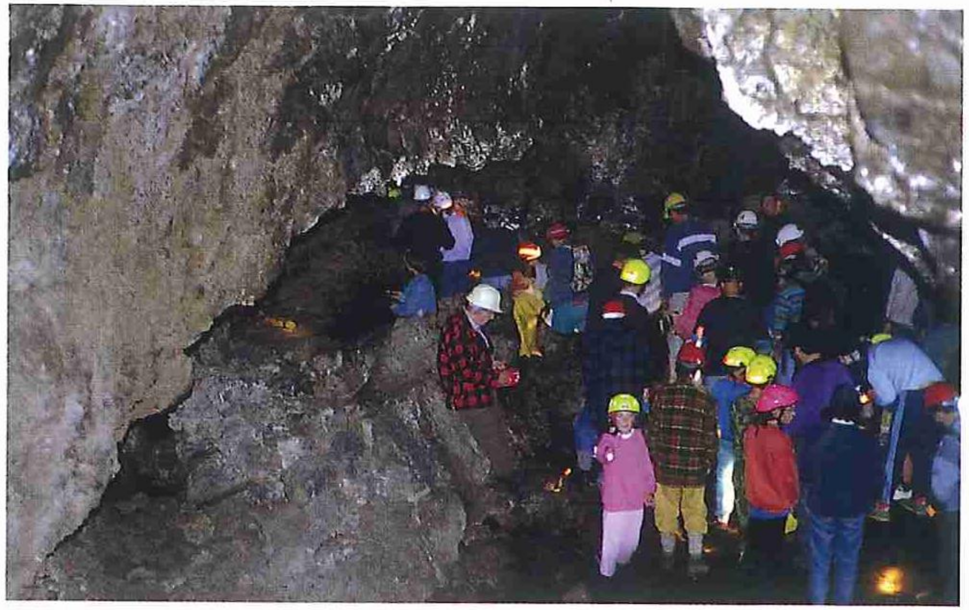
Last saved: Tue, 17 Oct 2017 12:22 pm
KEY :
BOREHOLES
PDP1 56.56 PDP, DRILLED OCT 2015 GROUND LEVEL (m RL)
T&T BH1 78.47 TONKIN & TAYLOR, DRILLED OCT 2015 GROUND LEVEL (m RL)
INF2 62.96 INFILTRATION TEST GROUND LEVEL (m RL)
BH1A WINSTONE AGGREGATES
SHB RR AUCKLAND COUNCIL
GOTH3-5 PDP, DRILLED 2002-2003
BH01 PDP, DRILLED AUG 2014
BHA1 PDP, DRILLED DEC 2014
BH9 TONKIN & TAYLOR
DW DEWATERING WELL
BH2B PROJECTED ONTO SECTION LINE
GEOLOGY
MODIFIED AREAS
SCORIA
RECENT DEPOSITS
TUFF DEPOSITS
BASALT
ECBF GROUP
OBSCURED BASALT
INFERRED EXTENT OF OBSCURED BASALT
THREE KINGS CRATER
A ISSUED FOR CONSENT OCT 17
NO. REVISION DATE APP.
COPYRIGHT ON THIS DRAWING IS RESERVED
CLIENT :
Fletcher Living
PROJECT :
THREE KINGS, STORMWATER MANAGEMENT PLAN
TITLE :
GEOLOGY
pdp
solutions for your environment
PATTLE DELAMORE PARTNERS LTD
Auckland Tauranga Wellington Christchurch
SCALE 1:10,000 (A3)
PROJECT NO. : AJ456307
FIGURE NO. : 003
REVISION : A
THREE KINGS BASALT
ONE TREE HILL BASALT (OBSCURED)
THREE KINGS VOLCANO
CENTRAL CONE
EAST KING
BIG KING
ALTERED SCORIA AND BASALT INTRUSIONS
QUARRY
BASALT INTRUSION
HIGHEST KING
EXTENT OF SCORIA
MT ROSKILL BASALT (PARTIALLY OBSCURED)
1437
25806
4693

Geology

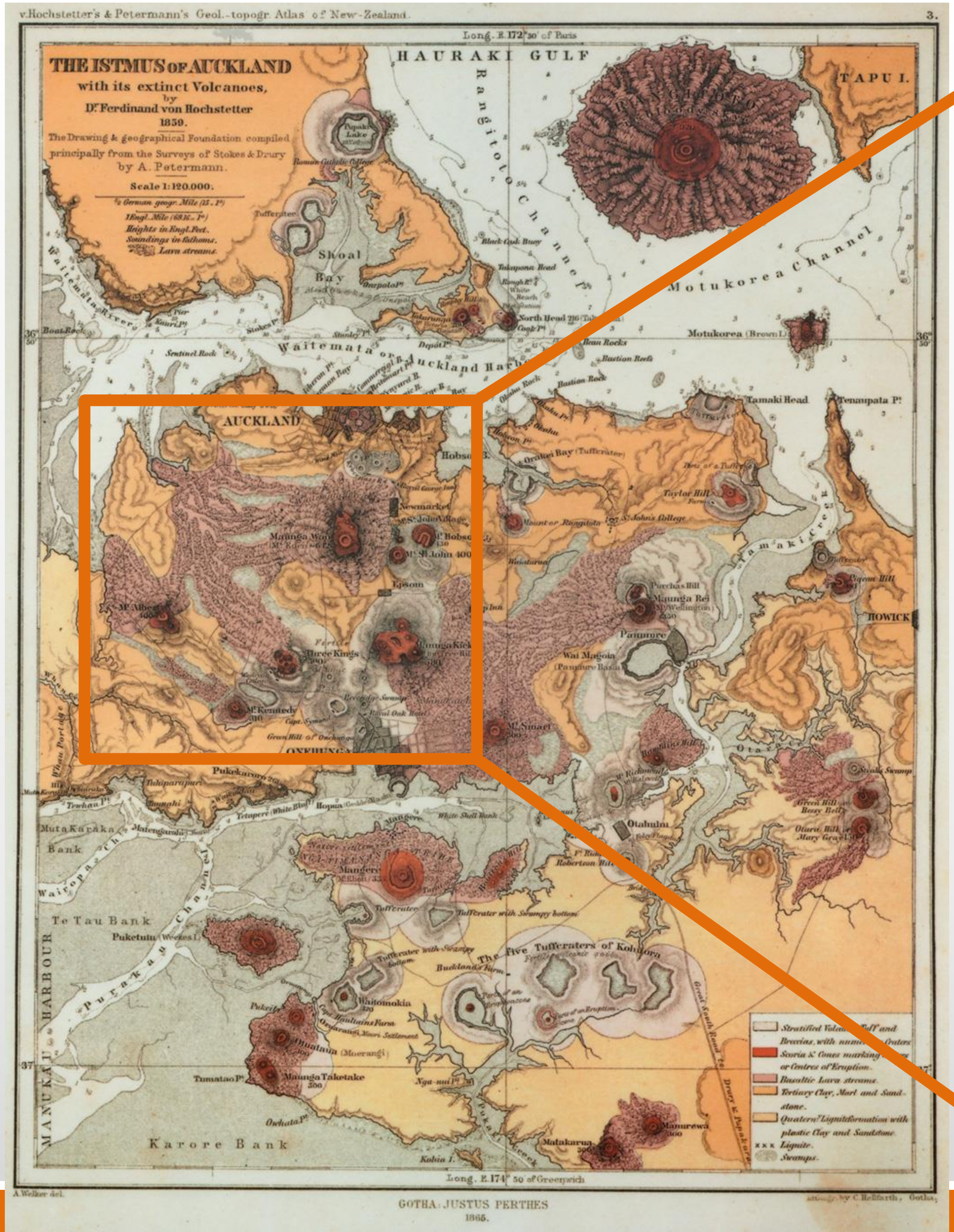
- Three Kings/Te Tatua a Riukiuta (the war belt of Riukiuta) is a complex set of volcanic vents over a wide area
- Large amounts of ash and debris forming tuff ring
- Five significant scoria cones and smaller scoria mounds inside an explosion crater approx. 1km wide
- Lava flowed down the Meola/Motions palaeovalley towards the Waitamata harbour
- Number of lava caves and tunnels

Volcanoes of Auckland





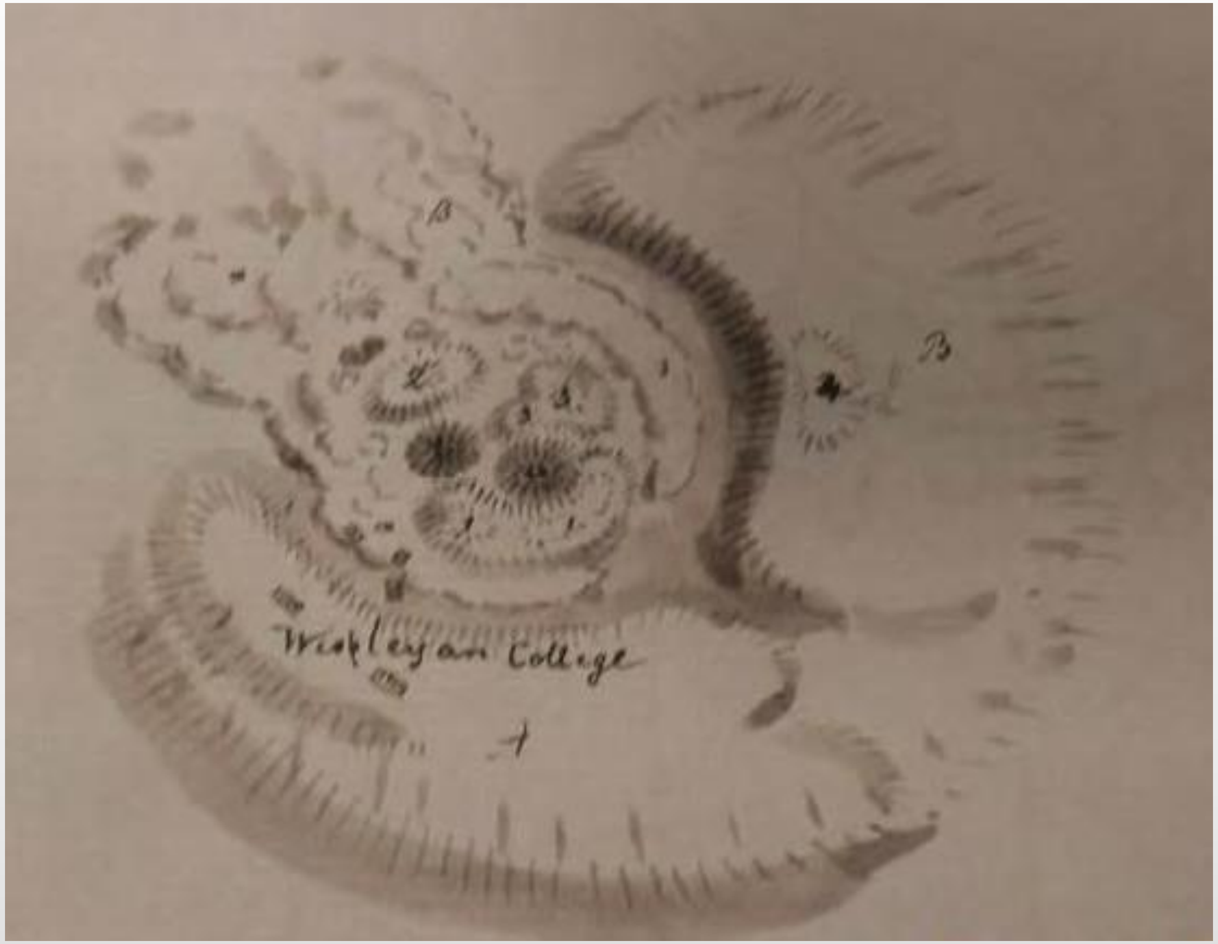
ABOVE LEFT This large entrance to a lava cave within a Three Kings lava flow has been landscaped in the back yard of a private house in Landscape Rd.
ABOVE RIGHT Organised groups are periodically guided through the privately owned Stewarts Lava Cave within a lava flow from Three Kings Volcano.



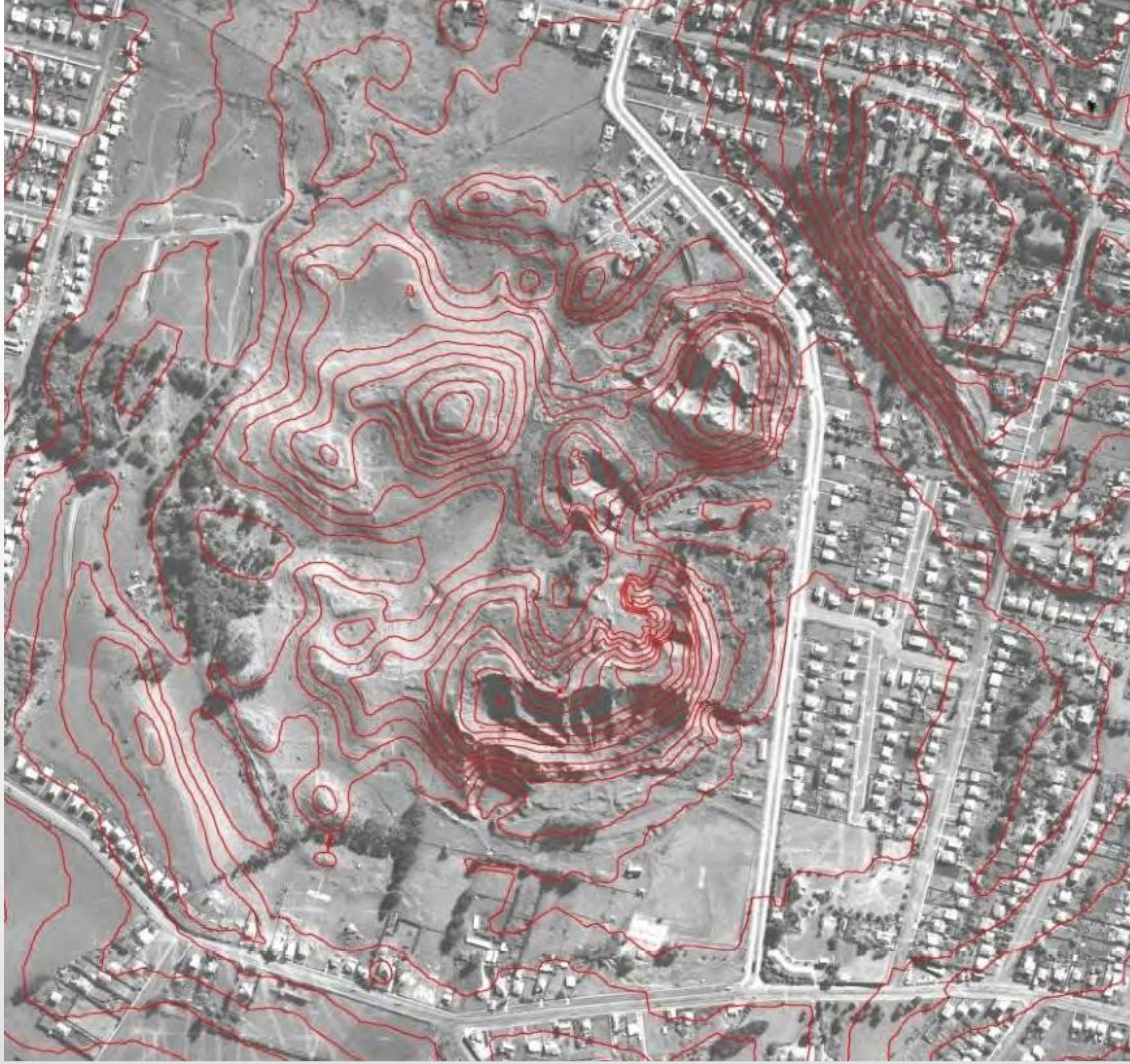
v.Hochstetter's & Petermann's Geol.-topogr. Atlas of New-Zealand.
3.
THE ISTMUS OF AUCKLAND
with its extinct Volcanoes,
by
Dr. Ferdinand von Hochstetter
1859.
The Drawing & geographical Foundation compiled principally from the Surveys of Stokes & Drury
by A. Petermann.
Scale 1:120.000.
HAURAKI GULF
RANGITOTO CHANNEL
TAPU I.
Motukorea Channel
Shoal Bay
Waitemata or Auckland Harbour
AUCKLAND
Tamaki Head
Tamaki Creek
HOWICK
Epsom
Three Kings
ONEHUNGA
MANUKAU HARBOUR
Te Tau Bank
Karore Bank
The Five Tufferaters of Kohimara
GOTHA: JUSTUS PERTHES
1865.

AUCKLAND
Hobson
Newmarket
Mt. St. John 400
Epsom
Three Kings
Mt. Kennedy
ONEHUNGA

Geology



Drawing by Dr Ferdinand von Hochstetter circa 1856



Topographical map – Winstones 2014

Geology

Geology

Geology

What is Soakage

Soakage in the Auckland sense

Soakage

Groundwater Modelling

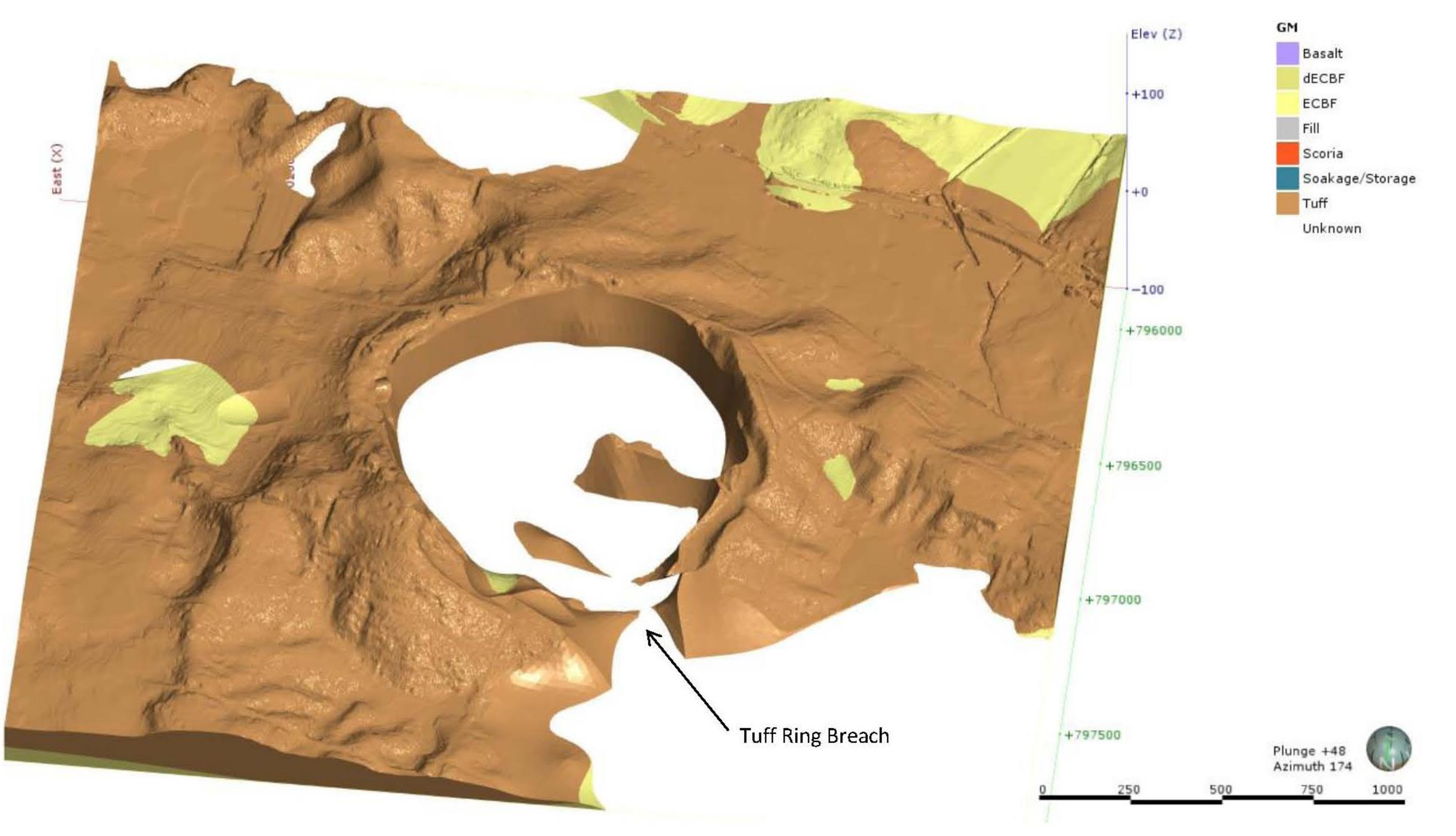
Understanding the recovery of the groundwater regime and determination of possible soakage

Groundwater Modelling

OBJECTIVES

- Determine the available "freeboard" above the "original" groundwater surface to host the groundwater rise associated with the design storms.
- Design scenarios modelled
  - 10-year ARI, 24 hour rainfall event;
  - 100-year ARI, 24 hour rainfall event; and
  - Sequential 2 x 100-year ARI, 24 hour rainfall events.

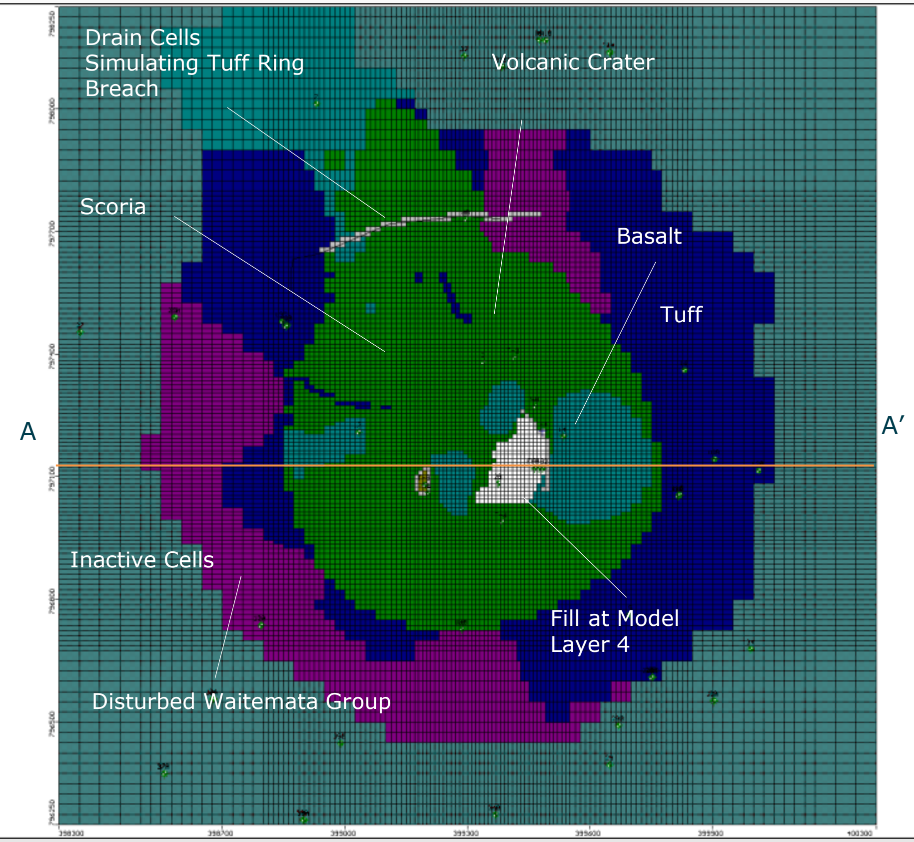
Groundwater Modelling

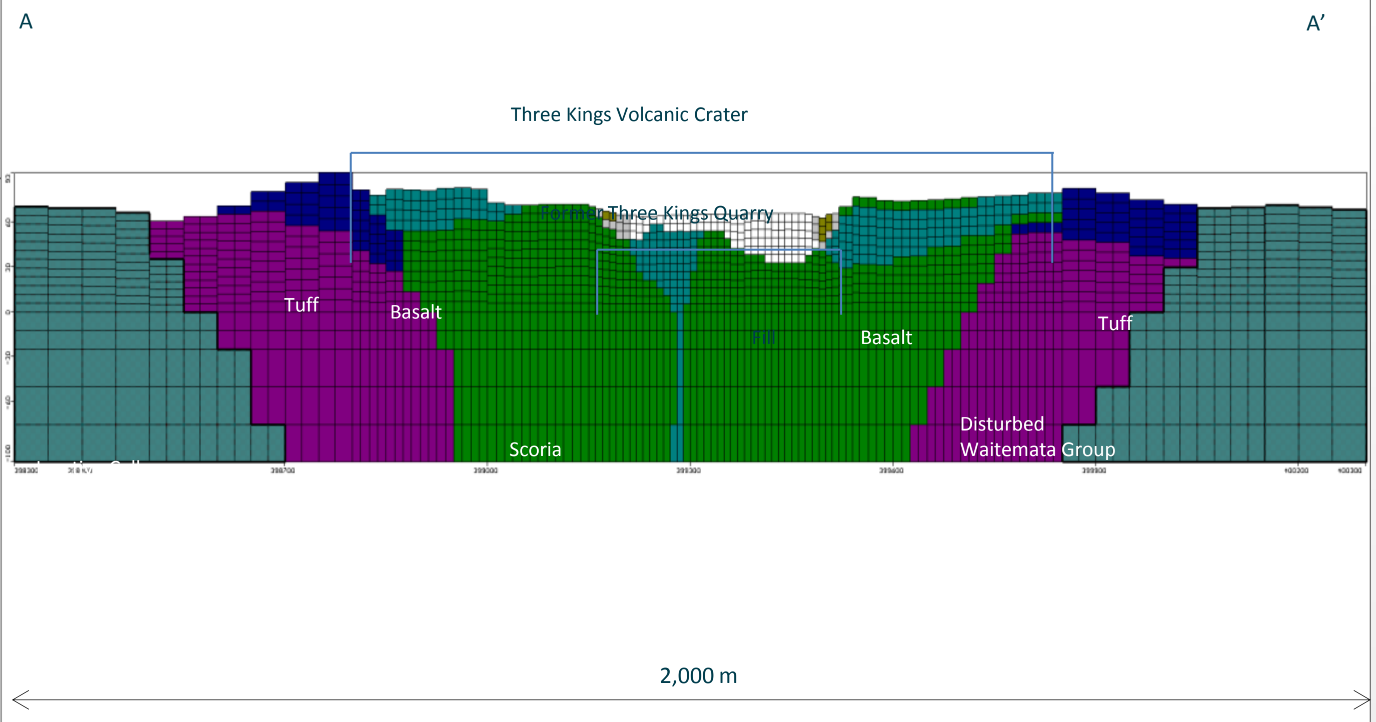


Hydrogeology

- Current gw level is RL34m
- Cessation will cause rise to RL56m
- Resume gw flow out of the crater
- No significant barriers within the crater
- "spillway" at RL48.0m
- Recharge estimated 85%

Groundwater Modelling

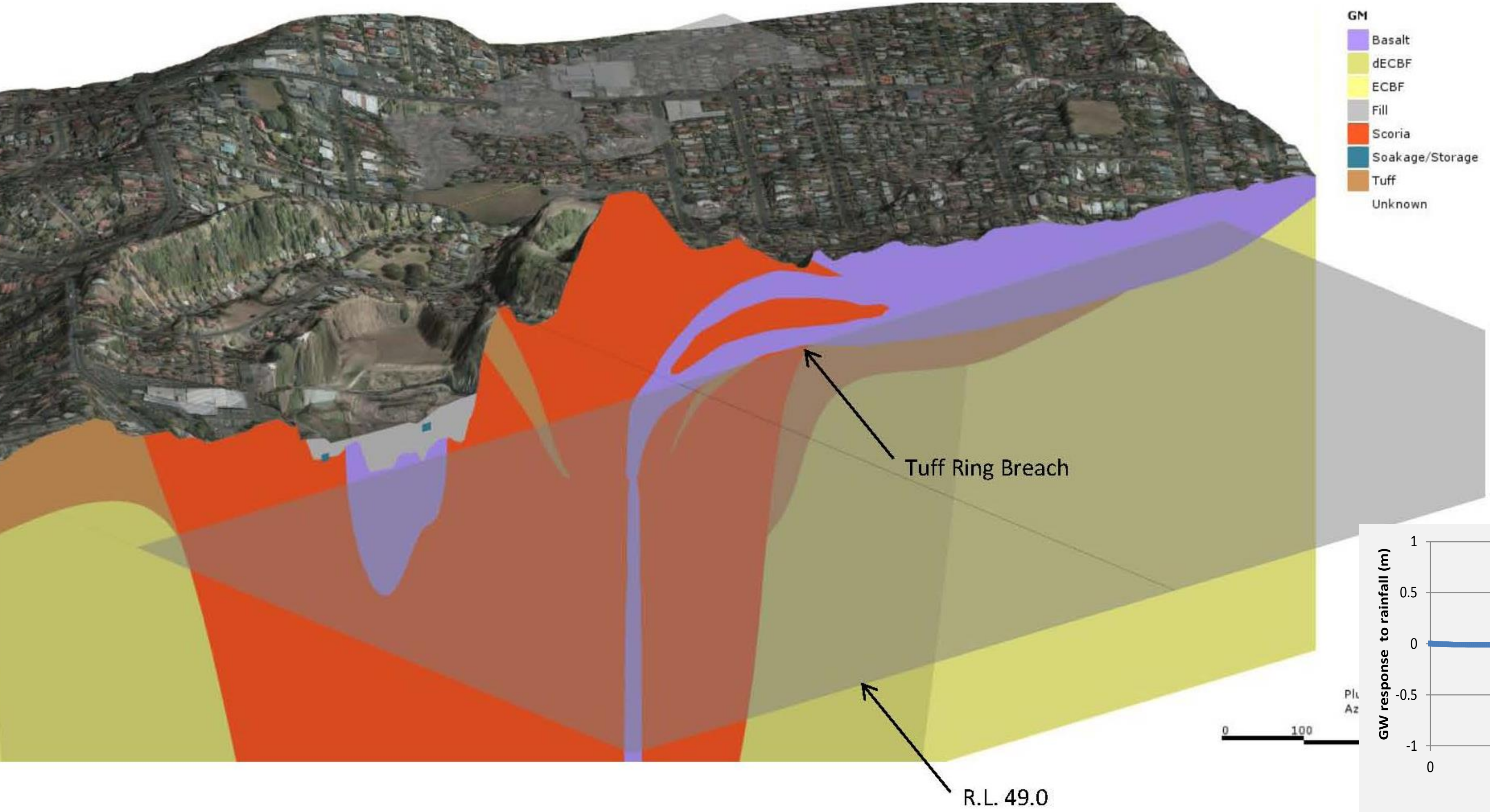




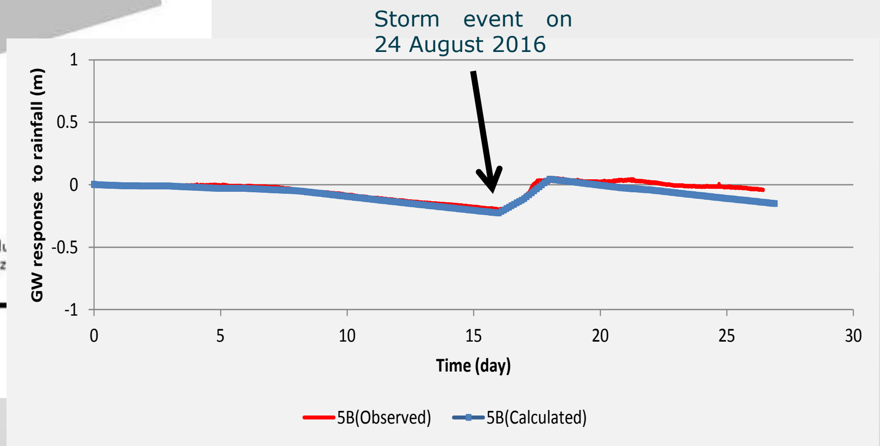
Groundwater Modelling

- Used MODFLOW

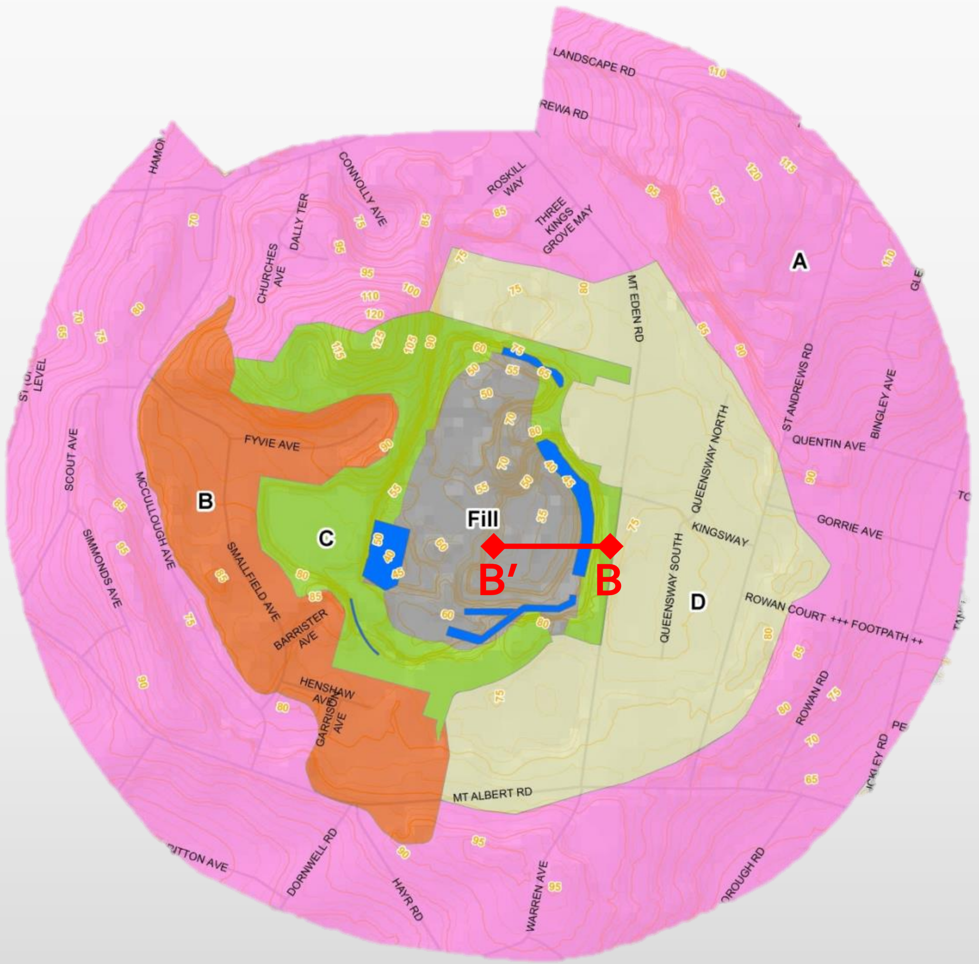
Groundwater Modelling



- Calibration using monitored gw levels, rainfall & dewatering pumping rates
- Best calibration using 8% (storage) for basalt and 20% (storage) for scoria (compatible with GAS Project)
- Sensitivity indicates parameters are conservative and suitable
- Predicted gw rise in bore 5B against observed



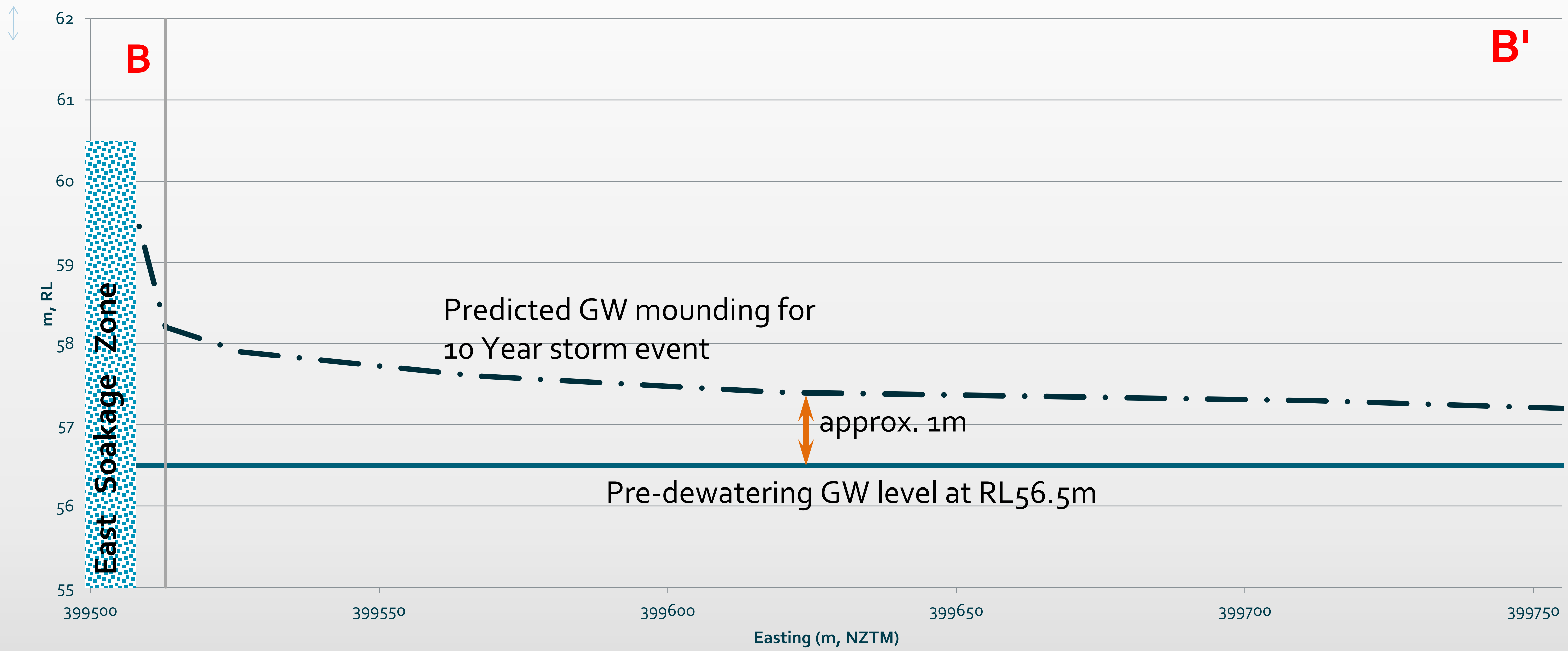
Predictive Simulations



Summary of Hydrogeological Properties			
Lithological Unit	Kh (m/s)	Kv/Kh	Storage Coefficient[1]
Scoria	0.0015	1.0	0.20
Basalt	0.0015	1.0	0.08
Soakage Zone Connection to Quarry Wall[2]	0.0005	1.0	0.20
Soakage Zone Material	0.010	1.0	0.25
Fill	1.0×10^{-7}	1.0	0.20
Disturbed Waitemata Group	9.4×10^{-7}	0.1	0.10
Waitemata Group	5.0×10^{-7}	0.1	0.10

Notes:
1. Specific Storage (Ss) is assumed to be 1×10^{-5} m^{-1}
2. Includes factor of safety of 3 for Kh

Section B-B' – East Soakage Zone



Modelling Results

Model Results				
Rainfall Event ARI	Soakage Zone	Water Level Rise (m)	Soakage Zone Groundwater Level (RLm)	Required Storage Volume Above the Ground (m^3)
10-year	Northeast	3.44	59.94	0
	East	3.13	59.63	
	South	3.29	59.79	
	Southwest	3.27	59.77	
100-year	All Zones	> ground level		20,300
2 x 100-year	All Zones	> ground level		56,500

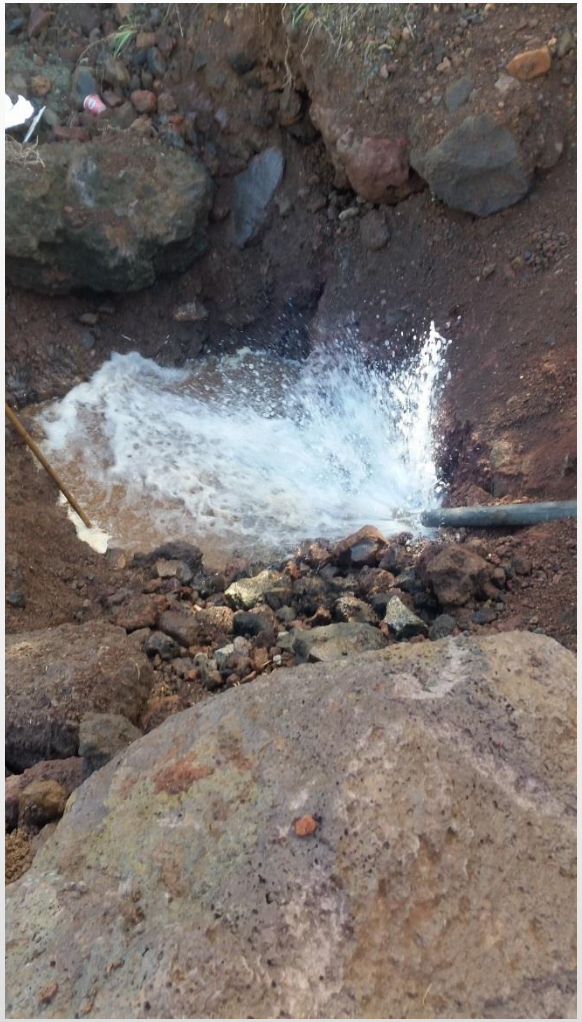
Modelling Results

100-Year ARI rainfall event	
Normal crater water level (no pumping)	RL56.5m
Normal seasonal maximum water table level variation	0.5m
Rainfall event water table response	1.2m
Allowance for future soakage development in surrounding area	0.3m
Minimum design water level for surface water storage	RL58.5m

Testing Phase

Laboratory and on site testing of materials for soakage zones

Soakage Testing



Soakage Testing

- Level of Confidence
- Used Student's T distribution (t-distribution) taking the 90% lower bound
- Probability of design soakage rate or lower is less than 5%
- Design used 1.3×10^{-5}m/s for western soakage zones and 5.2×10^{-4}m/s for eastern soakage zones

Soakage Test Results

Summary of Soakage Test Results		
Soakage Zone	**Accumulated Soakage Rate (L/s)**	**Median Permeability (m/s)**
Eastern	232	0.0019
Southern	438	0.0010
Northeast	314	0.0030
Grahame Breed Drive	52	0.0033

Notes:

1. **No testing was able to be completed for the Southwest soak hole – assumed permeability of 0.001 m/s.**

Porosity Testing

Porosity Testing

Porosity Testing Results

Soakage Fill Material Porosity	
Material	Porosity (%)
Rubble and rock fill[1]	46.3%
Drainage D65	44.6%
Notes: 1. **Sourced from Three Kings Quarry stockpiles.**	

Construction Phase

Construction of Soakage Zones

Soakage Blanket Rubble

Rubble Stockpile


Cleaned quarry face


Rubble

Start of East Face Soakage Zone

Soakage Blanket/Chimney Drain Construction – East Face

Soakage Blanket/Chimney Drain Construction – East Face

Soakage Blanket/Chimney Drain Construction – South Face

Slope to be cut back

Slot to be filled with Rubble from approx. RL54m

Quarry wall to be cleaned

Soakage Blanket/Chimney Drain Construction – South West Corner

Sediment Control

Keeping sediment away from the soakage zones

Conclusions

Thoughts thus far

Conclusions

The development of the Three Kings Quarry has and continues to provide a number of challenges as the development proceeds.

The overall concept of disposing stormwater into soakage has been proven to be viable from a conceptual, technical and construction point of view.

The concept of testing the soakage capacity of the target soakage areas such that the design soakage rates are exceeded, provides a level of confidence that has satisfied all parties involved in the development.

Soakage testing and investigations into suitable soakage zones is ongoing as the development is constructed.

Any changes are worked through with the regulatory authorities

Conclusions

The key aspects have been:

- The diligent and programmed soakage testing to achieve measured soakage rates in excess of the design requirements.
- The practical assessment of the porosity of the materials used in the construction.
- Ongoing surveillance and monitoring of the construction activities and a willingness of the contractors to keep all parties informed of progress and activities on site.
- Regular involvement of Fletcher Residential as the developer and overall project managers. This has proven to be invaluable to ensure the soakage design has not been compromised by other aspects of the development such as building location changes, foundation requirements and the like.

The willingness of Fletcher Residential to ensure that these aspects are coordinated and dealt with, provides additional confidence in the long term performance of the soakage system

Computer graphic of a future eruption in Auckland, near Mangere Bridge.
Image courtesy of Ministry of Civil Defence and Emergency Management

Acknowledgements

The authors would like to thank Fletcher Residential Ltd for permission to publish this paper.

Questions?