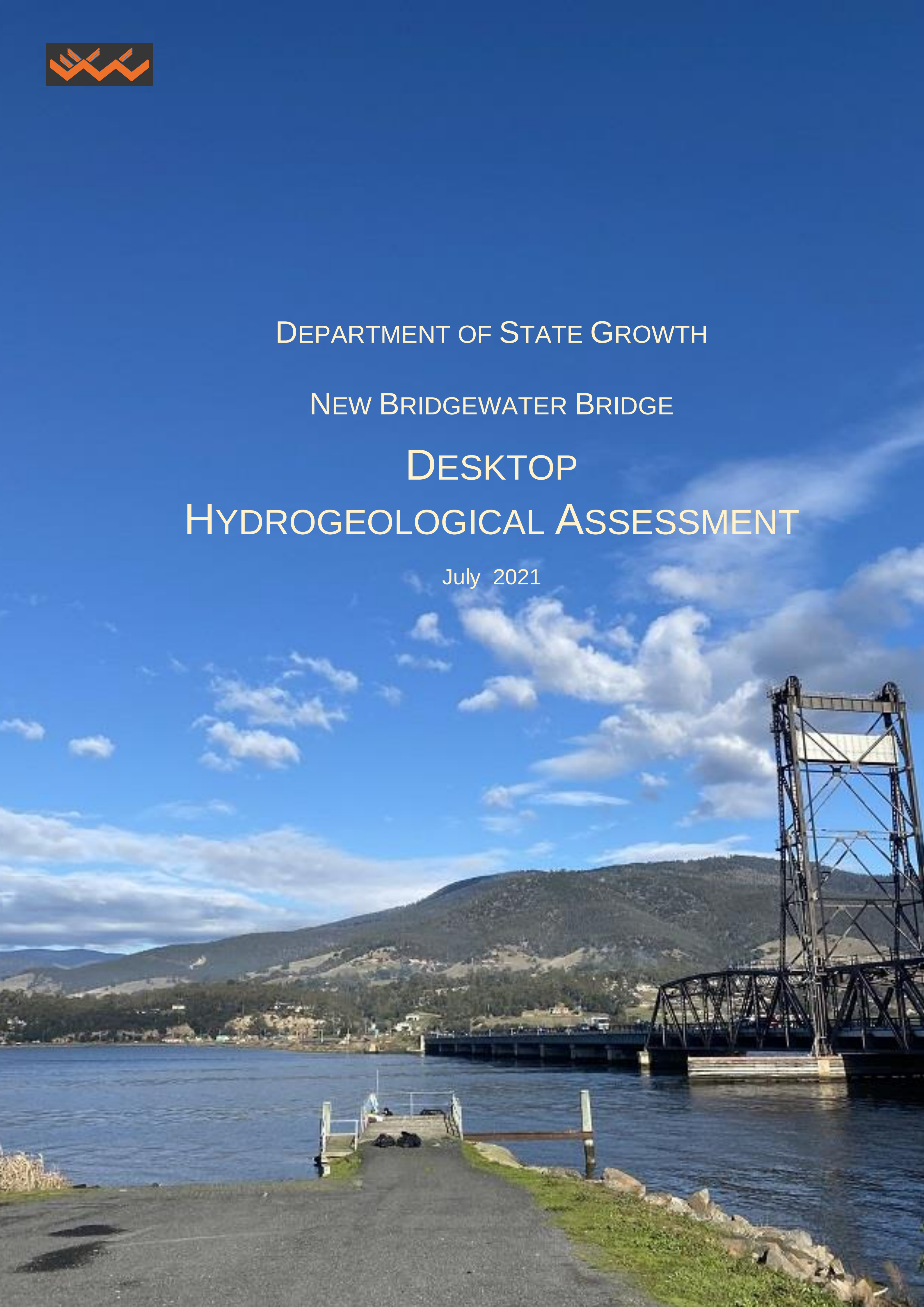
Department of State Growth

New Bridgewater Bridge

Desktop Hydrogeological Assessment

July 2021



Cover photo

View south-southwest over the River Derwent from the Bridgewater launching ramp, along the approximate alignment of the New Bridgewater Bridge.
Photo: 1 July 2021

Refer to this report as

Cromer, W. C. (2021). *Desktop Hydrogeological Assessment, New Bridgewater Bridge.* Report for the Department of State Growth by William C. Cromer Pty. Ltd., 29 July 2021.

SUMMARY

A desktop hydrogeological assessment suggests that Works proposed for the New Bridgewater Bridge Project, and the continued existence of the bridge itself, will have no unacceptable effects on intermediate-scale and regional-scale groundwater movement and quality.

The same conclusion applies to shallower, local-scale groundwater movement and quality at and near the water table, provided that where marine and terrestrial potential acid sulphate soils occur, they are properly managed.

CONTENTS

Figures

Tables

1 INTRODUCTION

1.1 Background

The Department of State Growth (DSG) is replacing the existing Bridgewater Bridge over the River Derwent at Bridgewater (Figure 1).

In June 2021, William C Cromer Pty Ltd (WCC) was commissioned by DSG to undertake a desktop hydrogeological assessment for the New Bridgewater Bridge (NBB) Project.

1.2 Hydrogeological Brief

A Major Project Impact Statement (MPIS) is being prepared to address a range of Assessment Criteria for the NBB, including the following issues relating to hydrogeology and forming the Brief for this assessment:

> *Section 5.1.5 Hydrogeology: Provide an assessment of the potential for hydrogeological changes, and how the potential impacts arising from construction have an acceptable impact[1] on groundwater receiving environment.*
>
> *S2.2.5 Hydrogeology. The following Information requirements and matters must be addressed for clause 5.1.5 Hydrogeology:*
>
>> *(a) provide a conceptual groundwater model for the project land indicating local and regional aquifer flows and identifying potential impacts of the project on groundwater; and*
>>
>> *(b) if necessary, mitigation should be proposed for potential impact to receiving environments from changed groundwater quality or flow, noting that controls to prevent migration of contaminants to groundwater at any storage locations for potentially contaminating materials [and known groundwater contamination areas] should be detailed in relation to the management of those facilities.*
>
> *5.1.6 Contaminated land*
> *Provide an assessment of how the potential impacts from contaminated land or material present within the project land have an acceptable impact on human health or the environment.*
> *S2.2.6 (a) identify the location,* ***volume*** *and properties of potentially contaminated material [i.e. groundwater]:*
>
>> *(i) Within and adjacent to the project land (particularly within the Derwent River); and*
>> *(ii) Proposed to be deposited on the project land, if any,*
>>
>> *which may pose a risk to the environment and human health, during the construction and operational phases of the project;*
>
> *S2.2.6 (c)*
>
>> *(iii) detail regarding proposed construction methodology, bridge footprint, extent of disturbance and how this may interact with contaminated material [including contaminated groundwater]*
>>
>> *(v) potential consequences of [groundwater] disturbance (i.e. potential impact/risks), and evaluation of their significance; and*
>>
>> *(vi) proposed management/mitigation measures for minimising disturbance [to groundwater] during construction and long-term use, including monitoring of impacts if relevant;*

[1] (My footnote) In the context of the hydrogeological assessment, I have interpreted "acceptable impact" to mean the same as "not unacceptable impact".

New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 1
LOCATION MAP AND PROJECT LAND
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A range of geotechnical and site contamination reports and preliminary engineering plans, was provided by DSG to WCC to assist with the hydrogeological assessment. Those that have been referred to are included in the References to the current assessment.

1.3 Scope and methodology of this assessment

This assessment comprises:

- a brief site inspection of the Project Land (Figure 1) in the company of Ms Fiona Keserue-Ponte from Pitt & Sherry on 1 July 2021,
- a desktop review of DSG-provided documents and publicly-available (mainly on-line) reports, maps and aerial images,
- a brief description of the regional and local geology, and a compilation of conceptual hydrogeological models based on fundamental groundwater principles supported by my experience in Tasmanian groundwater conditions, and
- a discussion which addresses the issues raised in the Brief.

2 HYDROGEOLOGY

2.1 Geology

2.1.1 Regional setting

Geologically, the Project Land and the broader district lies wholly within the Tasmania Basin, a large area of midland and southeastern Tasmania occupied by Permian marine and Triassic non-marine sedimentary rocks which have been intruded by sheets of Jurassic-age dolerite (Figure 2). The sedimentary rocks include mostly sub-horizontal (almost flat-lying) sandstone, siltstone, and mudstone.

Faulting is common throughout the district.

The dominant geological feature of the district is the elongate Derwent horst-and-graben structure up to several kilometres wide trending northeast – southwest south of Bridgewater, and swinging east – west west of the town.

The (down-faulted) graben is occupied by Tertiary and Quaternary unconsolidated sediments, and Tertiary volcanics. These overlie the older Tasmania Basin rocks in the gently undulating area north and east of Bridgewater, and geotechnical and other drilling in the River Derwent demonstrates that similar unconsolidated sediments overlying older rocks are present along the course of the present-day river.

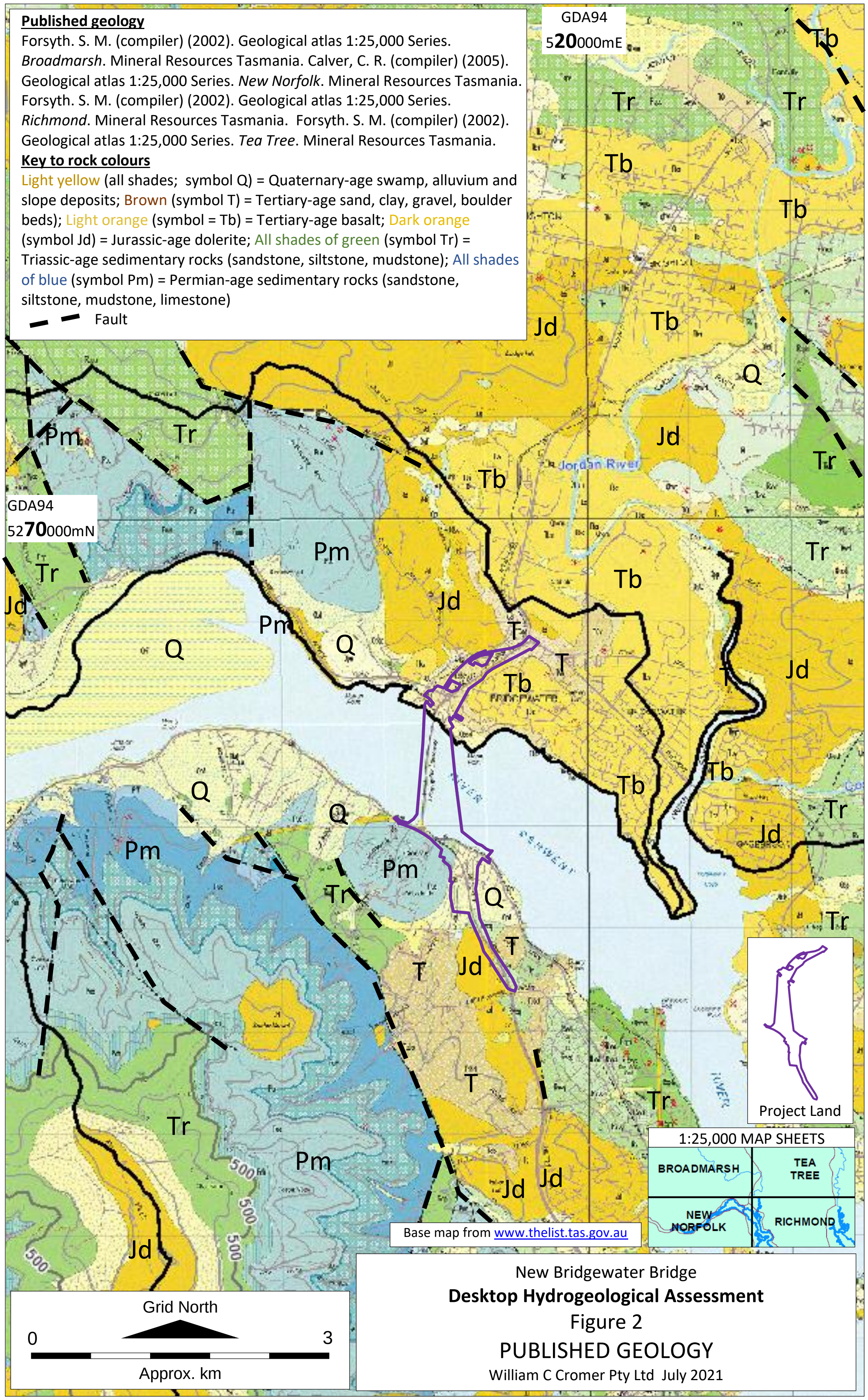
The uplifted horsts on both sides of the river exhibit the same Tasmania Basin sedimentary rocks intruded by Jurassic dolerite. On the southern side of the River Derwent, Mt. Faulkner rises to about 900mASL, but the horsts are more subdued on the opposite side of the estuary north of Bridgewater.

2.1.2 Geology at and near the Project Land

The southern part of the Project Land at Granton is on the lower slopes of Mt. Faulkner, underlain by shallowly south- and southeast dipping Permian sandstone and siltstone (Figure 3). These rocks are locally intruded by Jurassic dolerite, and faulted against Triassic sandstone and siltstone and Tertiary unconsolidated materials. Field observation and geotechnical drilling indicate the presence of probably three normal faults (north-side down) trending roughly northwest – southeast close to the foreshore at Granton. The downfaulted Triassic rocks next to one fault show almost vertical dips.

Southeast of Granton at the extremity of the Project land, the Brooker Highway climbs gently over Tertiary doleritic boulder beds (not dolerite as shown on Figure 3).

On the northern side of the River Derwent at Bridgewater, graben-infill materials comprise Tertiary-age basalts, associated volcanogenic sediments, and boulder and conglomerate beds, abutting against dolerite and Permian and Triassic rocks to the northwest. The younger materials may represent a former course of the river.



New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 2
PUBLISHED GEOLOGY
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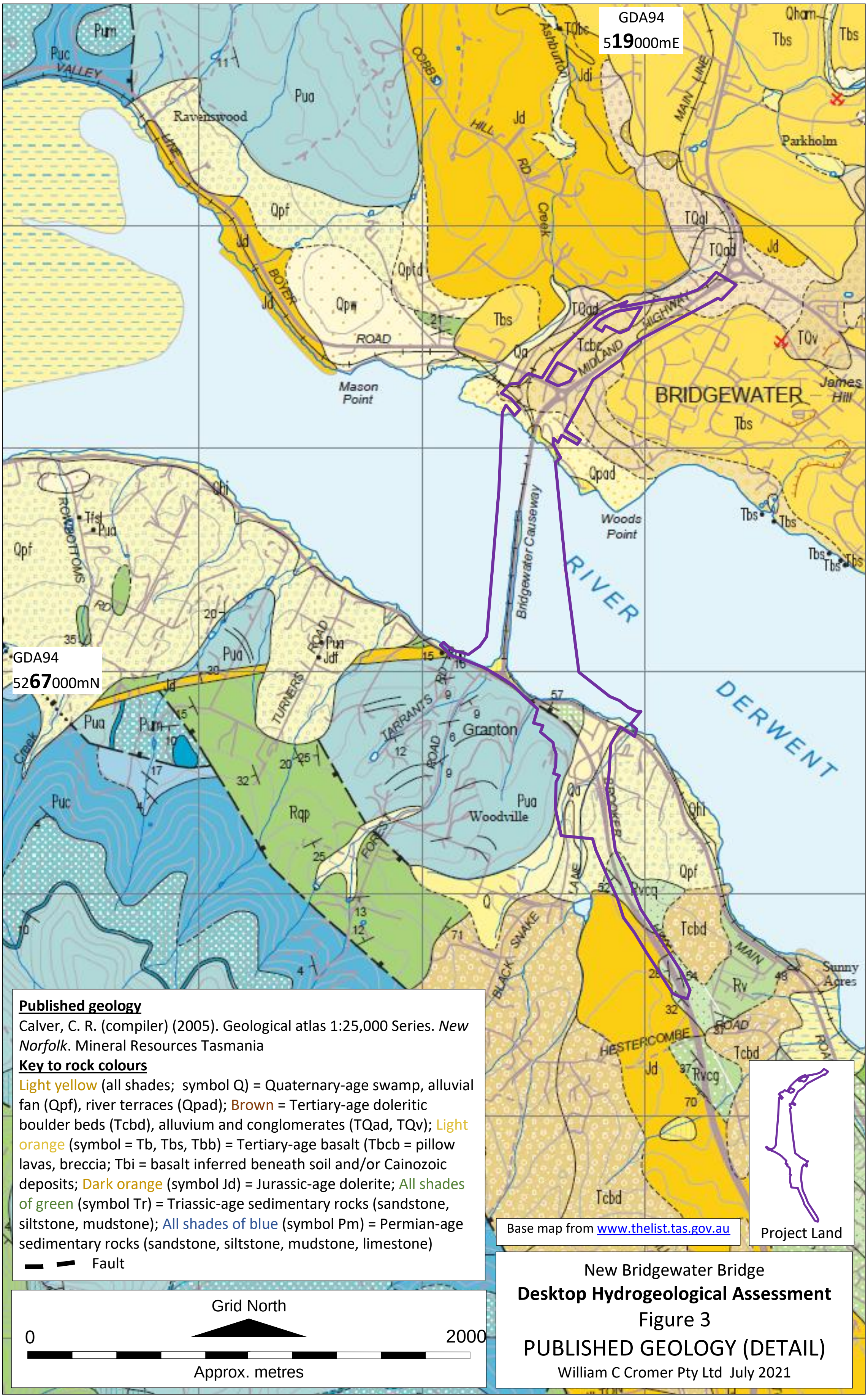

New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 3
PUBLISHED GEOLOGY (DETAIL)
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2.2 Groundwater

2.2.1 Groundwater fundamentals

Aquifers everywhere are of two types:

- intergranular aquifers (mainly unconsolidated, relatively young rocks of Quaternary and Tertiary age), where groundwater moves in primary[2], interconnected pore spaces between rock fragments and/or mineral grains, and
- fractured hard-rock aquifers, where groundwater is confined to secondary openings (eg joints, faults) in otherwise dry, consolidated rocks like sandstone, siltstone, mudstone, dolerite and basalt.

Most aquifers in Tasmania – including those within and near the Project Land – store and transmit groundwater under unconfined[3] rather than confined[4] conditions.

In this environment, Figure 4 illustrates different components of the land-based part of the hydrological cycle[5] at the scale of a single catchment or smaller. Effective rain (precipitation less evapotranspiration) flows overland to surface streams, or infiltrates (at a rate determined by soil and rock permeability) through the unsaturated zone to the water table.

An important aspect of Figure 4 is the interconnectivity between surface water and unconfined groundwater.

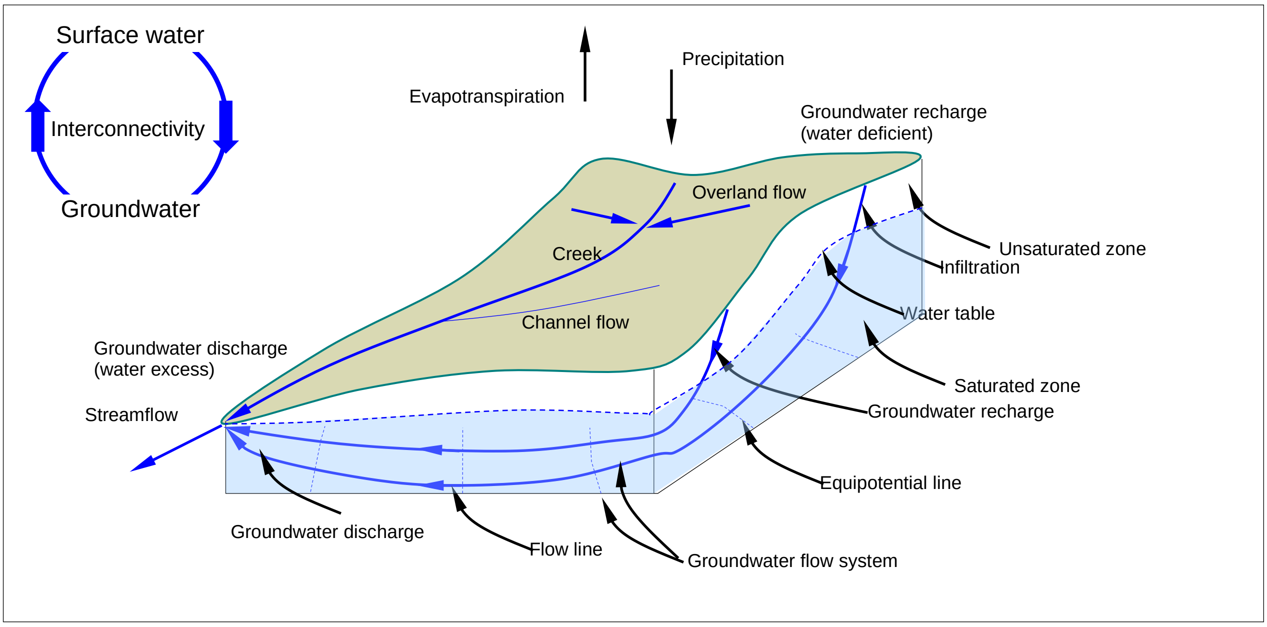

Figure 4. Aspects of the land-based hydrological cycle

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[2] Primary opening = formed at the same time as the rock. Secondary opening = formed later than the rock.

[3] Groundwater in unconfined aquifers is in direct contact with air at atmospheric pressure. The upper groundwater surface in an unconfined aquifer is called the water table. In confined aquifers, groundwater is confined by an overlying relatively impermeable layer, and is at a pressure greater than atmospheric. The level to which the groundwater would rise (for example, in a bore) is called the potentiometric surface.

[4] Some of the estuarine clays beneath the River Derwent may create local confined aquifer conditions.

[5] The *hydrological cycle* is the circulation of water in various phases through the atmosphere, over and under the earth, to the oceans, and back to the atmosphere. The cycle is solar-powered. Because water is a solvent it dissolves elements, and geochemistry is a fundamental part of the cycle, which is a flux for water, energy, and chemicals. Water enters the land-based cycle as precipitation; it leaves as surface streamflow (runoff) or evapotranspiration. The route which groundwater takes from a recharge point to a discharge point is a *flow path.*

The fundamentals of groundwater movement in an unconfined, gravity-driven groundwater flow system (GFS)[6] similar to that in the vicinity of the Project Land are depicted schematically in Figure 5.

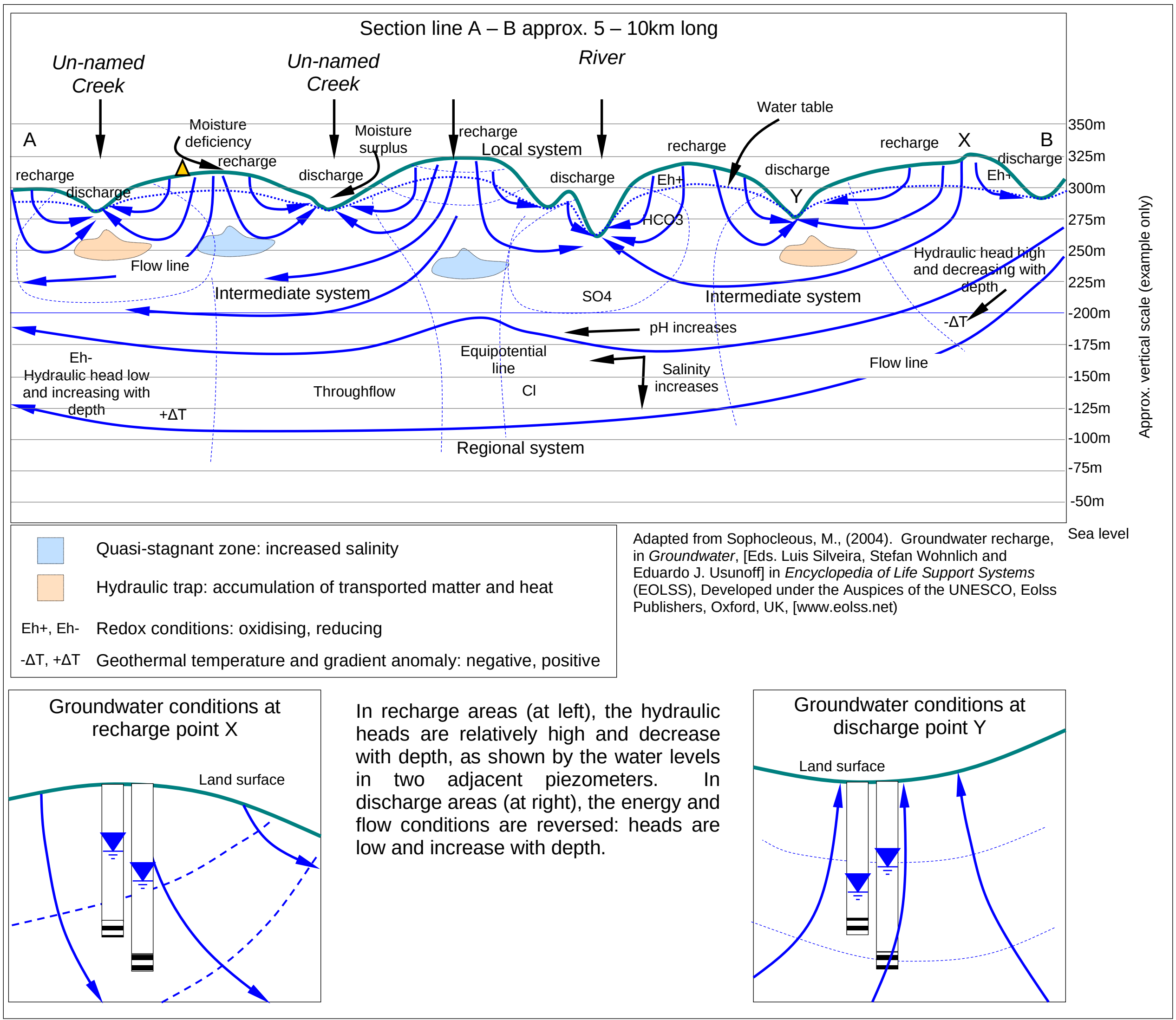


Figure 5. Fundamentals of groundwater hydrology in a gravity-driven groundwater system like that at and near the Project Land. Vertical exaggeration for the top section is about 5.

Important points are:

- the hydraulic heads in recharge areas are relatively high and decrease with depth. In discharge areas, the energy and flow conditions are reversed: heads are low and increase with depth. In between, the throughflow is almost horizontal as shown by the steeply dipping equipotential lines.
- the concept of a GFS[7] is fundamental to understanding groundwater conditions in the Project Land. Given the relief of the area, it can be expected that the near-surface dominant

[6] GFSs are identified in the field based on geology and geomorphology. Examples are local-scale GFSs in moderate – high relief fractured rock areas, and local- to intermediate-scale GFSs in low relief fractured rock areas.

[7] Sophocleous (2004) cited in Figure 5 defines a GFS as "a set of groundwater flow paths with common recharge and discharge areas. Flow systems are dependent on the hydrogeologic properties of the soil/rock material, and landscape position. Areas of steep or undulating relief tend to have dominant local *flow systems* (discharging to nearby topographic lows such as ponds and streams). Areas of gently sloping or nearly flat relief tend to have dominant *regional flow systems* (discharging at much greater distances than local systems in major topographic

groundwater flows to depths of a few tens of metres or so will be as local systems, with recharge on most elevated areas discharging to un-named minor streams. Some of the recharge will penetrate to depths of perhaps 50 – 100m or more, and will travel towards larger streams. This scale of groundwater movement is regarded as intermediate. Still deeper groundwater infiltration results in regional systems discharging to major rivers or the coast.

Hocking *et al* (2005) have studied groundwater issues in the Tasmanian southern Midlands, and have recognised many local- and intermediate-scale GFS. Their generalised scale of GFSs is shown in Figure 6, together with response (travel) times for groundwater flow through each system.

Table 1 The geographical extent and response time of local, intermediate and regional scale GFSs

Category	Length of flow (km)	Response time (yr)
Local	<1km <5	<30
Intermediate	1 – 10km 5-50	30-100
Regional	>10km >50	>100

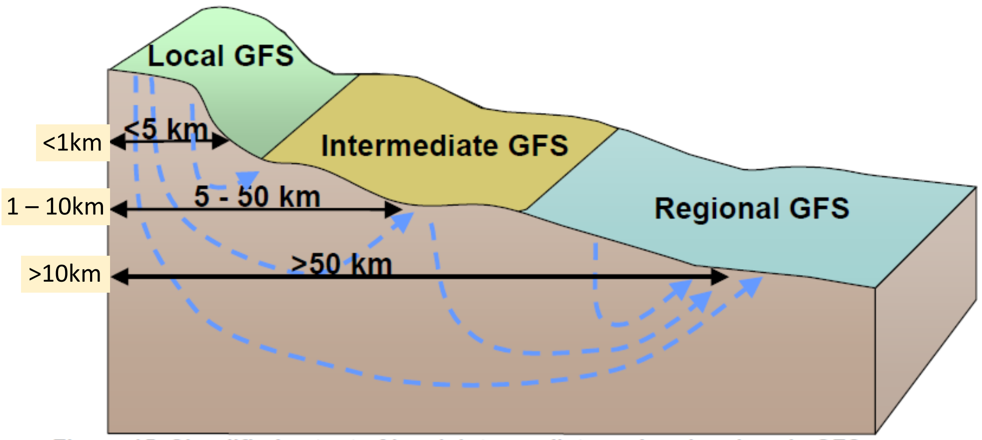


Figure 15 Simplified extent of local, intermediate and regional scale GFSs

Figure 6. Scales of local, intermediate and regional groundwater systems shown here are presumably based on mainland Australian conditions, and are not regarded as appropriate for the geological complexity and moderate relief in the vicinity of the Project Land. Suggested modified scales are superimposed on the Figure and Table. Response times are conceptual only, depending on aquifer permeability and transmissivity at all scales.
Source: Figure 15 and Table 1 from Hocking *et al* (2005).

2.2.2 Surface water catchments and groundwater systems

Figure 7 shows surface water catchments in the vicinity of the Project Land:

- *Catchments* (typically 1,000 – 3,000km^2 in area) correspond to dominant streams and rivers such as the Derwent and Jordan, and are separated by regional to sub-regional scale watersheds,
- *Subcatchments* (typically 50 – 300km^2 in area) include the catchment areas of lesser rivers and streams, and
- *Sub-subcatchments* (CFEV River Section Catchments on www.thelist.tas.gov.au) define the catchment areas of minor streams and typically range from 0.1 – 5km^2 in area.

lows or oceans)." A three-dimensional closed groundwater flow system that contains all the flow paths is called the *groundwater basin*.

The Project Land is largely within the Roseneath – Black Snake – Parramore Subcatchment (area 33km^2) itself contained within the Derwent Estuary – Bruny Catchment (area 1,274km^2).

A smaller part of the Project Land on the northern shore of the River Derwent is wholly within the Tributaries of the upper Derwent Estuary Subcatchment (area 53km^2) within the Lower Derwent Catchment (1,608km^2).

Importantly, because of the interaction between surface and subsurface water, the hierarchy of (and boundaries to) surface water catchments roughly corresponds to the hierarchy of regional, intermediate and local groundwater GFSs.

2.2.3 Groundwater flow directions in the vicinity of the Project Land

In Figure 8, the fundamentals of groundwater movement depicted in Figures 4 and 5 have been applied to the hierarchy of catchments in Figure 7, to show local, intermediate and regional groundwater flow directions in the vicinity of the Project Land.

The regional GFS flow direction is in a general easterly direction towards Storm Bay, at depths inferred to be hundreds of metres below sea level. Regional groundwater flow will have no effect on NBB construction, and vice versa.

The flow directions of intermediate GFSs are towards the River Derwent from the north and south. In the immediate vicinity of piers, piles and abutments, flow lines will be disrupted during and after NBB construction.

On land, flow lines from numerous local GFSs are in all directions controlled by topography. Closer to the River Derwent, they tend to align orthogonally to the north and south shorelines. Like intermediate-scale groundwater, local-scale flow lines will be disrupted during and after NBB construction but only in the immediate vicinity of piers, piles and abutments. Apart from near-shore environments, there are no local-scale systems within the footprint of the River Derwent.

2.2.4 Groundwater prospectivity in the vicinity of the Project Land

Figure 9 derived from Mathews and Latinovic (2006) shows that the fractured hard-rock aquifers in the vicinity of the Project Land are of Moderate – High prospectivity (ie they present a moderate – high chance of yielding useful amounts of acceptable-quality groundwater on drilling).

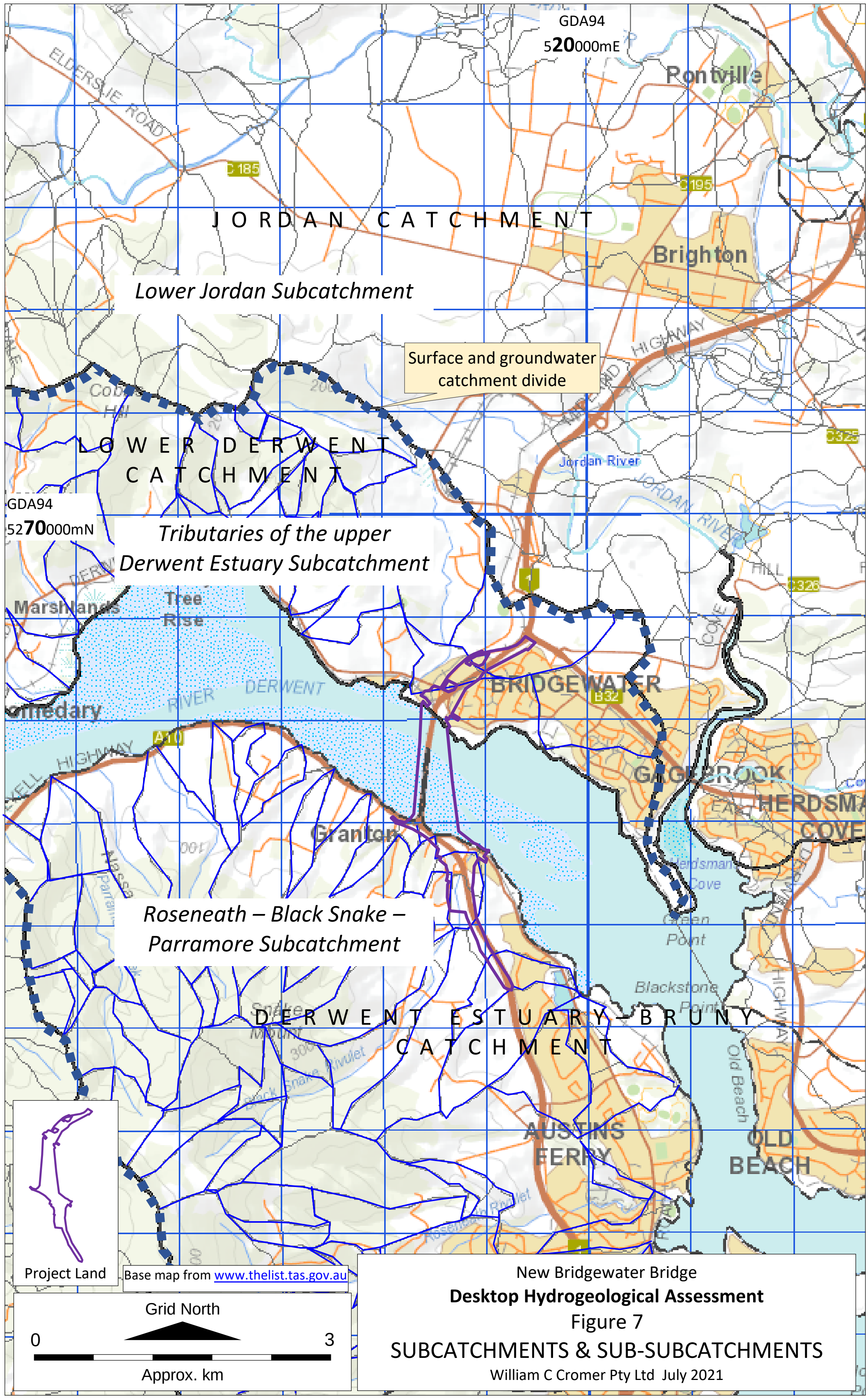
The Tasmanian groundwater bore database has records[8] (Table 1; Figure 9) of eight bores drilled for private interests within the vicinity of the Project Land. Locations of half the bores are not known within 2km, and so are of very limited use . The other four bores have been located to within 200m or better.

Seven bores were drilled into fractured hard-rock aquifers:

- six of the bores were drilled in Jurassic dolerite to depths of 20 – 60m: in three, no yield was reported; in two, yields were 0.06L/s and 0.25L/s; the remaining 36m deep bore in dolerite produced a high reported yield of 8.84L/s, and
- one dry bore was drilled to 85m in Permian rocks.

One bore in Tertiary intergranular materials was abandoned after 20m with no reported yield.

[8] The records are usually compiled from information provided by drillers.


GDA94
520000mE
GDA94
5270000mN
JORDAN CATCHMENT
Lower Jordan Subcatchment
Surface and groundwater catchment divide
LOWER DERWENT CATCHMENT
Tributaries of the upper Derwent Estuary Subcatchment
Roseneath – Black Snake – Parramore Subcatchment
DERWENT ESTUARY – BRUNY CATCHMENT
Pontville
Brighton
Bridgewater
Gagebrook
Herdsman Cove
Granton
Austins Ferry
Old Beach
Marshlands
Tree Rise
Jordan River
Derwent River
Green Point
Blackstone Point
Project Land
Base map from www.thelist.tas.gov.au
Grid North
0
3
Approx. km
New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 7
SUBCATCHMENTS & SUB-SUBCATCHMENTS
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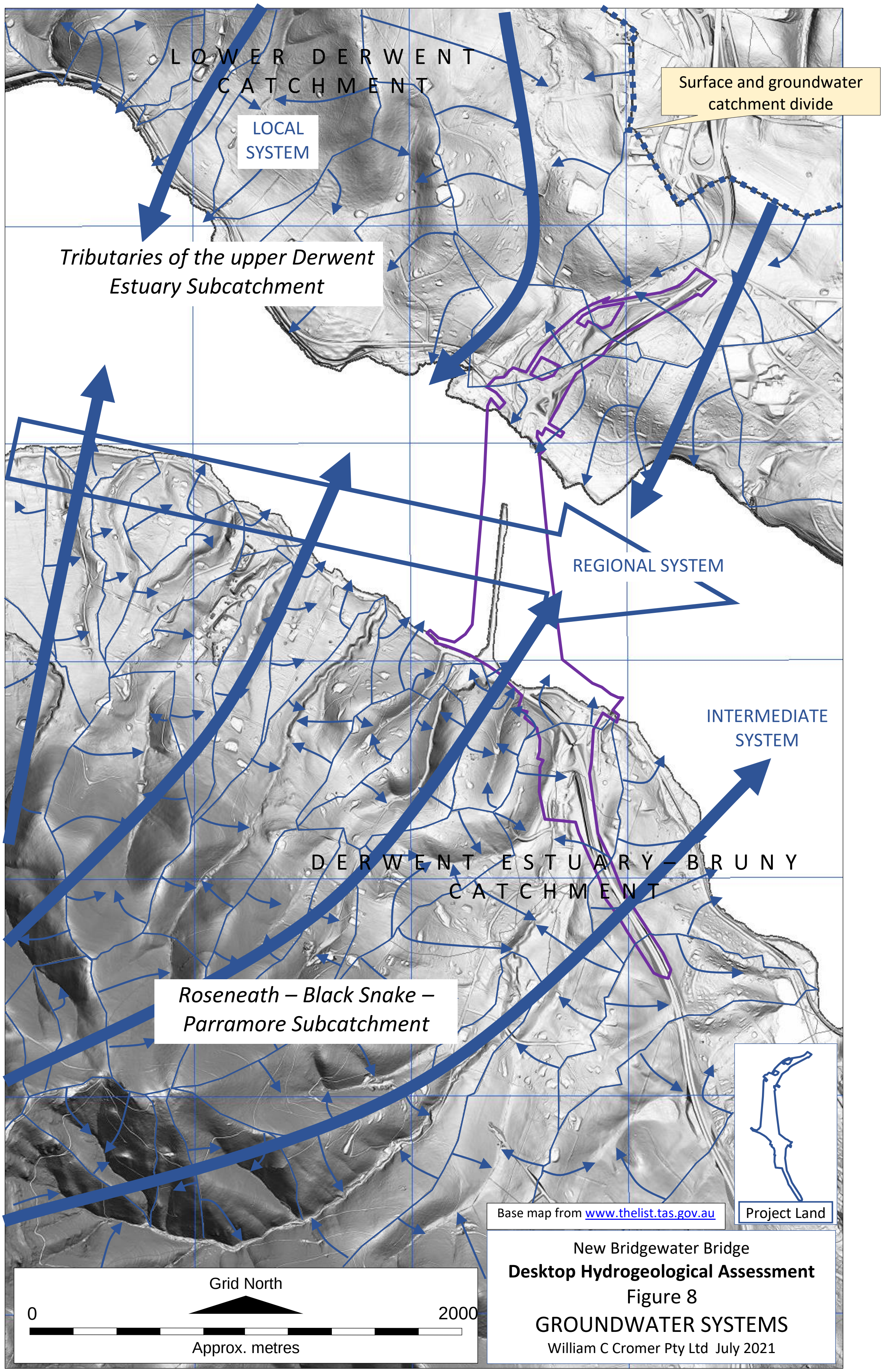

New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 8
GROUNDWATER SYSTEMS
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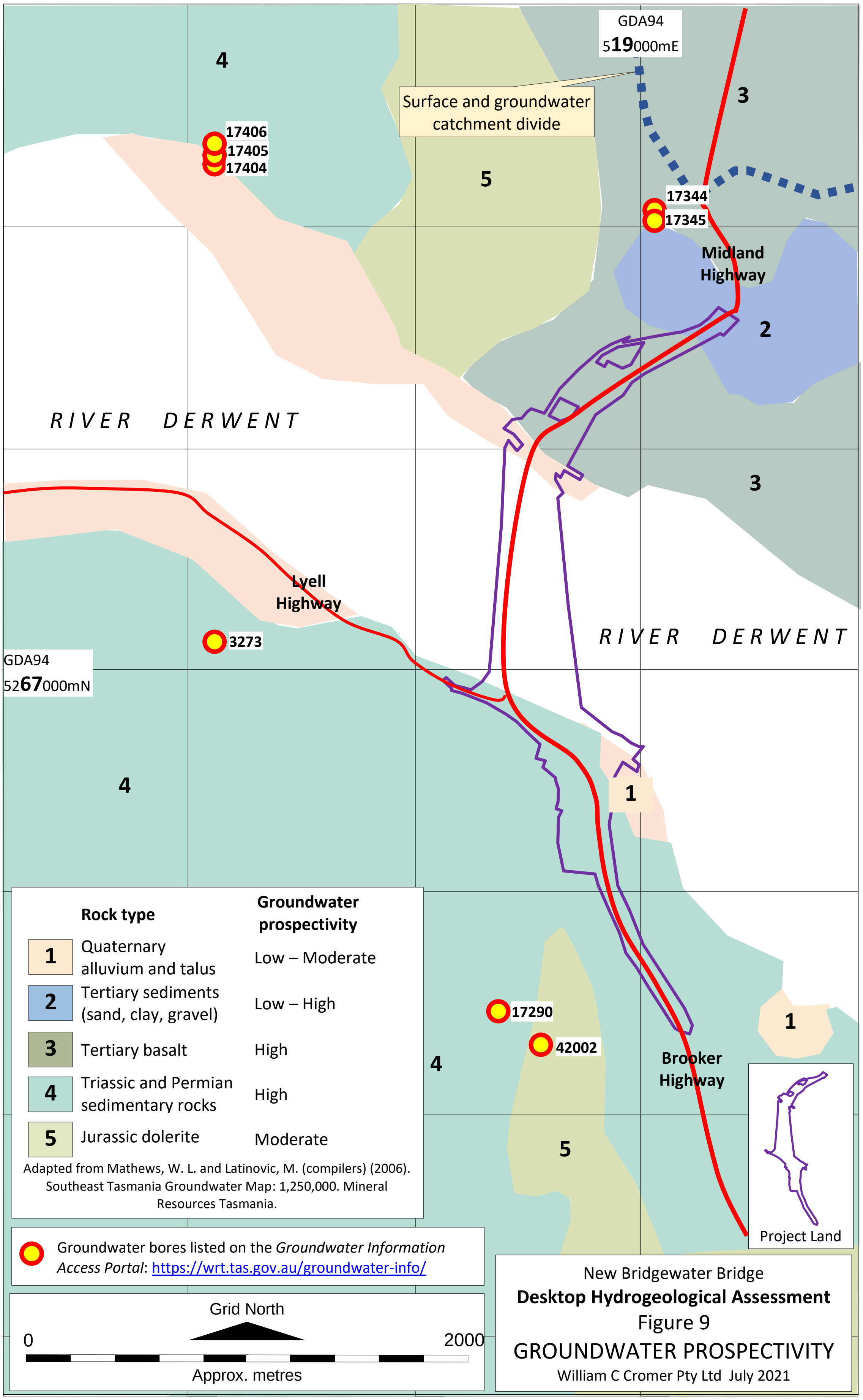
GDA94
519000mE
Surface and groundwater catchment divide
4
3
5
17406
17405
17404
17344
17345
Midland Highway
2
RIVER DERWENT
3
Lyell Highway
3273
GDA94
5267000mN
RIVER DERWENT
4
1
Rock type
Groundwater prospectivity
1 Quaternary alluvium and talus | Low – Moderate
2 Tertiary sediments (sand, clay, gravel) | Low – High
3 Tertiary basalt | High
4 Triassic and Permian sedimentary rocks | High
5 Jurassic dolerite | Moderate
Adapted from Mathews, W. L. and Latinovic, M. (compilers) (2006). Southeast Tasmania Groundwater Map: 1,250,000. Mineral Resources Tasmania.
17290
42002
4
1
Brooker Highway
5
Project Land
Groundwater bores listed on the *Groundwater Information Access Portal*: https://wrt.tas.gov.au/groundwater-info/
Grid North
0
2000
Approx. metres
New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 9
GROUNDWATER PROSPECTIVITY
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Table 1. Results of drilling for groundwater in the vicinity of the Project Land. Source: Groundwater Information Access portal (https://wrt.tas.gov.au/groundwater-info/)

Feature id	Feature type	Locality name	Easting	Northing	Datum	Coordinate accuracy (m)	Drilled date	Drilling company	Depth	Initial yield	SWL list	Last SWL date	Final TDS	Main aquifer geology	Last operating status	Last operating status date
3273	Bore	Granton	517113	5267083	GDA94	2000	09/02/1989	Gerald Spaulding Drillers Pty Ltd	85.30	0.00				Permian	Unknown	01/11/1996
17290	Bore	Granton	518403	5265423	GDA94	100	22/01/1998	KMR Drilling Pty Ltd	20.00					Tertiary Sediments	abandoned	22/01/1998
17344	Bore	Bridgewater	519150	5269100	GDA94	200	28/11/1995	KMR Drilling Pty Ltd	39.00	0.00				Jurassic Dolerite	Unknown	28/11/1995
17345	Bore	Bridgewater	519130	5269080	GDA94	200	29/11/1995	KMR Drilling Pty Ltd	36.00	8.84				Jurassic Dolerite	functioning	29/11/1995
17404	Bore	Bridgewater	517113	5269283	GDA94	2000	23/03/1998	KMR Drilling Pty Ltd	37.00					Jurassic Dolerite	abandoned	23/03/1998
17405	Bore	Bridgewater	517113	5269333	GDA94	2000	24/09/1998	KMR Drilling Pty Ltd	22.00					Jurassic Dolerite	Unknown	24/09/1998
17406	Bore	Bridgewater	517113	5269383	GDA94	2000	01/10/1998	KMR Drilling Pty Ltd	55.00	0.25				Jurassic Dolerite	Unknown	01/10/1998
42002	Bore	Granton	518562	5265273	GDA94	10	18/03/2014	KMR Drilling Pty Ltd	60.00	0.06			3000	Jurassic Dolerite	abandoned	18/03/2014

The high-yielding bore in dolerite was the only one reported as functioning in 1995.

The groundwater in bore 42002 (Figure 9) had a reported salinity of 3,000mg/L of Total Dissolved Solids, which is higher than recommended drinking water quality (600 – 1,200mg/L; NRMMC 2011) but suitable for most livestock uses (2,000 – 13,000mg/L; ANZECC 2000).

2.2.5 Contaminated sites within the Project Land

Soils and shallow groundwater at several sites within the Project Land have been potentially or demonstrably contaminated by former activities (Table 2, and Figures 10 and 11).

Table 2. Premises listed as "likely" to impact on the Project.
(Reproduced from Pitt & Sherry (2021b)).

Project Area	Address	Observations
North	18 Old Main Road, Bridgewater (12 Old Main Road, Bridgewater on the LIST)	• Former Caltex Service Station – Fuel storage – underground (UPSS reportedly removed, WST Mines File 0472) • Gravel surface – depressions in the surface suggest • UPSS may have been removed • May have had a workshop and septic system • associated with any toilet block • Land used for ad hoc car and truck parking • South of the heritage listed St Mary's Anglican Church
	40-42 Old Main Road, Bridgewater	• Former Shell storage depot • Fuel storage – underground (UPSS removed) • No infrastructure at surface (other than a driveway and hardstand area) • May have had a septic system associated with any toilet block • Fully fenced with a locked gate • Southern block (40 Old Main Road) is vacant and grassed; no visible evidence of contamination
	46 Old Main Road, Bridgewater	• Potentially associated with historical sawmill activities on Old Main Road, Bridgewater in 1960 and 1971 • Vehicle and boat parking • No evidence of gross contamination
	Railway corridor	• Railway activities • No evidence of gross contamination • Common contaminants include: asbestos fibres from brake pads, heavy metal fines from ballast, hydraulic and mechanical oils, herbicides, contaminating goods spills
South	37 Black Snake Road, Granton	• Fuel storage – underground • No evidence of UPSS (from the street), other than a possible vent pipe
	1 Lyell Highway, Granton	• Fuel storage – underground • Former service station and works depot – potentially septic system • Heritage listed 'Old Watch House' • Asbestos warning labels on the buildings • Groundwater wells visible around the Old Watch House and along the railway line
	640 Main Road, Granton	• The land closest to Black Snake Road is expected to be disturbed as part of the new roundabout • The land is currently used for parking vehicles, and apparent scrap • No detailed inspection was made as it is private land

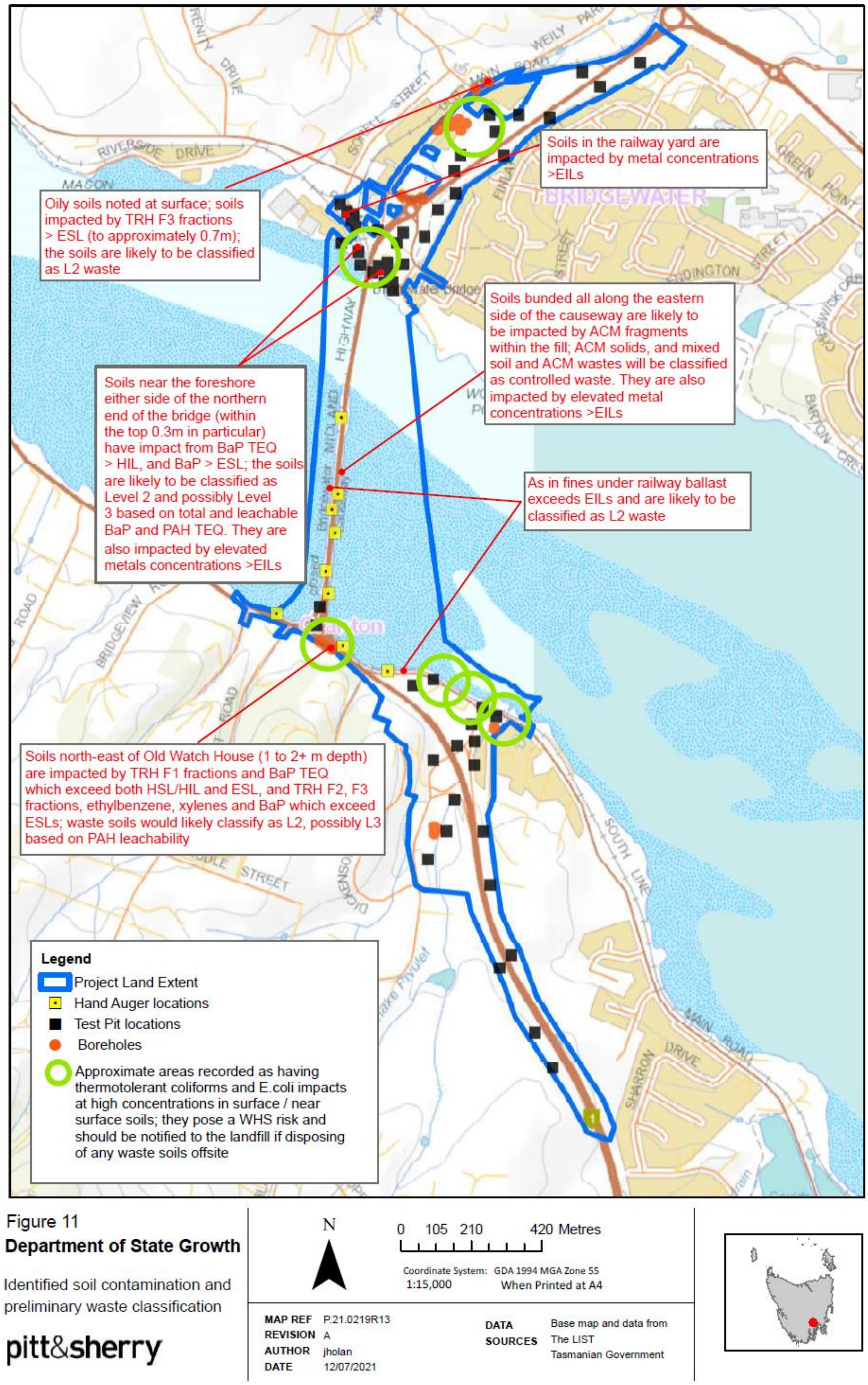


Figure 10. Identified soil contamination sites (excluding ASS and marine areas) and waste classification.
Source: Pitt & Sherry (2021b).

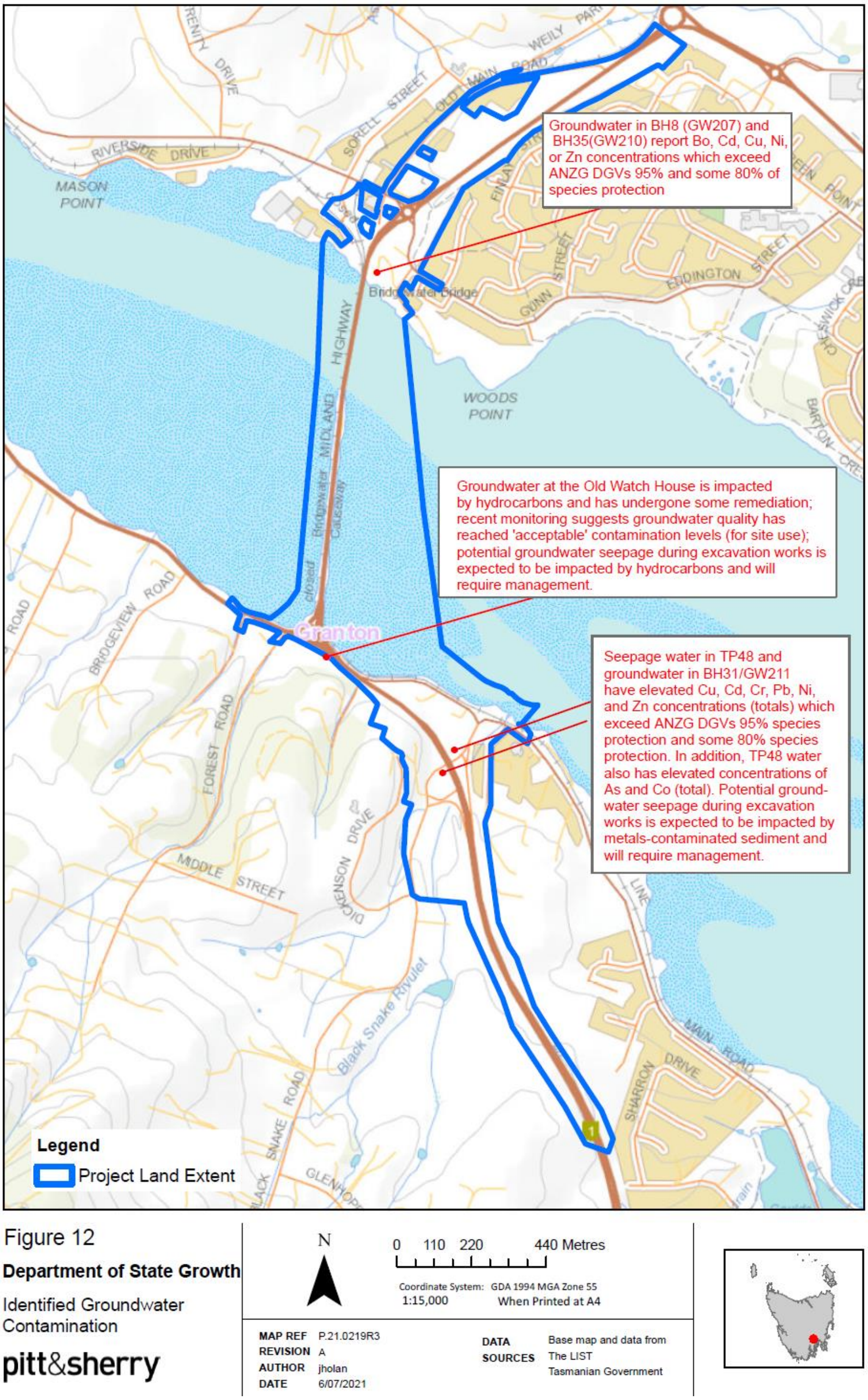
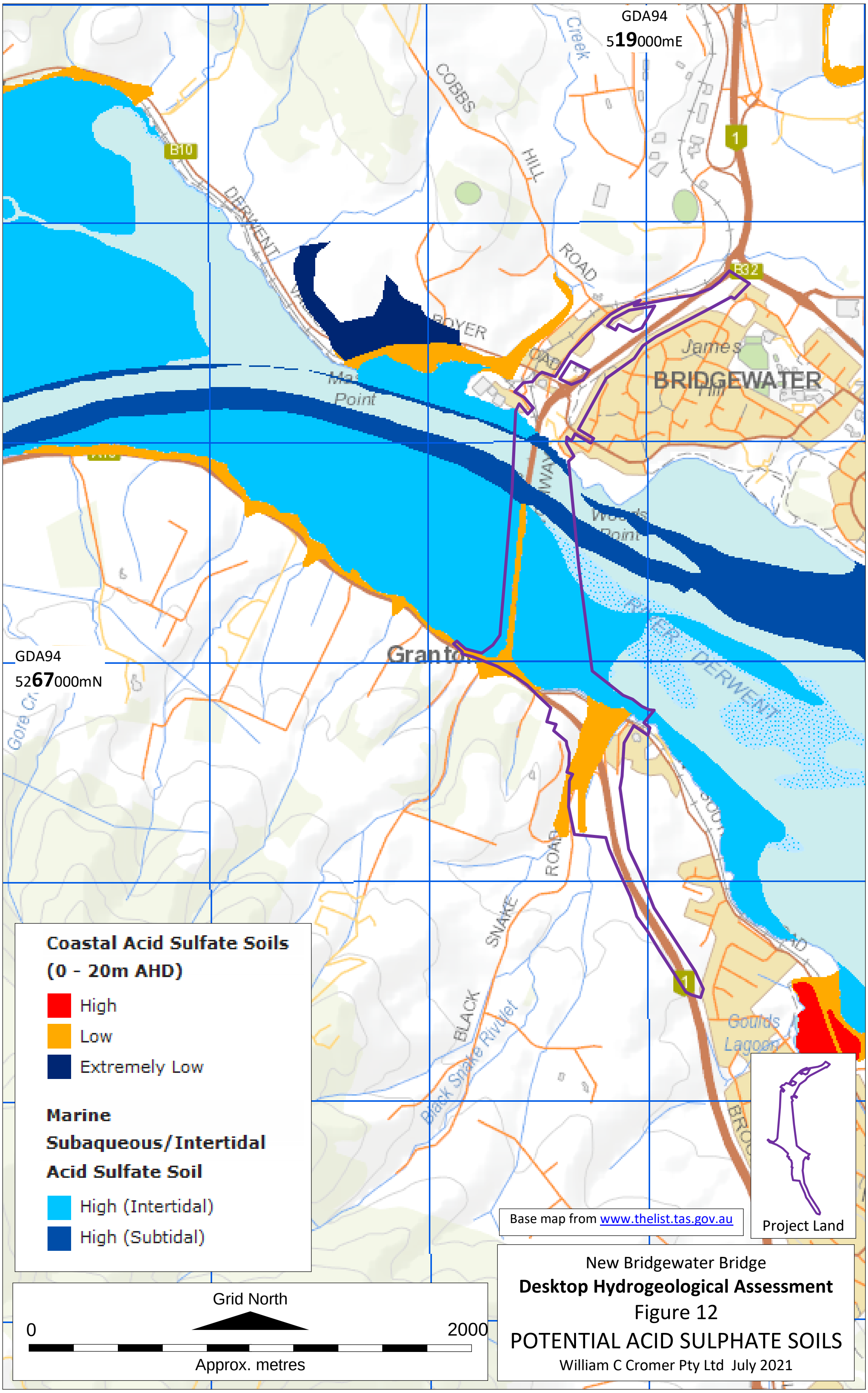


Figure 11. Identified contaminated groundwater sites (excluding ASS and marine areas). Source: Pitt & Sherry (2021b)

2.2.6 Acid sulphate soils

Terrestrial and marine potentially acid sulphate soils (PASS) are present in and adjacent to the Project Land (Figure 12). It is reasonable to assume that all in-situ dark grey to black estuarine sediments are PASS, to depths of up to 20m or so.



New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 12
POTENTIAL ACID SULPHATE SOILS
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3 DISCUSSION

3.1 Conceptual hydrogeological models

3.1.1 General comments

Thirteen conceptual hydrogeological cross sections (models) designated A – A' through to L – L' have been constructed in the vicinity of the Project Land.

Locations of the cross sections are shown in Figure 13, and all cross sections are included in Attachment 1.

Each cross section shows groundwater flow lines superimposed on published or interpreted geology. Across the River Derwent, the geology is largely from Pitt & Sherry (2020a; for ease of cross-reference, the colours and map symbols for various rock types used in that interpretative report have been retained in the current work).

The geotechnical investigation bores, site contamination bores and other drillholes which assisted in constructing the cross sections are show in Figure 14.

3.1.2 Comments on selected conceptual models

Section A – A'

Section A – A' is 10km long and extends 200m below sea level. It is intended to provide a hydrogeological picture at sub-regional scale, based on the published geology shown in Figures 2 and 3. Most groundwater flow lines are at inferred intermediate-scale, towards the River Derwent estuary. In the estuary, flow lines are vertically upward.

There is possibly regional flow out of the page beneath Mt. Faulkner.

Sections B – B' to E – E'

These four sections are located sequentially north-to-south subparallel to the possible alignment of the NBB and its approaches.

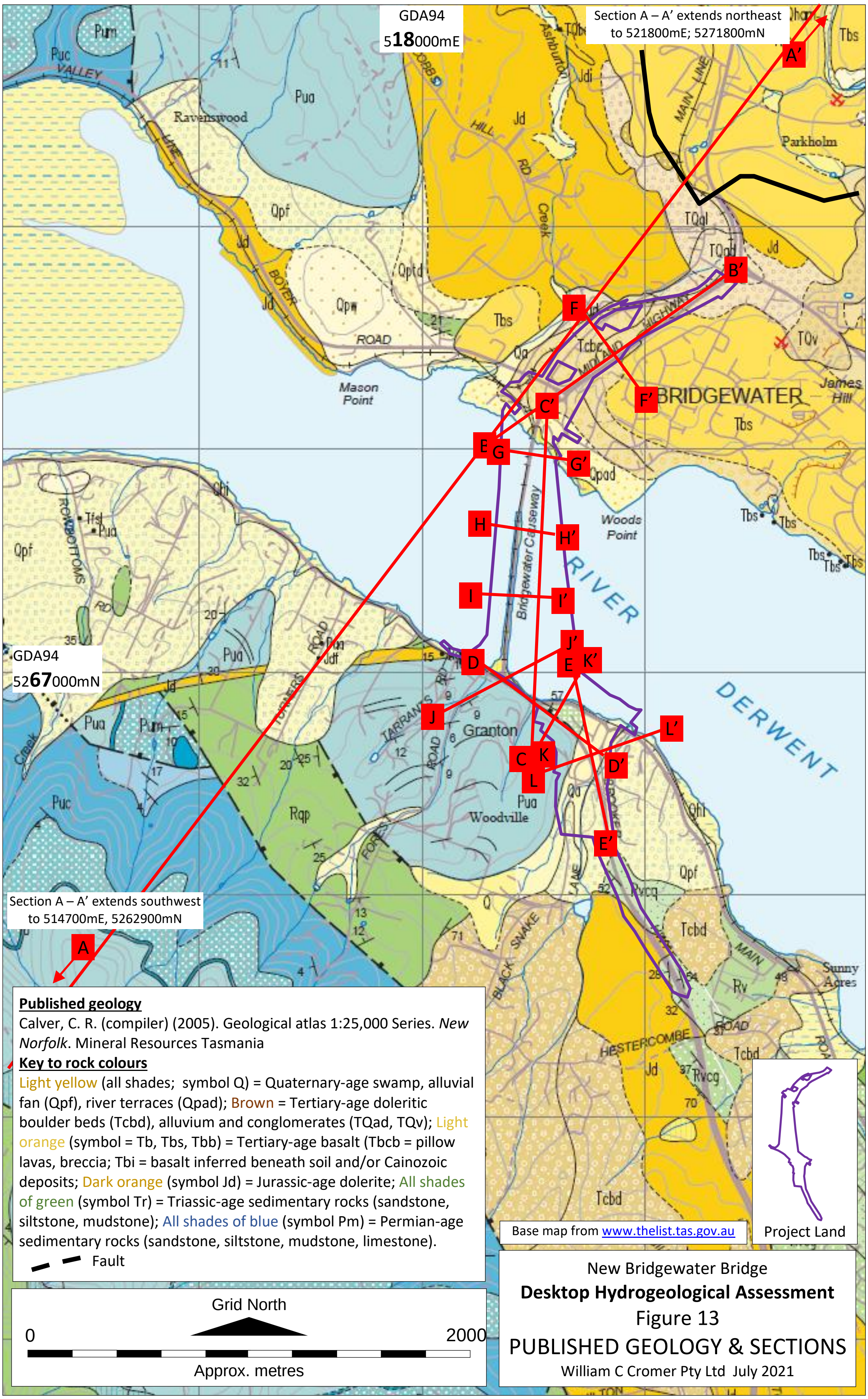
Sections F – F' to L – L'

These seven sections are located sequentially north-to-south and are roughly orthogonal to the possible alignment of the NBB and its approaches.

3.2 Estimates of groundwater flow rates

Table 3 characterises regional, intermediate and local groundwater flow systems with respect to rock and material types in the Project Land, assigns permeabilities[9], effective porosities, lengths of flow paths, and estimates rates of groundwater flow and the travel time within each groundwater system.

[9] All rock types and intergranular materials in Table 3 are assigned a permeability of 0.01m/day. There is limited data available for permeabilities generally in Tasmania. However, values of 0.01m/day have been obtained from testing in fractured rocks in western Tasmania (W. C. Cromer unpublished data). For intergranular materials in the estuary of the River Derwent, permeabilities possibly range from <0.0001m/day to >0.1m/day for clay to silty fine sand respectively. Some clay layers may act as confining layers. An "average" or "bulk" permeability of 0.01m/day for the estuarine materials seems not too unreasonable. In any case, the flow rates and travel times in Table 3 are intended to be indicative only, and should not be relied upon to reflect actual conditions at any site.



New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 13
PUBLISHED GEOLOGY & SECTIONS
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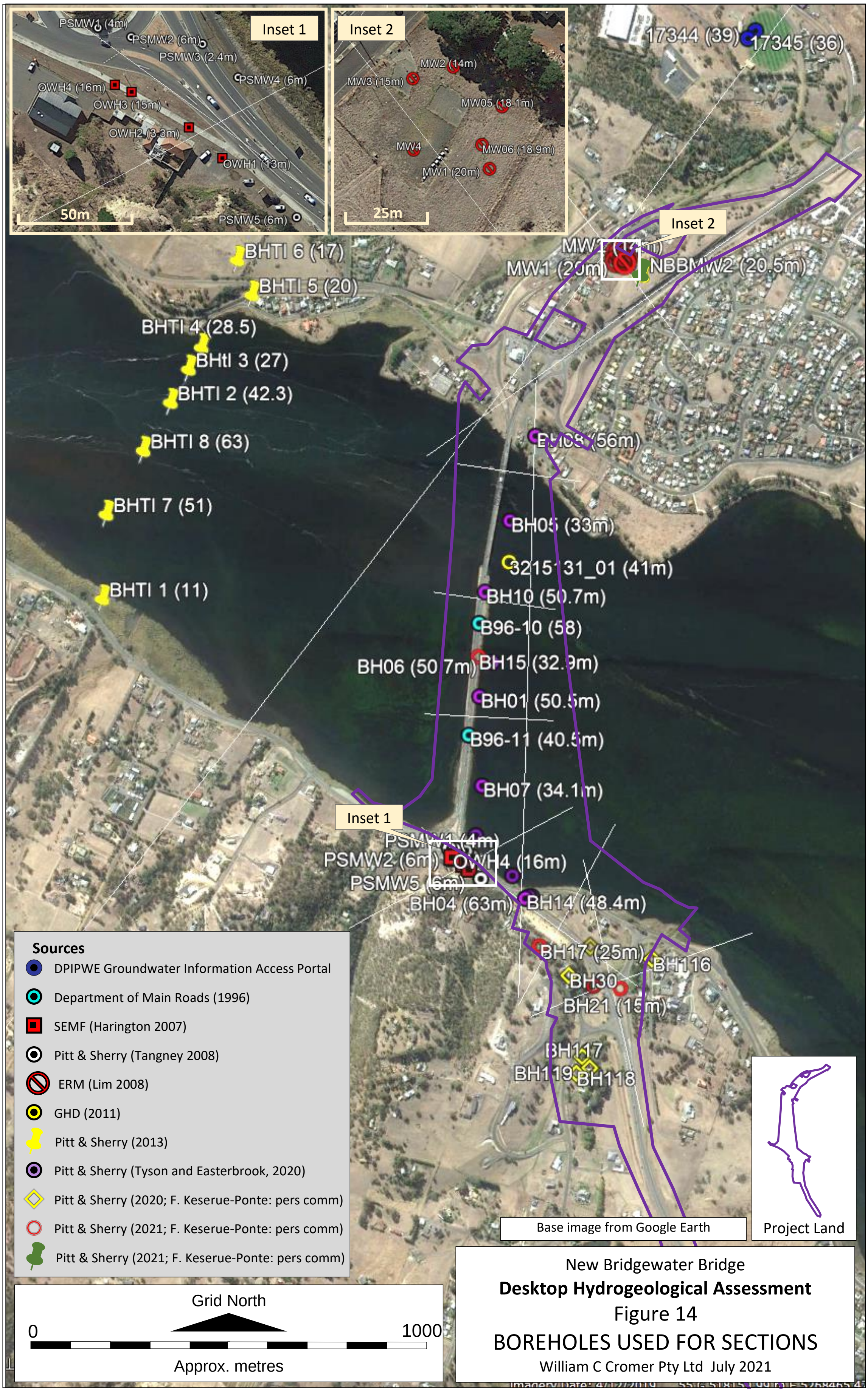
Inset 1
PSMW1 (4m)
PSMW2 (6m)
PSMW3 (2.4m)
PSMW4 (6m)
OWH4 (16m)
OWH3 (15m)
OWH2 (3.3m)
OWH1 (13m)
PSMW5 (6m)
50m
Inset 2
MW2 (14m)
MW3 (15m)
MW05 (18.1m)
MW4
MW06 (18.9m)
MW1 (20m)
25m
17344 (39)
17345 (36)
Inset 2
MW1 (20m)
NBBMW2 (20.5m)
BHTI 6 (17)
BHTI 5 (20)
BHTI 4 (28.5)
BHtI 3 (27)
BHTI 2 (42.3)
BHTI 8 (63)
BHTI 7 (51)
BHTI 1 (11)
BH05 (33m)
BH10 (50.7m)
B96-10 (58)
BH06 (50.7m)
BH15 (32.9m)
BH01 (50.5m)
B96-11 (40.5m)
BH07 (34.1m)
Inset 1
PSMW2 (6m)
OWH4 (16m)
PSMW5 (6m)
BH04 (63m)
BH14 (48.4m)
BH17 (25m)
BH116
BH30
BH21 (15m)
BH117
BH119
BH118
Sources
DPIPWE Groundwater Information Access Portal
Department of Main Roads (1996)
SEMF (Harington 2007)
Pitt & Sherry (Tangney 2008)
ERM (Lim 2008)
GHD (2011)
Pitt & Sherry (2013)
Pitt & Sherry (Tyson and Easterbrook, 2020)
Pitt & Sherry (2020; F. Keserue-Ponte: pers comm)
Pitt & Sherry (2021; F. Keserue-Ponte: pers comm)
Pitt & Sherry (2021; F. Keserue-Ponte: pers comm)
Base image from Google Earth
Project Land
Grid North
0
1000
Approx. metres
New Bridgewater Bridge
Desktop Hydrogeological Assessment
Figure 14
BOREHOLES USED FOR SECTIONS
William C Cromer Pty Ltd July 2021

Estimated travel times for flow in local-scale, intermediate-scale and regional-scale systems are broadly in agreement with Figures 6 and 15. Within the Project Land, and depending mainly on the length of flow path and hydraulic gradient, travel times:

- for regional flow systems probably range from centuries to millennia,
- for intermediate flow systems probably range from decades to centuries, and
- for local systems probably range from years to decades.

In Table 3 (last row), an example is given of flow rate (2cm/day) and travel time (7 years) for contaminated groundwater near the Old Watch House at Granton to reach the shoreline of the River Derwent.

A second example (second last row in Table 3) is flow rate (4cm/day) around bridge piles in River Derwent estuarine sediments.

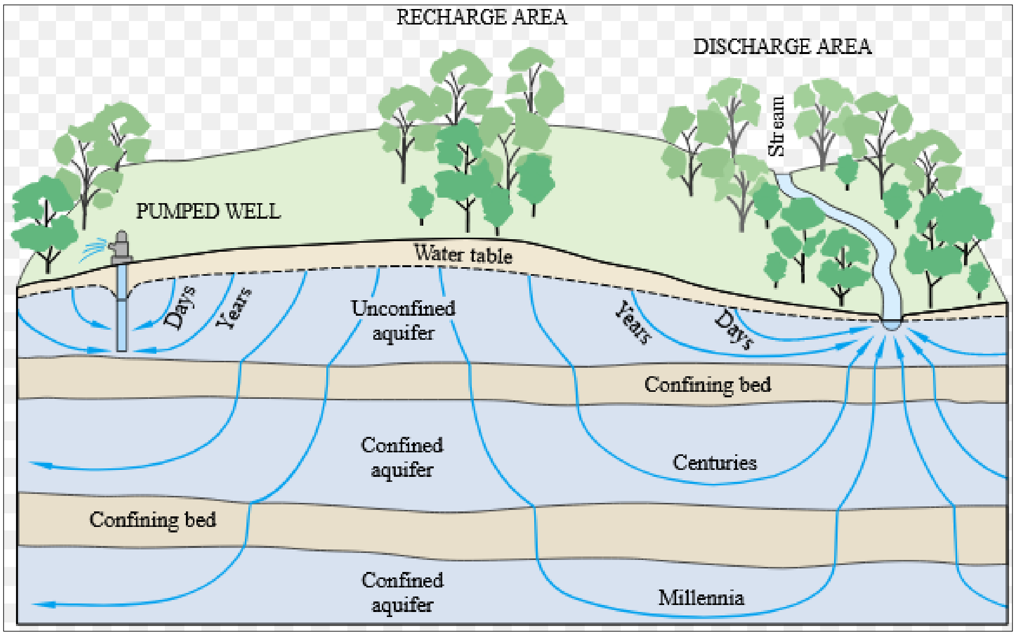

Figure 15. A schematic diagram showing inferred travel times for groundwater flow in interbedded unconfined and confined conditions may range from days to millennia depending on the travel distance. Source: https://en.wikipedia.org/wiki/Groundwater

3.3 Inferred groundwater flows before, during and after NBB construction

3.3.1 At known contaminated sites

Former Shell Depot, 40 – 42 Old Main Road, Bridgewater – current situation

Section F – F' in Attachment 1 depicts inferred local-scale groundwater flows in the vicinity of the former Shell Depot [O'Donnell (2006), Lim, (2008)].

Site infrastructure was reportedly removed between 1991 and 1996, and additional drilling and sampling completed in 2008. It was concluded then that: "…*based on the available data, the risk of exposure to hydrocarbon vapours is considered to be low considering the concentrations of dissolved*

Table 3. Regional, intermediate and local groundwater flow systems with respect to the various rock and material types in the Project Land, and estimated groundwater flow rates and travel times. The latter are indicative only.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Groundwater system	**Characteristics of flow paths**	**Aquifer**	**Example in and adjacent to Project Land**	**Aquifer permeability (m/day)**	**Head difference (m)**	**Length of flow path (m)**	**Hydraulic gradient**	**Flow volume (m3/day/m2)**	**Flow volume (L/day/m2)**	**Effective porosity**	**Flow rate (m/day)**	**Travel time (days; rounded)**	**Travel time (years; rounded)**	**Descriptor for travel time**
Regional	Irregular pathways through intersecting secondary openings	Fractured hard rock	Triassic and Permian sedimentary rocks; Jurassic dolerite; Teriary basalt	0.01	600	20,000	0.03	0.0003	0.3	0.01	0.03	670,000	1,800	"Centuries to Millennia"
Intermediate		Fractured hard rock		0.01	600	5,000	0.12	0.0012	1.2	0.01	0.12	40,000	100	"Decades to Centuries"
Intermediate		Intergranular sediments	Quaternary fill, interbedded clay/silt/sand estuarine sediments; Tertiary breccia, alluvium, conglomerate	0.01	50	1,500	0.03	0.0003	0.3	0.01	0.03	50,000	100	
Local	Laminar vertically upward flow to floor of River Derwent	Intergranular sediments		0.01	1	50	0.02	0.0002	0.2	0.01	0.02	2,500	10	"Years to Decades"
Local	Laminar subhorizontal flow past abutments and piles	Intergranular sediments		0.01	2	50	0.04	0.0004	0.4	0.01	0.04	1,300	4	
Local	Example: laminar subhorizontal flow from Old Watch House towards River Derwent	Intergranular sediments	Quaternary fill, interbedded clay/silt/sand	0.01	1	50	0.02	0.0002	0.2	0.01	0.02	2,500	7	

IMPORTANT: Inputs to this Table after Column 4 are rough estimates based on limited or no field data. Results should be treated with caution.

Notes for Columns

Column 1	Figures 2 and 3 in report; and Attachment 1 for hydrogeological cross sections
Column 2	Schematic, conceptual types of flow paths in the cross sections in Attachment 1
Column 3	Section 2.2.1 in report
Column 4	Published geology, interpreted cross sections; logs of bore holes
Column 5	0.01m/day is fairly typical of fractured rock aquifers in Tasmania. See also footnote to Section 3.2.
Column 6	Based on Attachment 1 cross sections
Column 7	Based on Attachment 1 cross sections
Column 8	Column 6 divided by Column 7
Column 9	From Darcy's Law: Flow volume = Column 5 x Column 8
Column 10	Column 9 x 1000. The flow through unit area of aquifer.
Column 11	Reasonable estimates
Column 12	Column 9 divided by Column 11
Column 13	Column 7 divided by Column 12
Column 14	Column 13 divided by 365

phase volatile compounds within the groundwater, the low permeability of the ground (clay) and the depth to groundwater (>10mbgs[10])"; Lim 2008).

Lim (2008) suggested groundwater flow was to the southeast based on standing water levels in monitoring bores MW1 – MW6 in 2008. While the measured water levels suggest flow in that direction at that time, it is at odds with fundamental hydrogeological principles. More recently (2021) a water table depth of 13m was recorded in nearby geotechnical bore NBBMW2 (F. Keserue-Ponte, *pers. comm.)* which supports the inference in Section F – F' that shallow flow is towards Ashburton Creek.

Deeper intermediate flow at and near the former Shell Depot is inferred to be in a general southerly direction (Figure 8) and there may well be a component of flow in that direction within the shallower monitoring bores which might help explain the 2008 water levels.

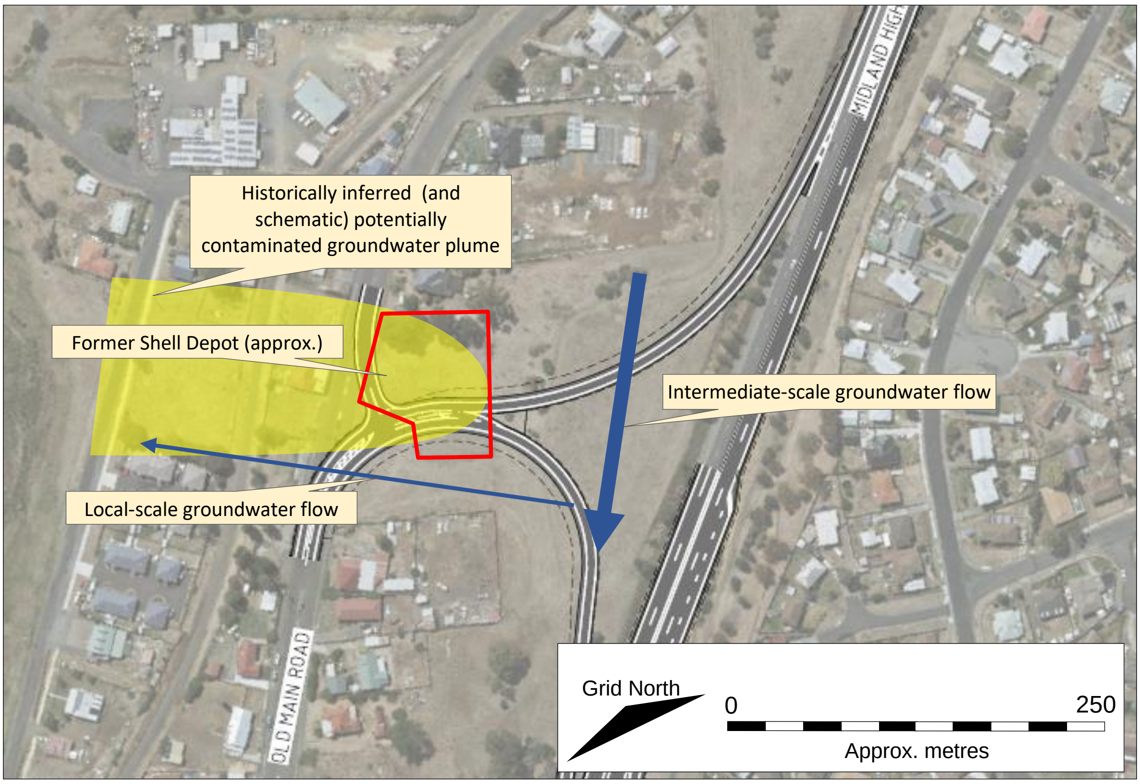

Figure 16. Potential interchange lanes between Old Main Road and the northern approaches to the NBB will pass over or close to the former Shell Depot. Image source: Department of State Growth Midland Highway Bridgewater Bridge Scoping and Investigations Northern Interchange (Drawing 20015-C-SK04; August 2020).

The volume of potentially contaminated groundwater in intergranular materials beneath and downgradient from the depot site (Figure 15) is difficult to estimate because its vertical extent is unknown. However, as a rough guide, assuming the site and plume covers about 2ha, and contaminated groundwater extends from a depth of 10mbg to 20mbg in clayey material with an effective porosity of 0.01, the volume of groundwater is 2,000m^3 (2ML). Groundwater flow rates away from the site towards Ashburton Creek are likely to be in the order of 2 – 4cm/day (Table 3).

Former Shell Depot, 40 – 42 Old Main Road, Bridgewater – during and after NBB construction

Figure 16 shows proposed interchange lanes over the former Shell Depot. Construction details are not clear but it is probable that near Old Main Road the lanes will be built on embankments over the

[10] (My footnote) mbgs = metres below ground surface.

existing surface. Local-scale groundwater at depths of about 10m are very unlikely to be affected by road construction, and vice versa[11].

Old Watch House, 1 Lyell Highway, Granton – current situation

Sections J – J' and part J – J' in Attachment 1 depict inferred local-scale groundwater flows in the vicinity of the old Watchhouse, based on previous geotechnical and site contamination drillholes [Harington (2007), Tangney (2008)].

The volume of potentially contaminated groundwater in intergranular materials beneath and downgradient from the site (Figure 17) is difficult to estimate because its vertical extent is unknown. However, as a rough guide, assuming the site and plume covers about 0.1ha, and contaminated groundwater extends from a depth of 1mbg to 3mbg in fill and clayey material with an effective porosity of 0.01 above shallow bedrock, the volume of groundwater is 20m^3 (2kL).

Local groundwater flow is northeast towards the River Derwent at rates likely to be in the order of 2 – 4cm/day (Table 3). Intermediate-scale flow is inferred to be in roughly the same direction.

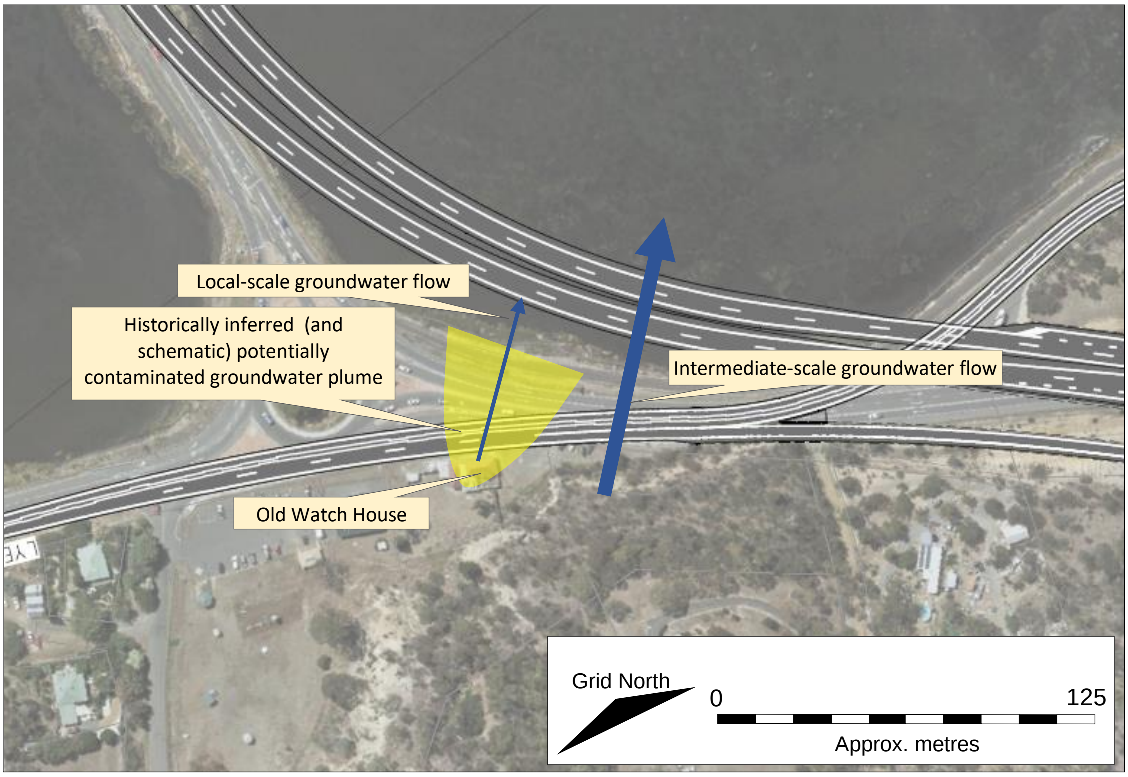

Figure 17. With respect to potential NBB road infrastructure at Granton, local-scale groundwater from near the Old Watch House flows northeast, as does deeper intermediate-scale groundwater. Image source: Department of State Growth Midland Highway Bridgewater Bridge Scoping and Investigations Southern Interchange (Drawing 20015-C-SK03; August 2020).

Old Watch House, 1 Lyell Highway, Granton – during and after NBB construction

Excavations (if any) in the vicinity of the shoreline opposite the Old Watch House are likely to encounter groundwater – potentially contaminated with hydrocarbons and metals – at depths near sea level. The water level in these near-shoreline excavations will fluctuate tidally.

As suggested in Section part J – J' in Attachment 1, local-scale groundwater flow is unlikely to enter the River Derwent at depths much below -1mASL.

[11] Whether or not construction will disturb potentially contaminated soils at the former depot is outside the scope of this report.

3.3.2 At proposed NBB abutments

Figures 18 and 19 depict inferred local-scale groundwater flow lines around circular piles in unconsolidated materials supporting the NBB abutments[12] north and south of the River Derwent.

Flow lines diverge on the upgradient side of the piles, and converge on the downgradient side. The effect decreases orthogonally away from the piles. Flow lines are unlikely to be affected at a distance of more than a few pile diameters.

Groundwater flow rates are inferred to be of the order of 4cm/day, but would increase marginally where flow lines curve around individual piles.

At these inferred rates of groundwater movement, local disturbance of individual flow lines around buried bridge structures is likely to be insignificant with respect to groundwater impacts.

3.4 Management of Potential Acid Sulphate Soils

3.4.1 Marine PASS (Figure 11)

Preliminary drawings (Department of State Growth, 2020) indicate 20 – 35 lines of piers on 40 – 140 piles (1.2 – 1.4m diameter) will support the NBB over the River Derwent estuary. To facilitate the installation of concrete plugs beneath piles, up to 5,500m^3 (in-ground) of material representing the top 10 – 15m of piles will be removed and will need to be managed (DPIPWE, undated) to minimise the production of Actual ASS (AASS).

Piles are likely to be driven, so PASS will be disturbed and will require management.

Marine PASS management will be addressed by others.

3.4.2 Terrestrial PASS (Figure 11)

Terrestrial PASS will be exposed near the southern abutments (possibly 1,000m^3 in ground to a depth of 1m), and also extending inland from the mouth of Black Snake Rivulet, including the proposed Black Snake Road “interchange”. In this latter area, approximately 30,000 – 40,000m^3 of soil and unconsolidated materials to a depth of 1m or so may be disturbed, but it unclear how much of this is PASS.

Depending on the depth of excavation, local-scale groundwater is only likely to be encountered along and adjacent to Black Snake Rivulet.

Terrestrial PASS management will be addressed by others.

3.5 Groundwater quality

3.5.1 Current groundwater quality

The lateral and vertical variability in groundwater quality in and adjacent to the Project Land is essentially unknown, apart from a few instances:

[12] The abutments are to be supported by piers or piles and are proposed to be above ground, or at least above local groundwater. They will not affect existing groundwater flow directions.

- 3000mg/L Total Dissolved Solids in groundwater bore 42002 in 2014, from Jurassic dolerite at depths up to about 60m (Table 1 and Figure 9) – possibly representing intermediate- or regional-scale groundwater quality at that location,
- electrical conductivities in the range 1,200 – 5,000µS/cm (approximately 700 – 3,000mg/L) for local-scale groundwater in monitoring bores adjacent to the Old Watch House at Granton in November 2019 (GES 2020), and
- electrical conductivities of about 1100µS/cm (approximately 700mg/L) in April 2006, and 2,000µS/cm (approximately 1,200mg/L) in February 2008, for local-scale groundwater in adjacent monitoring bores at the former Shell Depot at 40 – 42 Old Main Road in Bridgewater [O'Donnell (2006); Lim (2008)].

3.5.2 Potential changes to groundwater quality during and after NBB construction

Installing piles and piers across the River Derwent

Because intermediate-scale groundwater is inferred to flow vertically upwards beneath most of the River Derwent, Project Works associated with the installation of piles and piers are unlikely to cause significant changes to groundwater quality in the estuarine sediments.

It is assumed that PASS will be effectively managed during Project Works.

At interchanges and similar roadworks

Depending on DSG's chosen design, it is likely that the northern interchange from the Midland Highway to Old Main Road near the Shell Depot will be embankment fill in an area where groundwater is about 10m deep. These Works will not affect groundwater quality (assuming that accidental spills of potentially-contaminating materials do not occur, or are at least adequately managed).

Depending on DSG's chosen design, it is likely that the southern interchange near Black Snake Road will in places disturb PASS. Local-scale groundwater quality in this area will likely be affected if the PASS is not appropriately managed (mismanagement might cause infiltration of acidified water to the water table).

At temporary storage locations

No changes to groundwater quality are expected unless contaminants infiltrate to the water table.

It is assumed that these locations will be managed appropriately.

3.6 Low strength estuarine sediments

In drill holes BHTI 2 (42.3m deep) and BHTI 3 (27m deep) drilled about one kilometre upstream from the Project Land (Figure 14), the 0.3m long push tube used for sampling fell 0.1 – 0.2m under its own weight through estuarine sandy silt and silty sand on many occasions over the depth intervals 2 – 25m and 6 – 9m respectively [Pitt & Sherry (2013)].

These materials have effectively no strength. One explanation is that (slow) vertically upward groundwater flow is causing "quick" conditions in susceptible sediments.

Similar conditions might locally exist in the estuarine sediments in the Project Land.

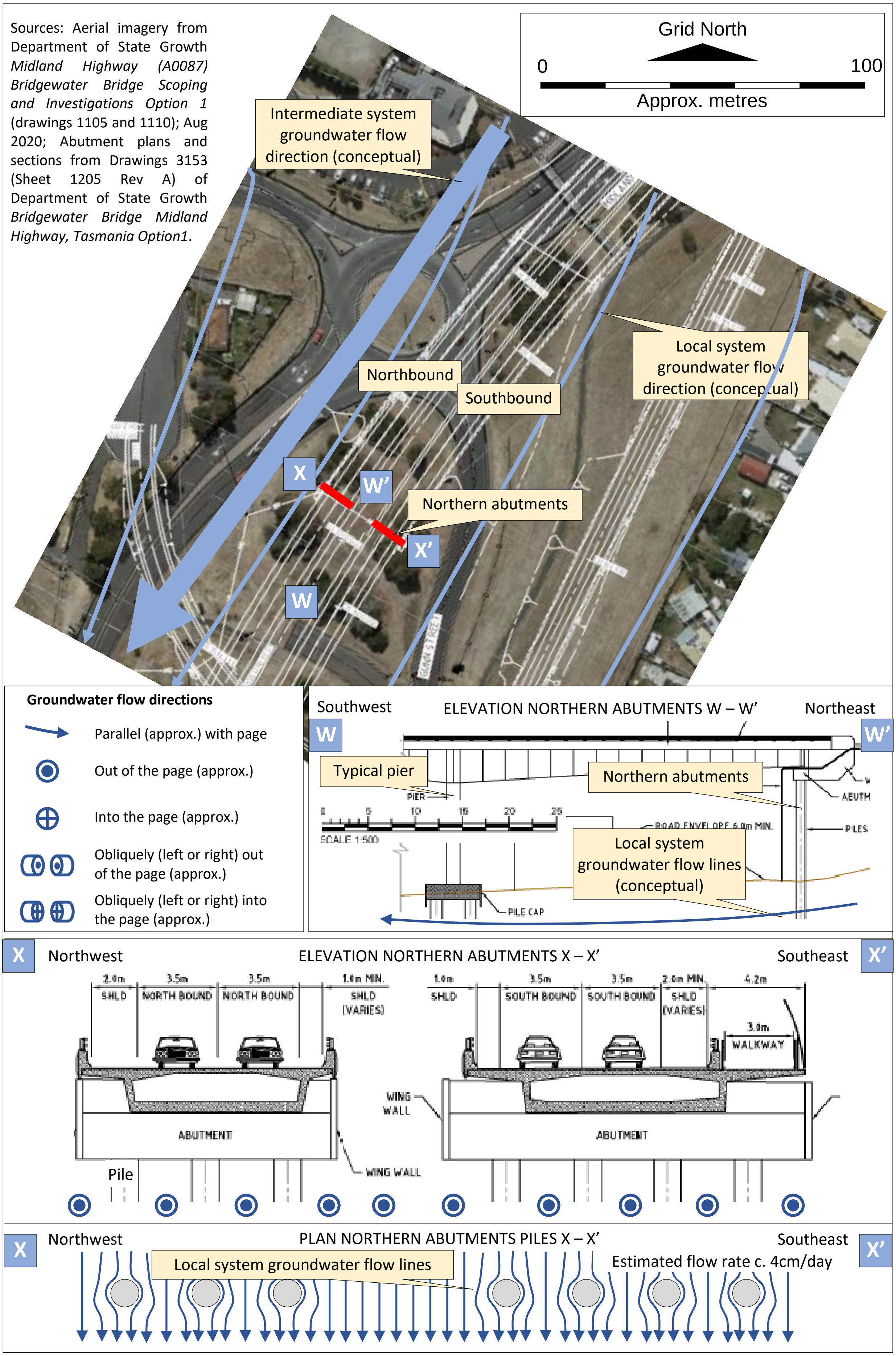

Figure 18. Inferred local-scale groundwater flow lines around circular piles in unconsolidated materials supporting the northern NBB abutments.

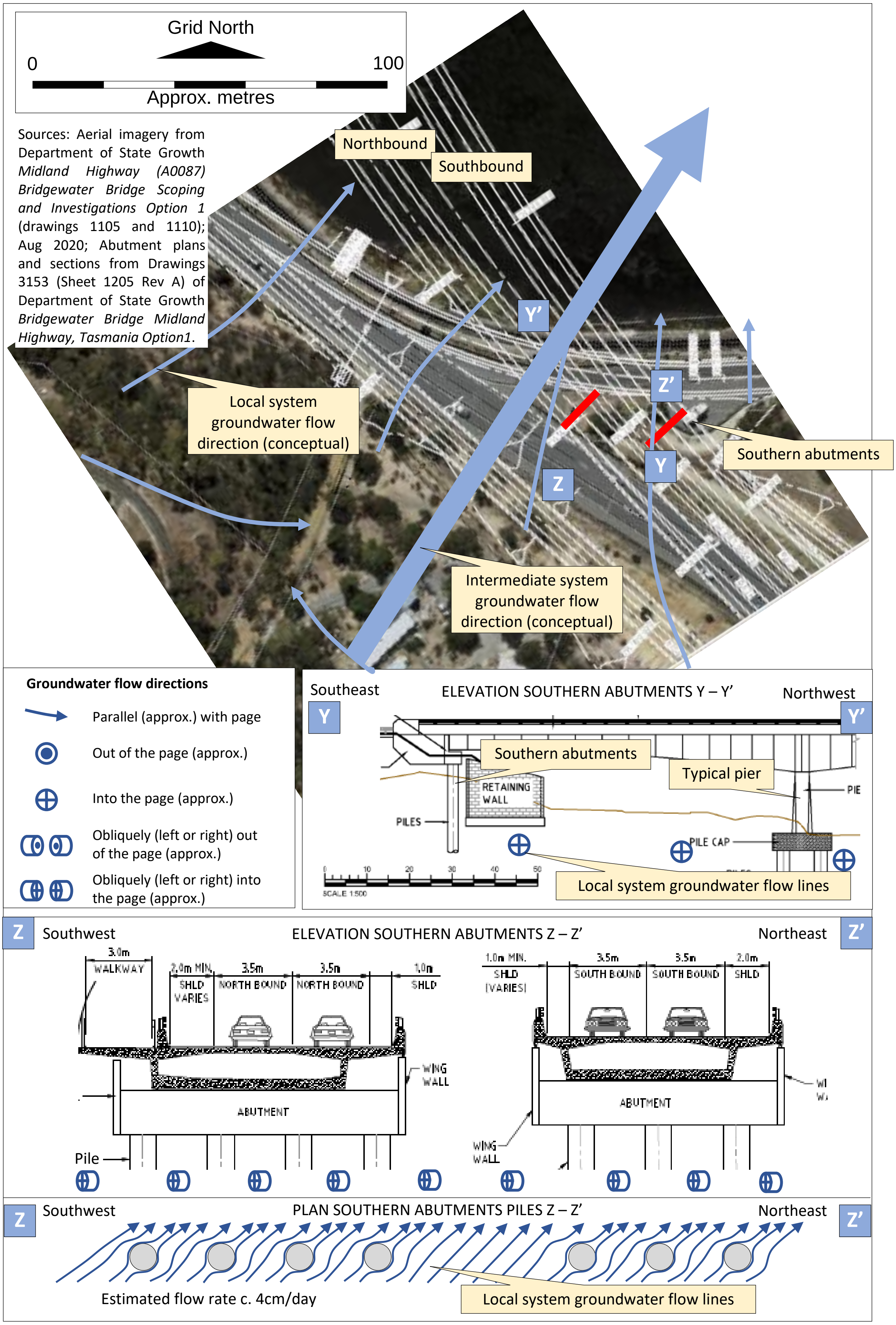

Figure 19. Inferred local-scale groundwater flow lines around circular piles in unconsolidated materials supporting the southern NBB abutments.

4 CONCLUSIONS

This desktop assessment concludes:

- groundwater occurs in all rocks and unconsolidated materials in the Project Land, at local, intermediate and regional scales. Intergranular and fractured hard-rock aquifers both exist, with the groundwater in unconfined conditions.
- local-scale groundwater at and near the water table flows towards the River Derwent from the north and south, and discharges at and near river level. The water table fluctuates tidally along the shoreline. Deeper intermediate-scale groundwater flows in similar directions beneath Granton and Bridgewater, but across the width of the River Derwent estuary the flow lines are mostly vertically upwards (the estuary is a discharge zone).
- from fundamental hydrogeological considerations, groundwater flow rates in all three systems are thought to be similar (a few centimetres per year): travel times through each are described as "Centuries to Millennia", "Decades to Centuries" and "Years to Decades" for regional-scale, intermediate-scale and local-scale systems respectively.

The groundwater conditions are depicted in thirteen conceptual hydrogeological models.

Project Works will interact with local and intermediate scale groundwater, but not regional scale groundwater. Interactions are likely to include:

- insignificant modifications to vertically-upward intermediate-scale groundwater flow lines in the immediate vicinity of piles and piers (and no effect elsewhere),
- insignificant to minor modifications to subhorizontal local-scale groundwater flow lines in the immediate vicinity of abutments and retaining walls (and no effect elsewhere),
- no effect on local- and intermediate-scale groundwater flow lines or quality for Project Works (interchange and Midland Highway widening works) on the northern approaches to the NBB,
- potential changes (occasioned by PASS) to local-scale groundwater flow lines and quality for Project Works at interchanges and related road works in the vicinity of Black Snake Road on the southern approaches to the NBB,
- potential changes to local-scale groundwater flow lines and quality where PASS originating from installation of piles and piers in the estuary, is stockpiled/treated on the land surface at Temporary Works locations,
- possible exposure to potentially contaminated local-scale groundwater originating from the Old Watch House and entering downgradient near-shoreline excavations (if any), and
- possible changes to local-scale groundwater quality caused by leachate infiltration from contaminated materials stockpiled at temporary works locations.

The volumes of potentially contaminated local-scale groundwater at and near two known contaminated sites is very approximately estimated to be 2,000m^3 at the former Shell Depot, and 20m^3 at the Old Watch House.

No intermediate-scale groundwater moving vertically upwards through estuarine sediments in the River Derwent estuary is likely to be contaminated by Project Works. Regional-scale groundwater will remain unaffected.

From a hydrogeological perspective, the overall effect on groundwater movement and quality of the proposed Project Works is very likely to be not unacceptable. The generation of acidic leachate from disturbed PASS – and its possible effect on local-scale groundwater – is likely to be the issue requiring most attention.

5 RECOMMENDATIONS

Arising from the desktop review, it is recommended that in relation to the hydrogeology of the Project Land,

1. groundwater sampling should continue at the contaminated locations currently being monitored (the results of sampling may indicate selected monitoring bores may be decommissioned, or new ones commissioned);
2. outside of these current groundwater monitoring locations, no additional groundwater monitoring bores need to be drilled,
3. PASS should be appropriately managed, and
4. these recommendations may need to be amended as Project Works progress.

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Attachment 1

(16 pages including this page)

CONCEPTUAL HYDROGEOLOGICAL CROSS SECTIONS (MODELS)

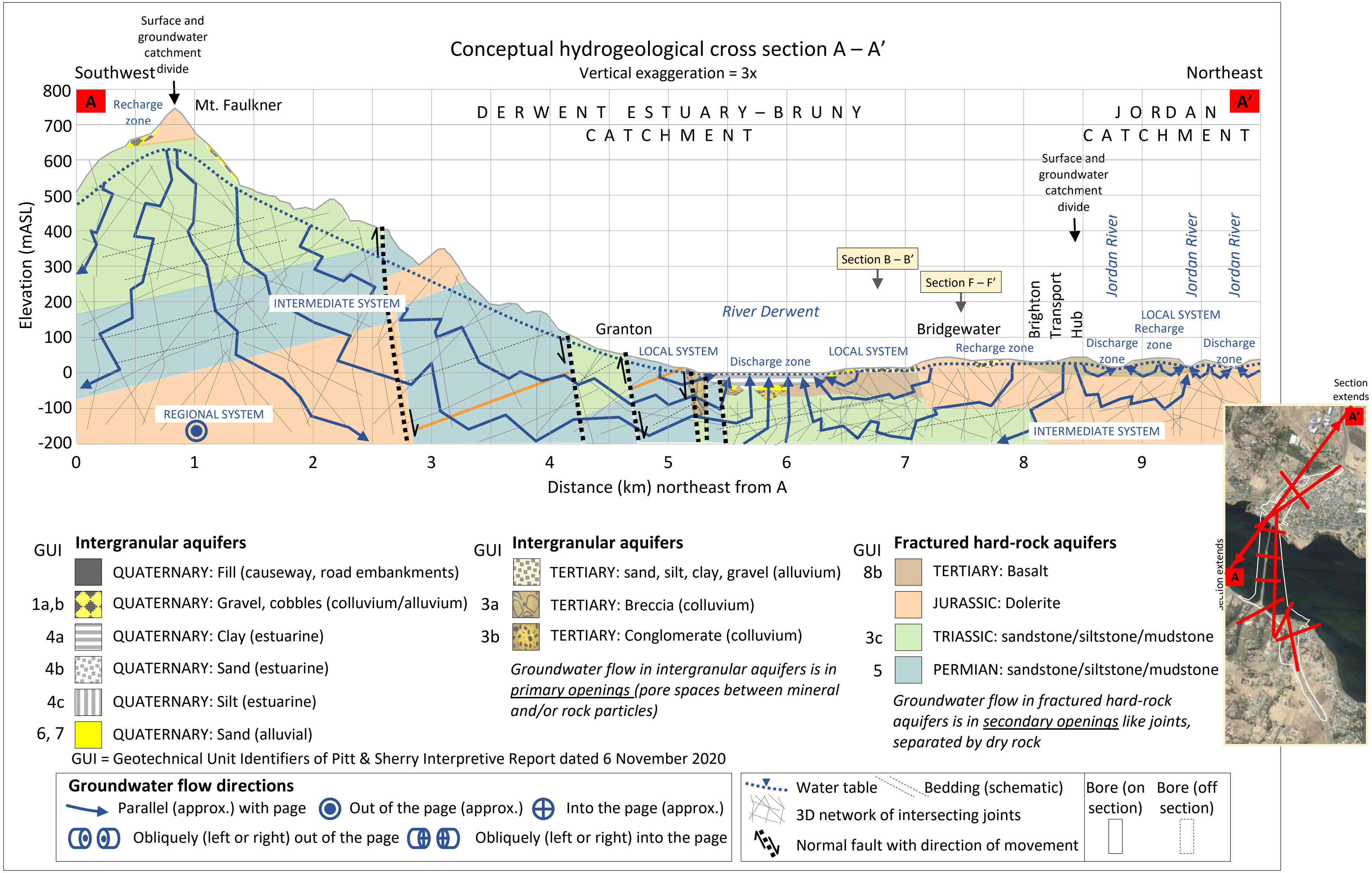
See Figure 12 for locations of the models.
An inset map on each model page also shows the location.

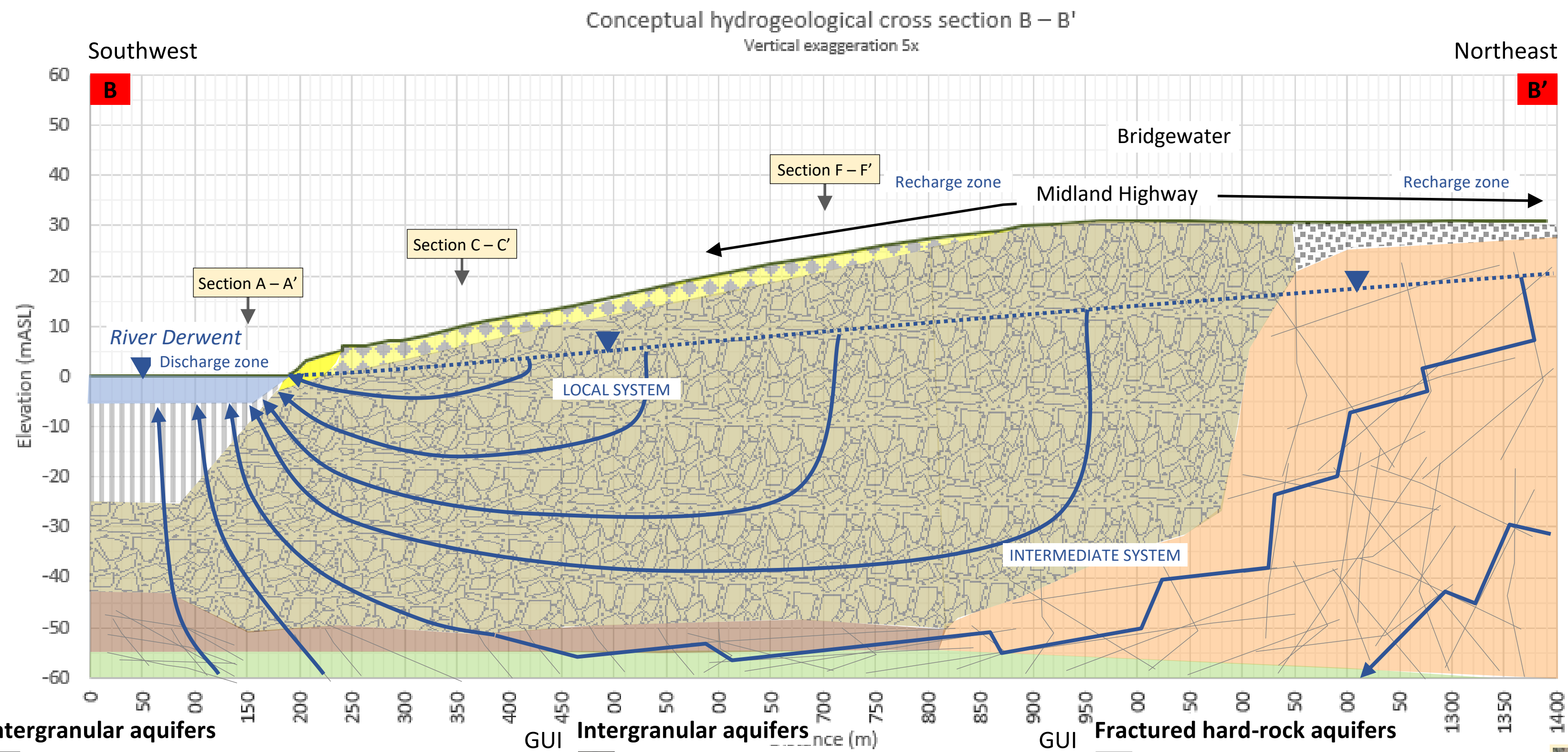
Notes

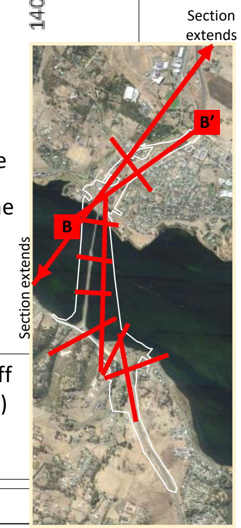
The geology shown in the accompanying conceptual hydrogeological cross sections (models) is based on published geological maps, observation of some surface exposures, logs of groundwater, geotechnical and site-contamination drillholes (see the list of sources on Figure 13) and my own interpretations. Particularly where data are missing or scarce, there is no claim that the models accurately represent the subsurface.

The local and intermediate groundwater systems superimposed on the inferred geology are based primarily on fundamental groundwater principles (including Figures 4, 5 and 8), assisted by site contamination investigations near the Old Watch House [Harington (2007) and GES (2020)], and at the former Shell Depot at 40a Old Main Road [Lim (2008)].

As with all (conceptual hydrogeological) models, further subsurface information will lead to correction and refinement.


Conceptual hydrogeological cross section A – A’
Vertical exaggeration = 3x
Southwest
Northeast
Surface and groundwater catchment divide
Recharge zone
Mt. Faulkner
D E R W E N T E S T U A R Y – B R U N Y C A T C H M E N T
J O R D A N C A T C H M E N T
Surface and groundwater catchment divide
Jordan River
Section B – B’
Section F – F’
River Derwent
Granton
Bridgewater
Brighton Transport Hub
INTERMEDIATE SYSTEM
LOCAL SYSTEM
Discharge zone
Recharge zone
REGIONAL SYSTEM
Elevation (mASL)
Distance (km) northeast from A
Section extends
GUI Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)





GUI	Intergranular aquifers
	QUATERNARY: Fill (causeway, road embankments)
1a,b	QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a	QUATERNARY: Clay (estuarine)
4b	QUATERNARY: Sand (estuarine)
4c	QUATERNARY: Silt (estuarine)
6, 7	QUATERNARY: Sand (alluvial)

GUI	Intergranular aquifers
	TERTIARY: sand, silt, clay, gravel (alluvium)
3a	TERTIARY: Breccia (colluvium)
3b	TERTIARY: Conglomerate (colluvium)

Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)

GUI	Fractured hard-rock aquifers
8b	TERTIARY: Basalt
	JURASSIC: Dolerite
3c	TRIASSIC: sandstone/siltstone/mudstone
5	PERMIAN: sandstone/siltstone/mudstone

Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock

GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020

Groundwater flow directions

Parallel (approx.) with page | Out of the page (approx.) | Into the page (approx.)

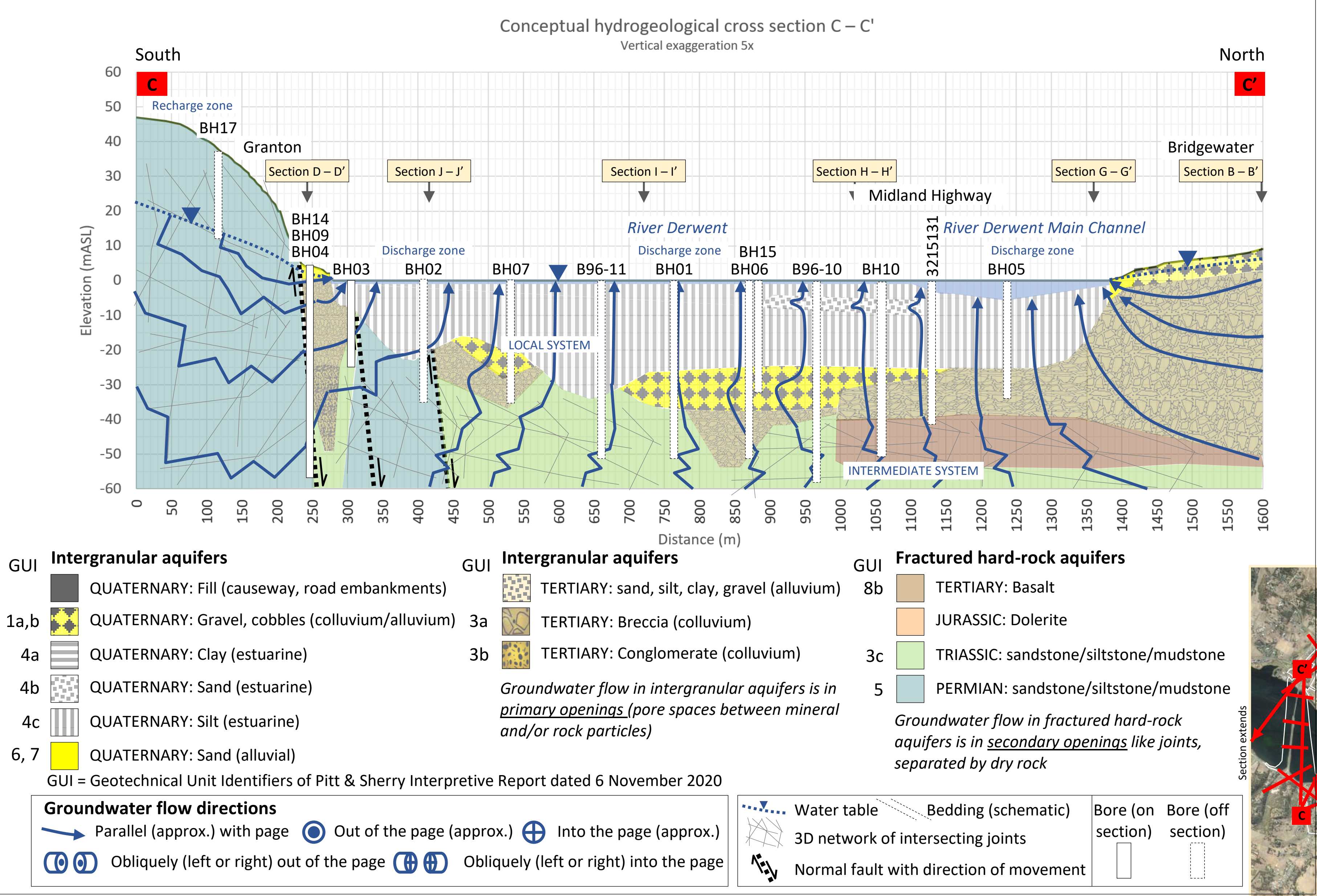
Obliquely (left or right) out of the page | Obliquely (left or right) into the page

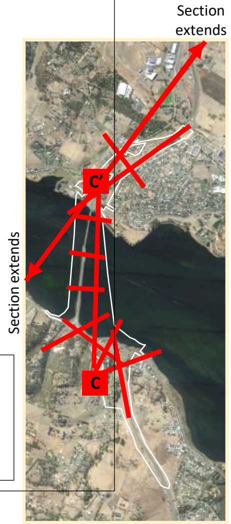
Water table | Bedding (schematic)

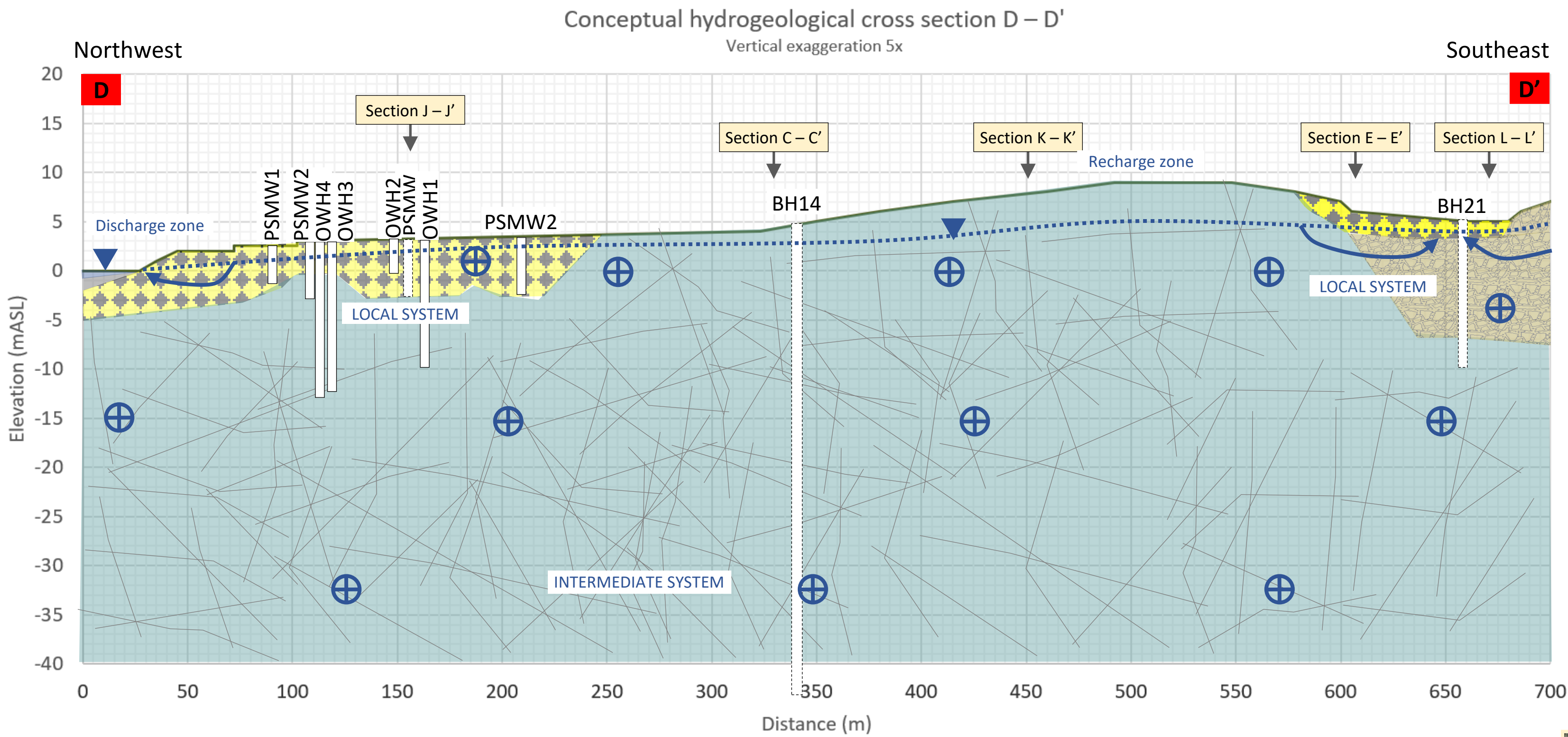
3D network of intersecting joints

Normal fault with direction of movement

Bore (on section) | Bore (off section)


Conceptual hydrogeological cross section C – C'
Vertical exaggeration 5x
South
North
C
C'
Recharge zone
BH17
Granton
Bridgewater
Section D – D'
Section J – J'
Section I – I'
Section H – H'
Section G – G'
Section B – B'
Midland Highway
River Derwent
River Derwent Main Channel
Discharge zone
BH14
BH09
BH04
BH03
BH02
BH07
B96-11
BH01
BH15
BH06
B96-10
BH10
3215131
BH05
LOCAL SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
Distance (m)
GUI
Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI
Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI
Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)


Section extends
Section extends
C'
C



GUI	Intergranular aquifers
	QUATERNARY: Fill (causeway, road embankments)
1a,b	QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a	QUATERNARY: Clay (estuarine)
4b	QUATERNARY: Sand (estuarine)
4c	QUATERNARY: Silt (estuarine)
6, 7	QUATERNARY: Sand (alluvial)

GUI	Intergranular aquifers
	TERTIARY: sand, silt, clay, gravel (alluvium)
3a	TERTIARY: Breccia (colluvium)
3b	TERTIARY: Conglomerate (colluvium)

Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)

GUI	Fractured hard-rock aquifers
8b	TERTIARY: Basalt
	JURASSIC: Dolerite
3c	TRIASSIC: sandstone/siltstone/mudstone
5	PERMIAN: sandstone/siltstone/mudstone

Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock

GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020

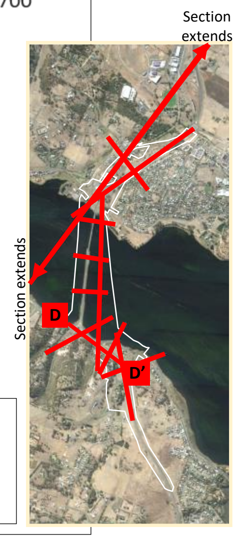
Groundwater flow directions

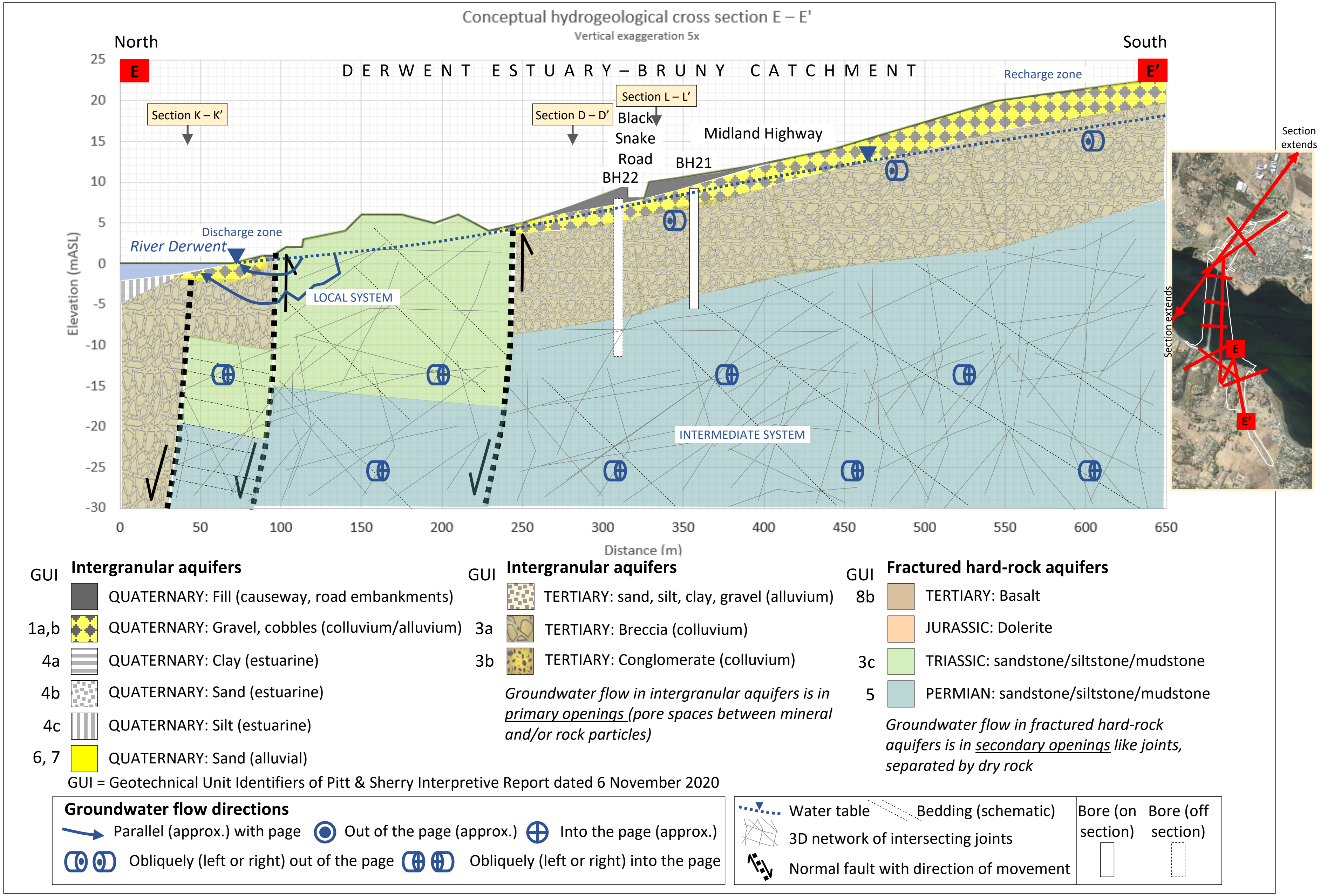
Parallel (approx.) with page; Out of the page (approx.); Into the page (approx.)

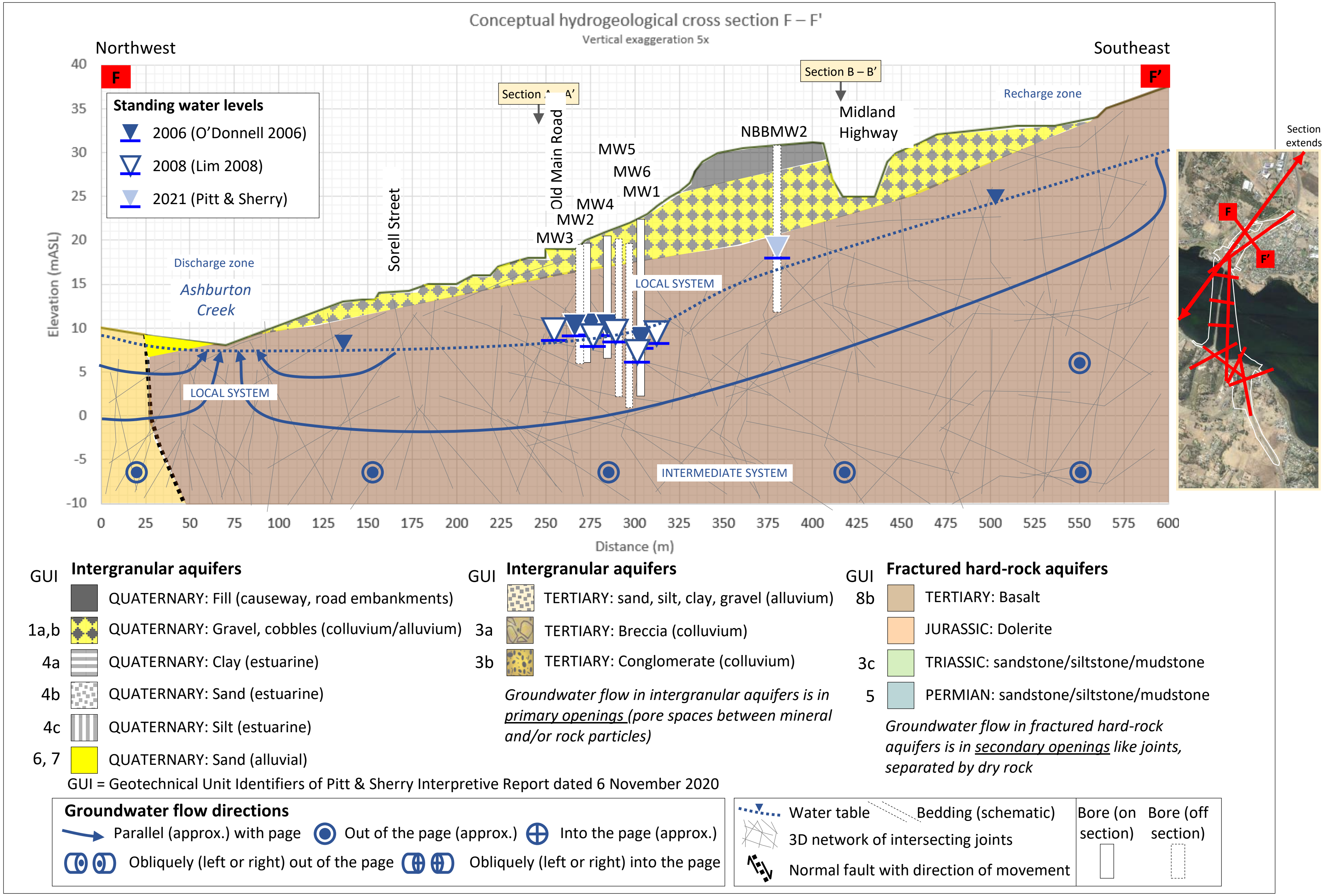
Obliquely (left or right) out of the page; Obliquely (left or right) into the page

Water table; Bedding (schematic); 3D network of intersecting joints; Normal fault with direction of movement

Bore (on section); Bore (off section)

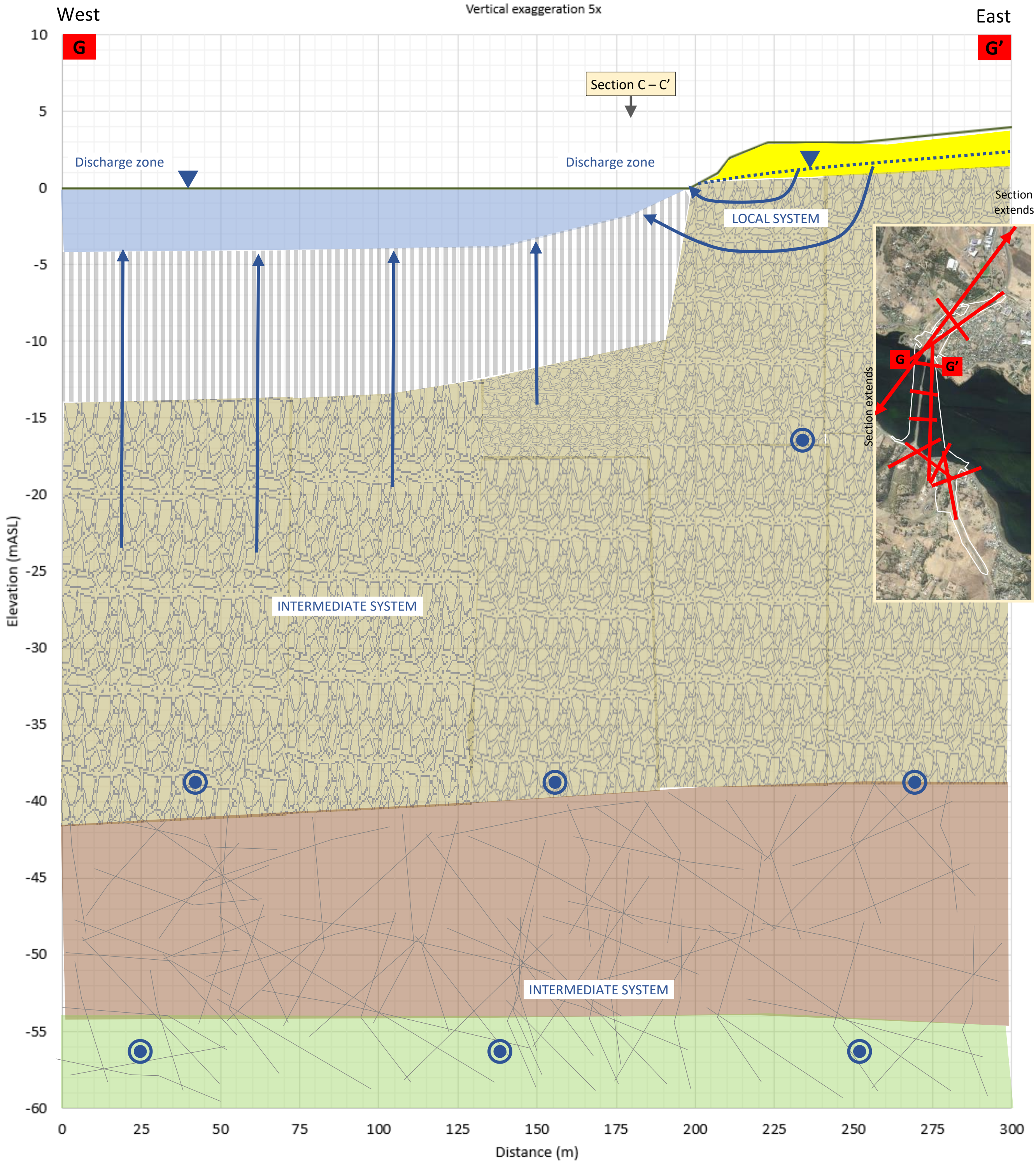



Conceptual hydrogeological cross section E – E'
Vertical exaggeration 5x
North
South
E
E'
DERWENT ESTUARY – BRUNY CATCHMENT
Recharge zone
Section K – K'
Section D – D'
Section L – L'
Black Snake Road
Midland Highway
BH22
BH21
Discharge zone
River Derwent
LOCAL SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
Distance (m)
Section extends
GUI Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)


Conceptual hydrogeological cross section F – F'
Vertical exaggeration 5x
Northwest
Southeast
F
F'
Standing water levels
2006 (O'Donnell 2006)
2008 (Lim 2008)
2021 (Pitt & Sherry)
Section B – B'
Midland Highway
Recharge zone
NBBMW2
Old Main Road
MW5
MW6
MW1
MW4
MW2
MW3
Sorell Street
Discharge zone
Ashburton Creek
LOCAL SYSTEM
LOCAL SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
Distance (m)
Section extends
GUI Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)

Conceptual hydrogeological cross section G – G'

Vertical exaggeration 5x



GUI	Intergranular aquifers
	QUATERNARY: Fill (causeway, road embankments)
1a,b	QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a	QUATERNARY: Clay (estuarine)
4b	QUATERNARY: Sand (estuarine)
4c	QUATERNARY: Silt (estuarine)
6, 7	QUATERNARY: Sand (alluvial)

GUI	Intergranular aquifers
	TERTIARY: sand, silt, clay, gravel (alluvium)
3a	TERTIARY: Breccia (colluvium)
3b	TERTIARY: Conglomerate (colluvium)

Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)

GUI	Fractured hard-rock aquifers
8b	TERTIARY: Basalt
	JURASSIC: Dolerite
3c	TRIASSIC: sandstone/siltstone/mudstone
5	PERMIAN: sandstone/siltstone/mudstone

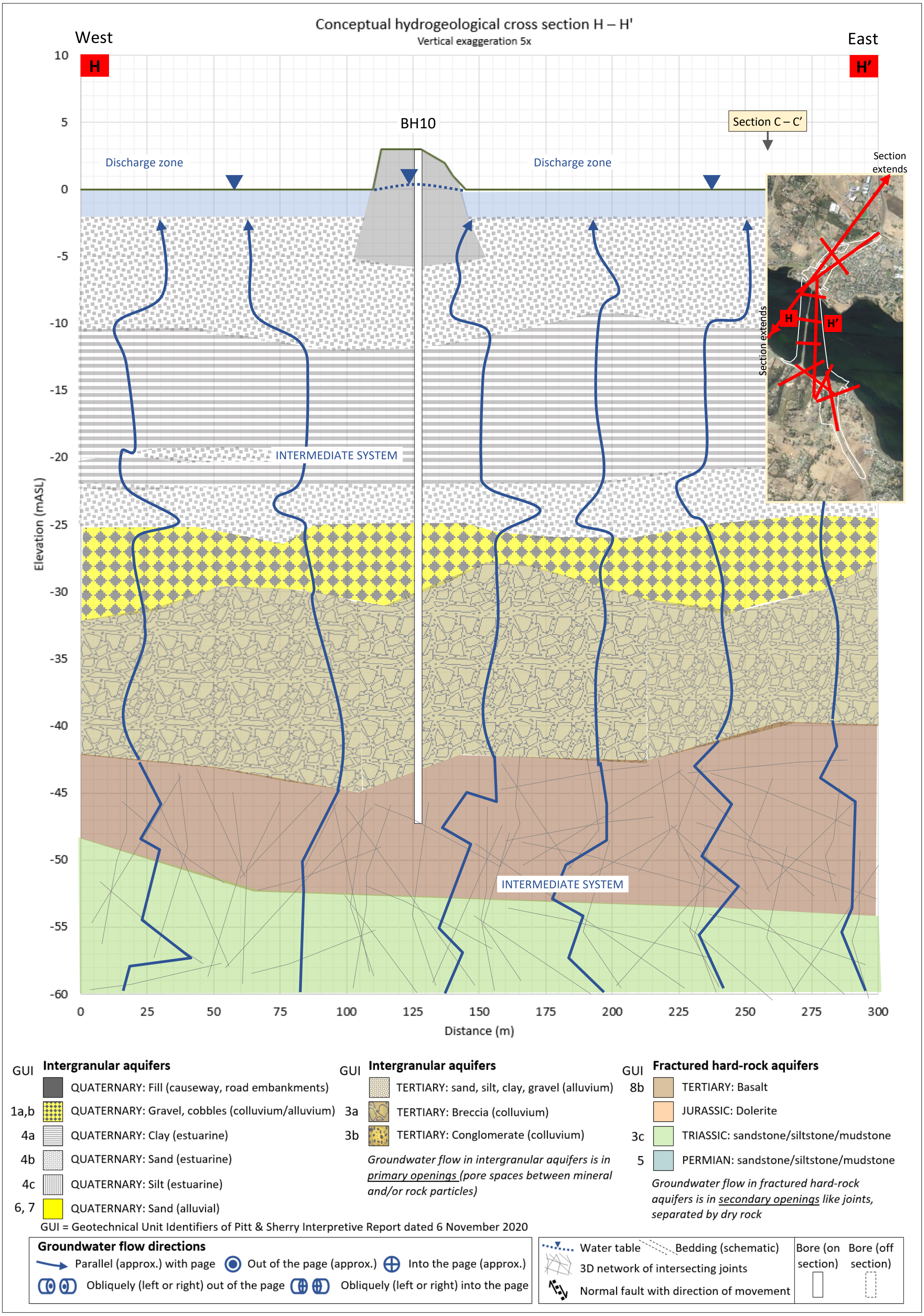
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock

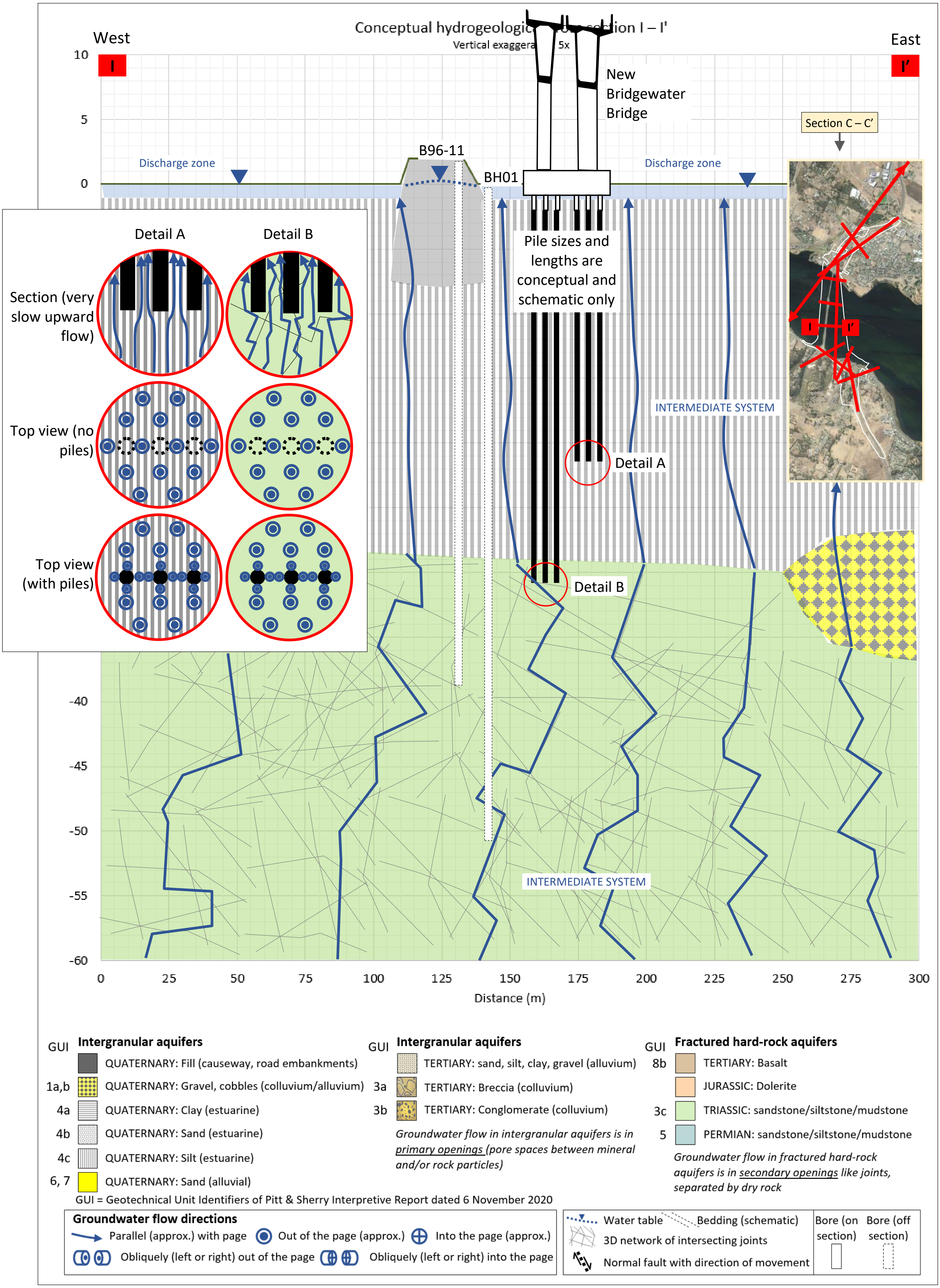
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020

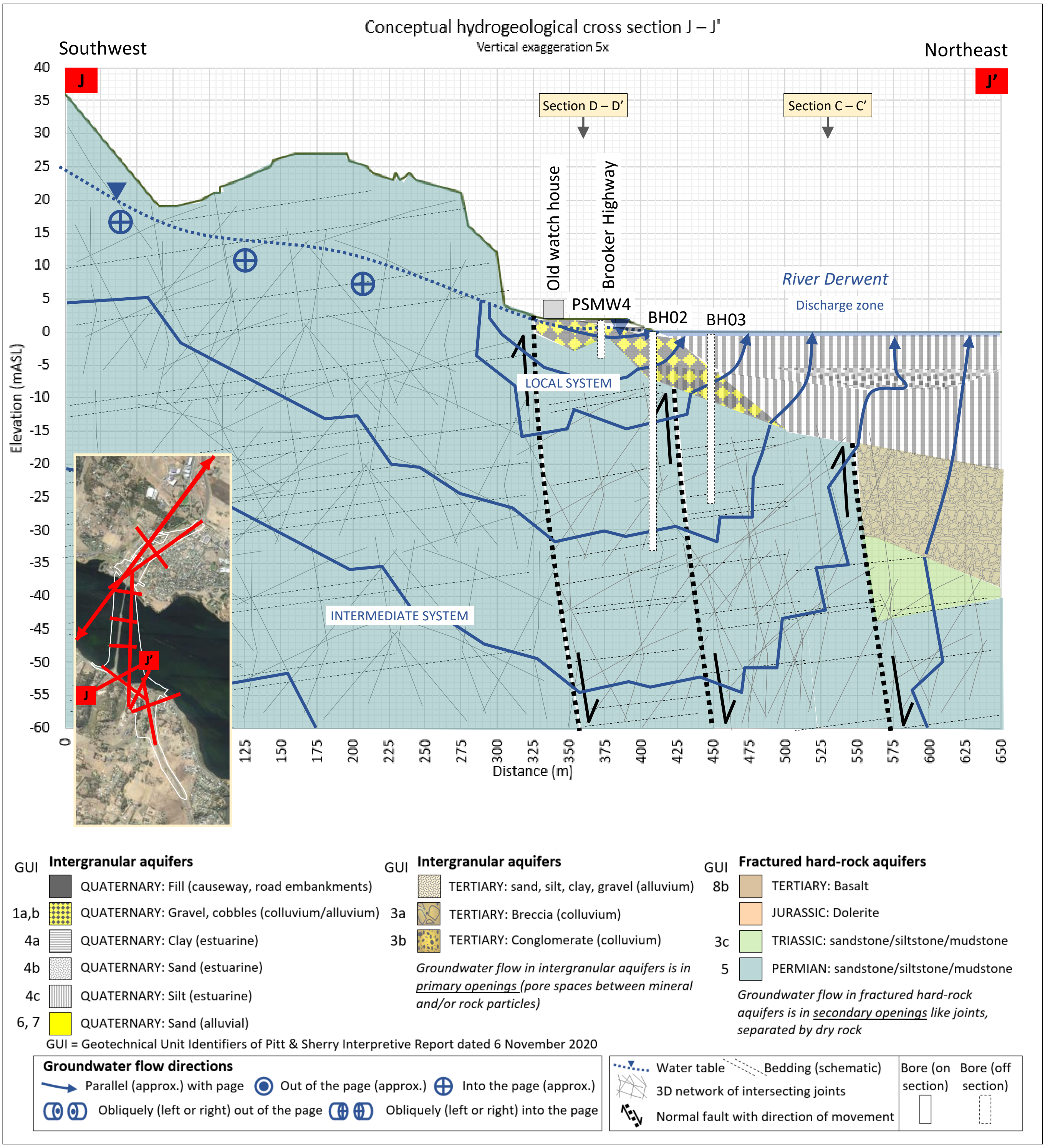
Groundwater flow directions

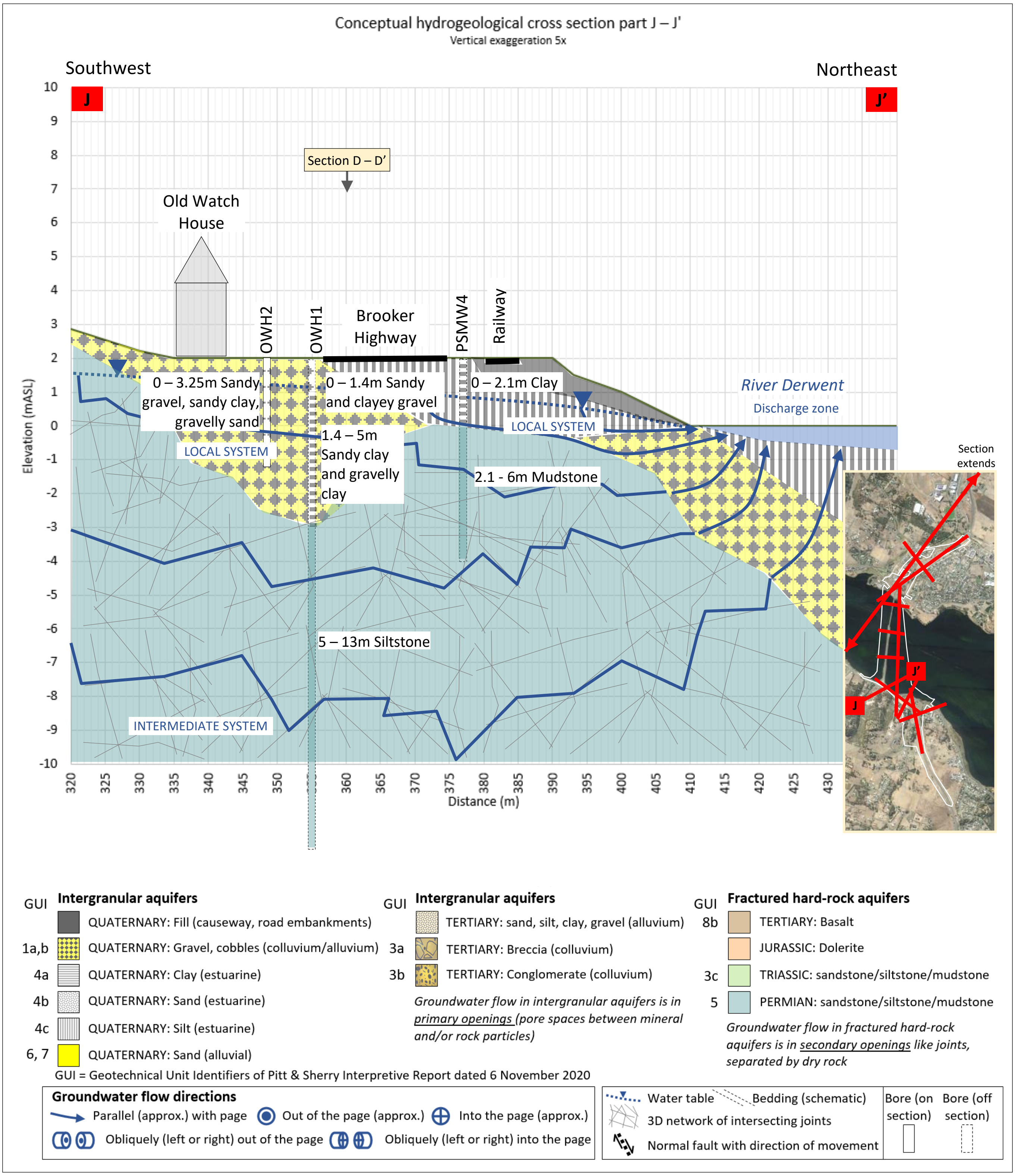
- Parallel (approx.) with page
- Out of the page (approx.)
- Into the page (approx.)
- Obliquely (left or right) out of the page
- Obliquely (left or right) into the page

- Water table
- Bedding (schematic)
- 3D network of intersecting joints
- Normal fault with direction of movement
- Bore (on section)
- Bore (off section)


Conceptual hydrogeological cross section H – H'
Vertical exaggeration 5x
West
East
H
H'
BH10
Section C – C'
Discharge zone
Discharge zone
Section extends
Section extends
INTERMEDIATE SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
0
25
50
75
100
125
150
175
200
225
250
275
300
Distance (m)
GUI Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)

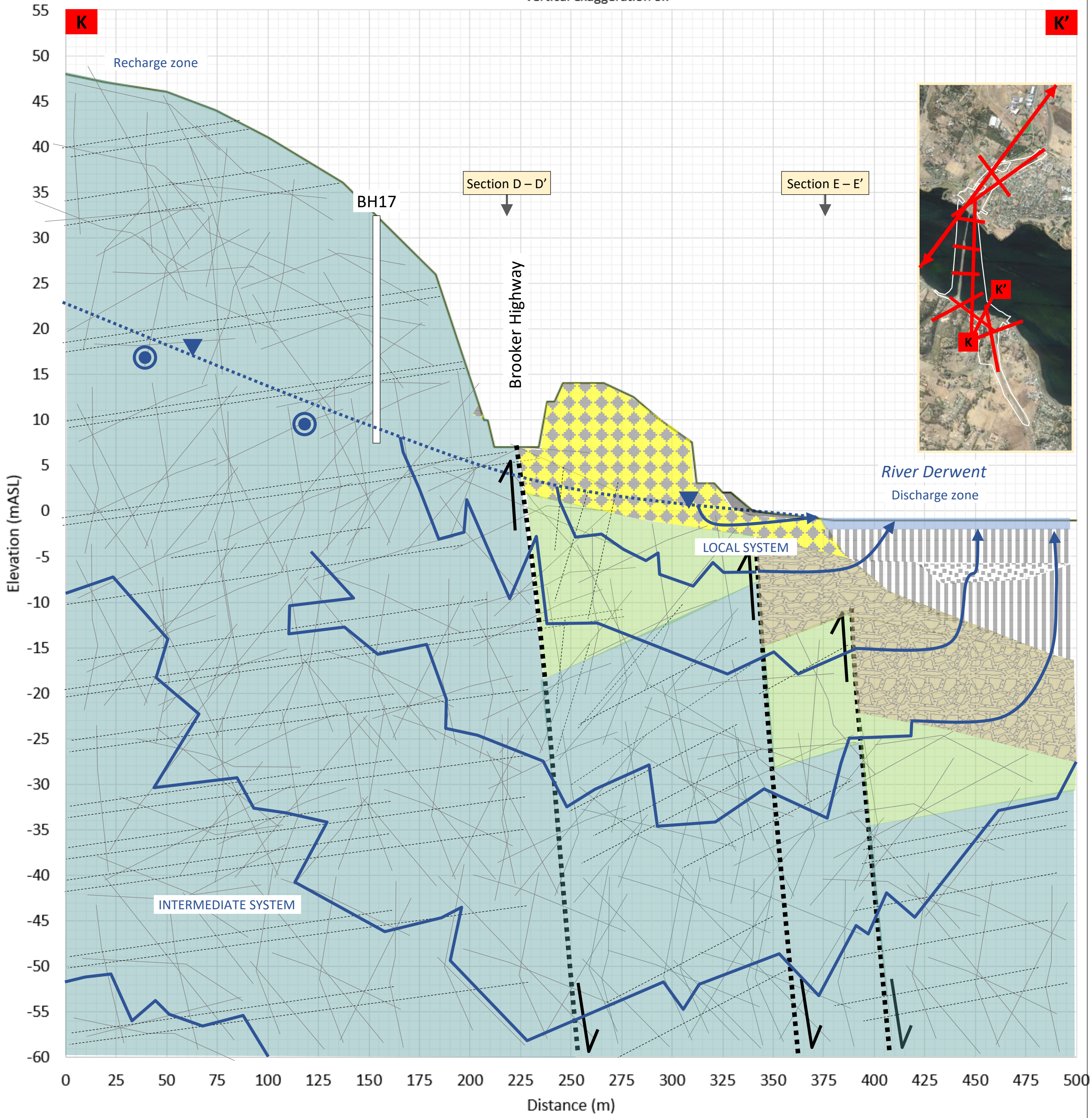

Conceptual hydrogeological section I – I'
Vertical exaggeration 5x
West
East
I
I'
New Bridgewater Bridge
Section C – C'
B96-11
BH01
Discharge zone
Discharge zone
Pile sizes and lengths are conceptual and schematic only
INTERMEDIATE SYSTEM
INTERMEDIATE SYSTEM
Detail A
Detail B
Section (very slow upward flow)
Top view (no piles)
Top view (with piles)
10
5
0
-40
-45
-50
-55
-60
0
25
50
75
100
125
150
175
200
225
250
275
300
Distance (m)
GUI
Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI
Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI
Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)


Conceptual hydrogeological cross section J – J'
Vertical exaggeration 5x
Southwest
Northeast
J
J'
Section D – D'
Section C – C'
Old watch house
Brooker Highway
River Derwent
Discharge zone
PSMW4
BH02
BH03
LOCAL SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
Distance (m)
0
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
GUI
Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b
QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a
QUATERNARY: Clay (estuarine)
4b
QUATERNARY: Sand (estuarine)
4c
QUATERNARY: Silt (estuarine)
6, 7
QUATERNARY: Sand (alluvial)
GUI
Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a
TERTIARY: Breccia (colluvium)
3b
TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI
Fractured hard-rock aquifers
8b
TERTIARY: Basalt
JURASSIC: Dolerite
3c
TRIASSIC: sandstone/siltstone/mudstone
5
PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)


Conceptual hydrogeological cross section part J – J'
Vertical exaggeration 5x
Southwest
Northeast
J
J'
Section D – D'
Old Watch House
OWH2
OWH1
Brooker Highway
PSMW4
Railway
0 – 3.25m Sandy gravel, sandy clay, gravelly sand
0 – 1.4m Sandy and clayey gravel
0 – 2.1m Clay
1.4 – 5m Sandy clay and gravelly clay
2.1 - 6m Mudstone
5 – 13m Siltstone
LOCAL SYSTEM
LOCAL SYSTEM
INTERMEDIATE SYSTEM
River Derwent
Discharge zone
Section extends
Elevation (mASL)
Distance (m)
GUI
Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI
Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI
Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)

Conceptual hydrogeological cross section K – K'

Vertical exaggeration 5x



GUI	Intergranular aquifers
	QUATERNARY: Fill (causeway, road embankments)
1a,b	QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a	QUATERNARY: Clay (estuarine)
4b	QUATERNARY: Sand (estuarine)
4c	QUATERNARY: Silt (estuarine)
6, 7	QUATERNARY: Sand (alluvial)

GUI	Intergranular aquifers
	TERTIARY: sand, silt, clay, gravel (alluvium)
3a	TERTIARY: Breccia (colluvium)
3b	TERTIARY: Conglomerate (colluvium)

Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)

GUI	Fractured hard-rock aquifers
8b	TERTIARY: Basalt
	JURASSIC: Dolerite
3c	TRIASSIC: sandstone/siltstone/mudstone
5	PERMIAN: sandstone/siltstone/mudstone

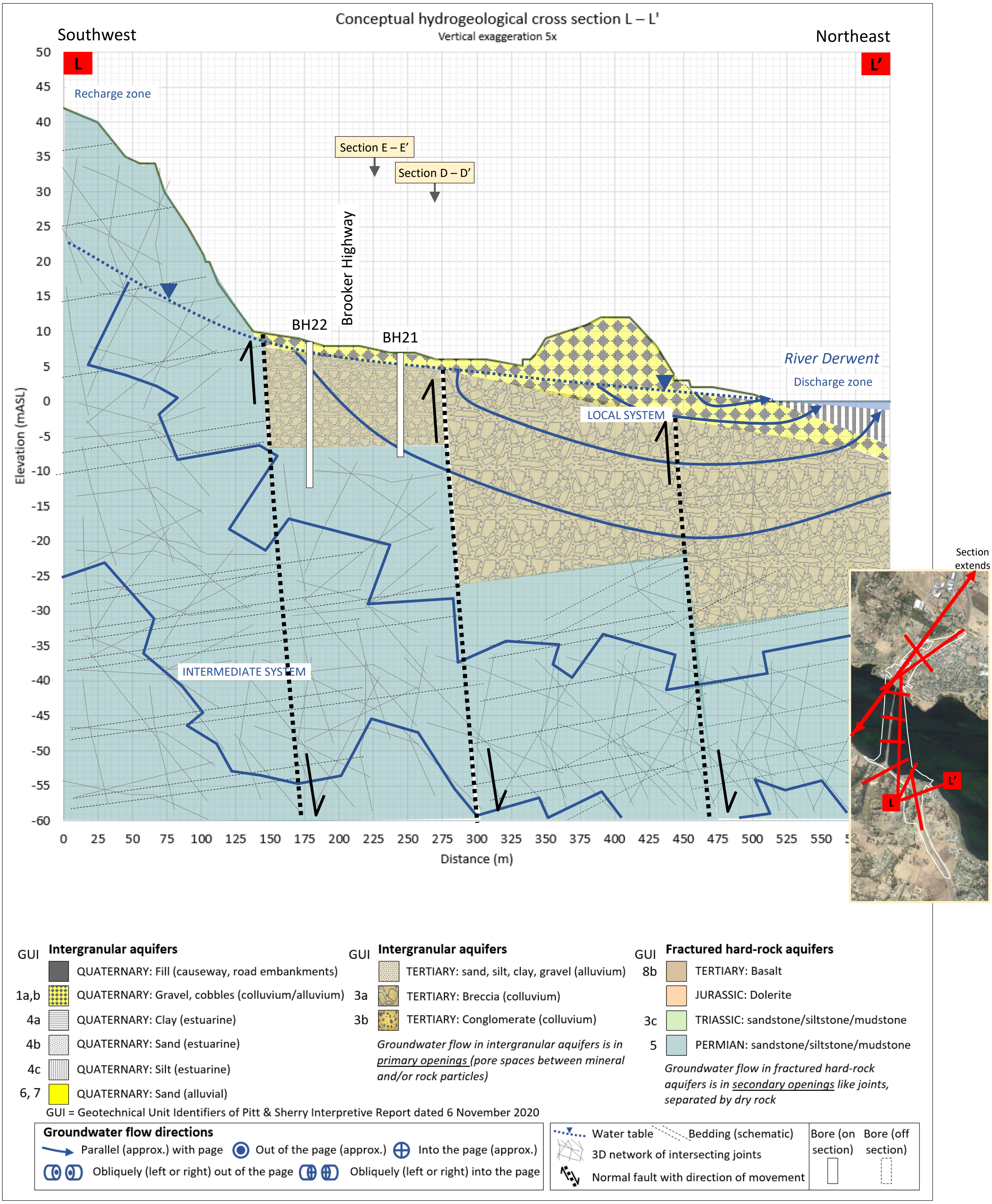
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock

GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020

Groundwater flow directions

- Parallel (approx.) with page
- Out of the page (approx.)
- Into the page (approx.)
- Obliquely (left or right) out of the page
- Obliquely (left or right) into the page

- Water table
- Bedding (schematic)
- 3D network of intersecting joints
- Normal fault with direction of movement
- Bore (on section)
- Bore (off section)


Conceptual hydrogeological cross section L – L'
Vertical exaggeration 5x
Southwest
Northeast
L
L'
Recharge zone
Section E – E'
Section D – D'
Brooker Highway
BH22
BH21
River Derwent
Discharge zone
LOCAL SYSTEM
INTERMEDIATE SYSTEM
Elevation (mASL)
Distance (m)
Section extends
GUI Intergranular aquifers
QUATERNARY: Fill (causeway, road embankments)
1a,b QUATERNARY: Gravel, cobbles (colluvium/alluvium)
4a QUATERNARY: Clay (estuarine)
4b QUATERNARY: Sand (estuarine)
4c QUATERNARY: Silt (estuarine)
6, 7 QUATERNARY: Sand (alluvial)
GUI Intergranular aquifers
TERTIARY: sand, silt, clay, gravel (alluvium)
3a TERTIARY: Breccia (colluvium)
3b TERTIARY: Conglomerate (colluvium)
Groundwater flow in intergranular aquifers is in primary openings (pore spaces between mineral and/or rock particles)
GUI Fractured hard-rock aquifers
8b TERTIARY: Basalt
JURASSIC: Dolerite
3c TRIASSIC: sandstone/siltstone/mudstone
5 PERMIAN: sandstone/siltstone/mudstone
Groundwater flow in fractured hard-rock aquifers is in secondary openings like joints, separated by dry rock
GUI = Geotechnical Unit Identifiers of Pitt & Sherry Interpretive Report dated 6 November 2020
Groundwater flow directions
Parallel (approx.) with page
Out of the page (approx.)
Into the page (approx.)
Obliquely (left or right) out of the page
Obliquely (left or right) into the page
Water table
Bedding (schematic)
3D network of intersecting joints
Normal fault with direction of movement
Bore (on section)
Bore (off section)